HUTT RIVER MOUTH

Coastal sediment transport processes and beach dynamics

Prepared for Greater Wellington

Hutt River Mouth

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Executive Summary

The mixed gravel-sand beach at Petone is a very dynamic landform. It is subject to a high degree of spatial and temporal variability and change. This change is a response to variations in sediment supply and character, the wave and wind regime, and sea level. Variability in the beach exists at a range of temporal scales including daily, seasonally, and annually.

A range of measurements have been made relating to the lower channel of the Hutt River, and along Petone beach. These measurements include: river bed cross-sections; dredging extraction and deposition volumes; harbour floor hydrographic surveys; aerial photography; and beach profile surveys and sediment analysis. It is important to recognise, however, that these data are of varying quality, and have different temporal resolution. Furthermore, these data usually reflect those conditions on the beach immediately prior to the measurement, or following the last major beach changing event.

Detailed analysis of these measurements shows that the beach and river mouth respond largely to natural processes of sedimentation and sediment transport. The processes and changes identified from these measurements are generally consistent over time. That is, no significant change in behaviour is apparent in the most recent information collected.

Between the Waione Street Bridge and Hutt River mouth the main channel has remained largely unchanged, although overall the bed is higher and therefore the channel slightly shallower. In places the channel has widened and the thalweg (i.e., the deepest part of the channel) deepened. The overall rise in bed level indicates a net surplus of material even after sediment extraction. However, the flood capacity of the channel has been maintained by the wider channel and deeper thalweg.

Beyond the river mouth the main channel has deepened slightly. These deeper bed levels tend to mitigate the flood risk by reducing the backwater effect during floods.

There is very little change on the harbour floor beyond its interface with the river. The slight apparent rise in the sea bed is likely to be within the measurement error of the sampling and modelling techniques used. Measurable change is observed in the area of the ‘dumping site’ which is to be expected. Aggradation of the sea bed in this area confirms that the dumping site is beyond the limit of natural sediment mobilisation.

The profile of Petone beach varies significantly between each survey, although no consistent trend of either progradation or erosion is apparent. Since the dumping of coarse material ceased, the beach has retreated back towards its likely original position. The beach in this area now appears to be in equilibrium. The material eroded from the eastern end of the beach was re-deposited towards the west, resulting in slight progradation along much of Petone Beach.

Other change between successive surveys is likely to reflect the wave environment immediately prior to sampling. It is not possible to identify any effect of extraction or dumping apart from that discussed close to the river mouth.

While there are constraints relating to the available particle size data, the results indicate no net change in beach character. Like the profiles, the sediment character reflects the wave environment prior to sampling, and the relative position of the sample along the beach profile.

Overall, the Hutt River mouth and Petone beach reflect a range of natural processes. There has been slight net aggradation of the lower river channel and sea bed. This reflects a surplus of sediment, above the rate of extraction, moving down the river.

Contents

1. Introduction

Beaches reflect the balance between the processes operating on the land and in the coastal zone. Consequently, beaches are dynamic systems subject to a high degree of spatial and temporal variability and change. The principal controls on beach form and process are the energy of the wave regime, and the character of the sediment on the beach; including the input, loss, and storage of sediment on the active beach face. The wave regime affects the amount of energy which is available to do work i.e., to cause change to the beach. Whether any change actually occurs depends on the nature of the material forming the beach; including its type, character, size, amount, and resistance.

Beach form is therefore the result of a complex set of interactions and not a single factor. Change is natural and ongoing. Sand and gravel beaches such as at Petone are among the most mobile, and changeable, of all landforms.

Beaches change over different temporal scales: daily, with the tidal cycle; seasonally, in response to shifts in dominant weather patterns; and over longer timescales in response to sediment supply, erosion or deposition, and changes in sea-level. Any assessment of beach form and changes over time must be viewed in the context of overall beach dynamics.

Figure 1.1 presents a simple model for shoreline stability (i.e., whether shorelines are advancing, stable, or eroding). It expresses the overall trend of shoreline behaviour in terms of the balance between sedimentation and sea level change. The model makes a primary separation between shorelines that advance, and those that retreat. Advance can be caused by an excess supply of sediment, a fall in sea level relative to the land, or a combination of both factors. Similarly, coasts that retreat will reflect a shortage of sediment, a rise of sea level, or a combination of both factors. Stable shores are those where sea level and sedimentation are relatively constant (Kirk and Single, 2000). However, while the long term trend may be one of stability, short term variation in response to pulses of either energy or sediment is still apparent.

Figure 1.2 illustrates the role of sediment supply in beach dynamics. The diagram presents the concepts of “beach compartments” and of the “sediment budget”. The notion of a beach compartment is essentially that of an organised system of sediment flows and storages with identifiable boundaries. On a beach, the most obvious boundaries might be headlands or other barriers which interrupt the supply or movement of sediment (Kirk and Single, 2000). Other boundaries to beach systems are: the highest active beach ridge (which marks the elevation of the highest storm wave run-up); the line to which onshore winds can blow sediment; and stream and river mouths. Offshore, the boundary to a beach compartment is the depth at which exchange of sand with the beach by wave action becomes limited.

Beaches are commonly supplied with sediment from stream catchments, erosion of shoreline outcrops, and longshore transport under wave action. Common losses are by transport into deeper water under the effect of storm waves, storage in beach ridges, and transport around headlands.

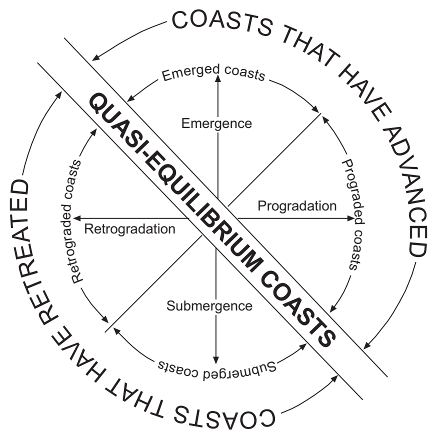

Figure 1.1: Model of shoreline stability (after Kirk and Single, 2000).

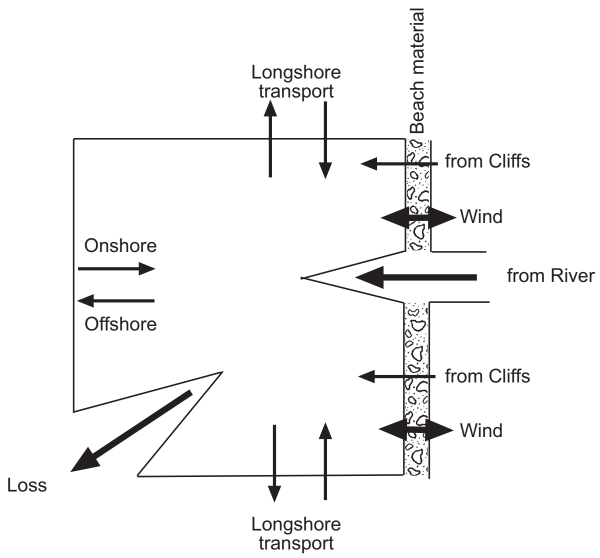

Figure 1.2: Shoreline sediment budget (after Kirk and Single, 2000).

Beach sediment budgets distinguish between inputs (gains) to the beach system, outputs (losses), and internal transfers. In a 'book-keeping' sense, if inputs exceed outputs over a defined period then the budget is in surplus. The beach will consequently advance seaward.

Similarly, if outputs exceed inputs the budget is in deficit and the shoreline will erode. It should be noted from this that shoreline erosion is always an indication of a sediment budget in deficit. The deficit may arise through: a decrease in sediment supply; an increase in losses, including the extraction of sediment; a change in the energy regime; or some combination of factors (Kirk and Single, 2000). Where a beach sediment budget is in deficit erosion is inevitable. Persistent beach erosion is not apparent at Petone.

Figure 1.3 presents a third conceptual model of beaches relevant to the management of sediment. This "Process-Response" model focuses on those processes that cause shoreline change, and the effects that may result. A three-part distinction is made between processes (factors that cause change), morphology (the beach shape), and sediments (the earth materials comprising the beaches). The model shows that the action of processes, mostly wave action on beach sediments, is to cause a mutual adjustment between the forces of the waves and the resistance of the material to transport. The outcome is the observed state of the beach. It follows therefore that as waves change, so does the shape of the beach. This fact causes beaches to be among the most dynamic and changeable features on Earth (Kirk and Single, 2000).

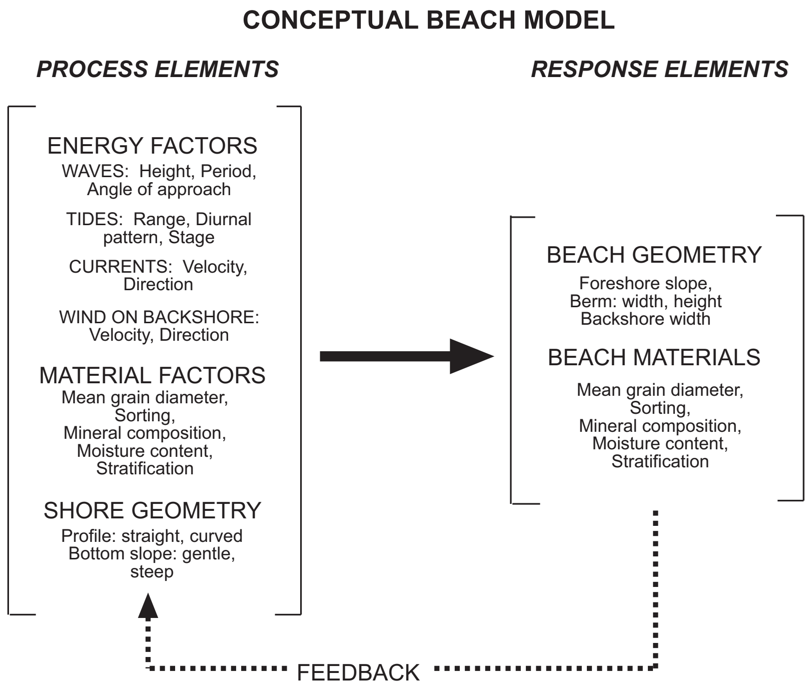

Figure 1.3: Conceptual beach model (after Kirk and Single, 2000).

Important relationships also exist between wave characteristics and beach form. Coarser-grained sediments give rise to more steeply sloping beaches. Consequently, there is a greater concentration of wave energy per unit area of beach surface than where the beach is formed from finer-grained sediments. Generally, erosion leads to the flattening of the beach slope while accretion steepens the foreshore (Kirk and Single, 2000).

2. Coastal dynamics

2.1 Introduction

Gravel extraction from the Hutt River mouth removes 'excess' sediment and inhibits the formation of a bar. This helps to ensure that the channel remains open, and flood flows into the harbour are not restricted. This mitigates the risk of flooding upstream because any backwater effect is lessened.

From the mid-1950s until 1995 annual sediment extraction rates varied between 27,000m³ and 67,000m³ (CER, 1995). This was considered an appropriate extraction rate for the interim management of the area (CER, 1995). Winstone Aggregates Ltd (Winstone's) have a resource consent, since May 1996, to extract sand and shingle from the bed of the Hutt River mouth. They can extract not more than 65,000m³ in any one year, and no more than an average of 50,000m³/yr over a 5-year period (Consent No. WGN950154 (01)). These volumes followed recommendations by Williams (1991), and were considered to be sustainable.

Winstone's gained resource consent in July 1999 to dump coarse waste dredge material onto the sea floor within Wellington Harbour (over an area of 6ha) about 700m south of the river mouth. Average rates for this activity were set at 5,200m³/yr, with a maximum annual rate of 6,700m³ (Consent No. WGN990012 (01)).

Both of the above consents expire in May 2011. They are currently being considered for renewal. This technical report therefore reviews the sediment transport processes in and around the Hutt River mouth, and along Petone Beach. It assesses the environmental effects of past dredging and waste disposal operations in this area.

Figure 2.1 shows the Hutt River mouth area including: zones of extraction and no extraction; offshore and foreshore disposal areas; Winstone's sand plant; the hydraulic line for flood flows; the location of the cross-sections for successive surveys of the river; and the eastern end of Petone Beach in front of Hikoikoi Reserve. These features are referred to in the body of this report.

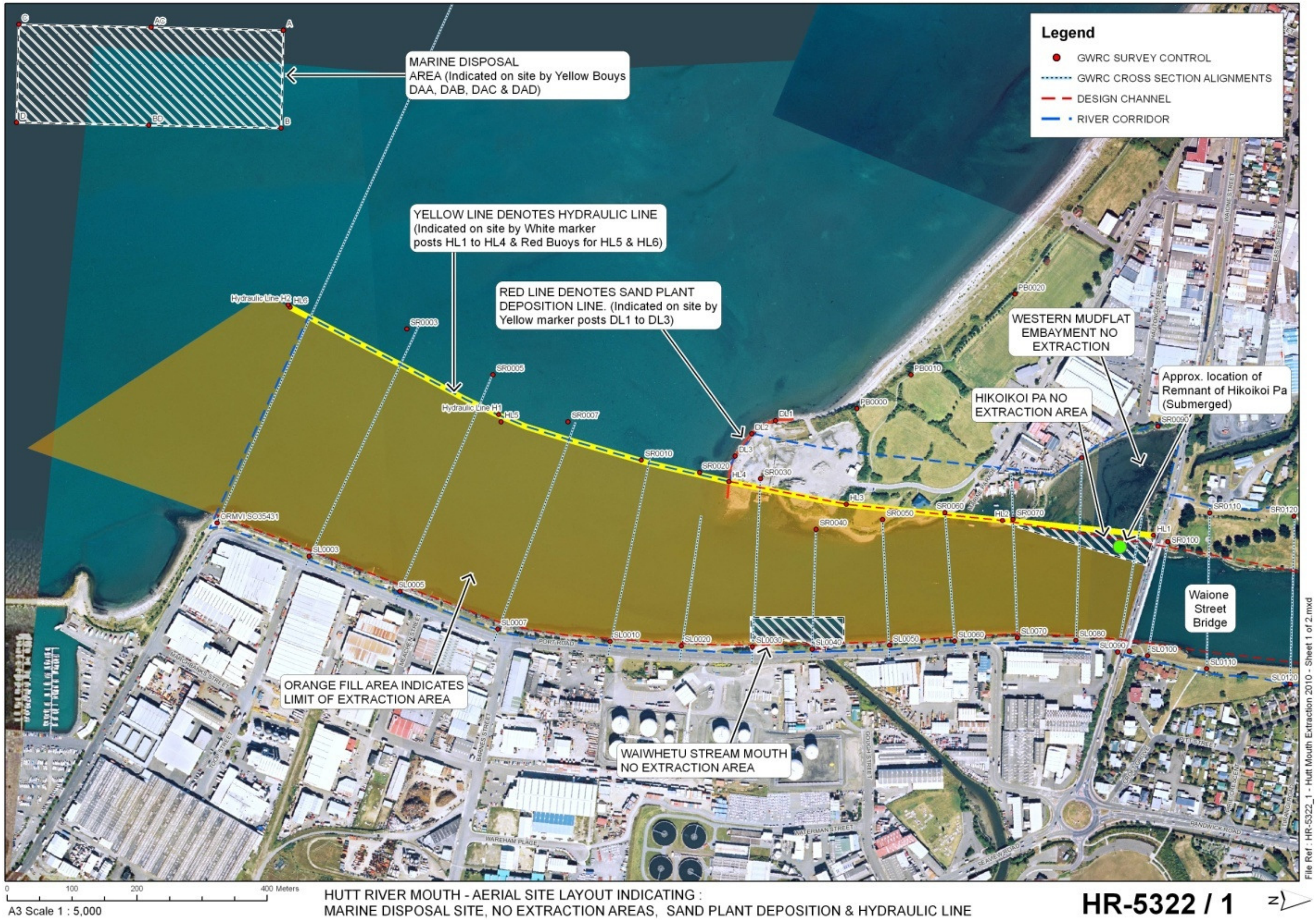

Figure 2.1: Layout of river dredging activities and zones in the vicinity of the Hutt River mouth (Source GWRC 2010 HR-5322_1).

2.2 Hutt River Mouth

The Hutt River mouth has been transformed considerably since 1900; from a coastal estuary to a well-defined river channel. The channel has been straightened and the bed excavated for flood management purposes. A large area has been reclaimed on the east bank. This now forms the Seaview industrial area. This reclamation was completed in two parts. The first 81ha was completed in 1934 using material dredged from the lower river. This area was then enlarged to its current extent after World War II (CER, 1995).

The most hydraulically-efficient channel shape for the Hutt River mouth was defined in 1973. This is now known as the "Hydraulic Line" and forms the effective true right bank of the river (Figure 2.1). The true left bank has been formed by the land reclamations described above. The area now being dredged for sand is between these two banks, downstream of the Waione Street Bridge. The area excludes the section of river in front of Hikoikoi Pa, and the western mudflat embayment. It also excludes the area directly in front of the Waiwhetu Stream confluence (Figure 2.1).

Sediment transported down the Hutt River includes silt, sand, and gravel. This material is eroded either from the flood plain or the slopes of the upper catchment. The method by which this material moves depends largely on its particle size as discussed in Opus (2010). A mobile hydraulic excavator on a barge extracts some of this material from the river bed to a maximum depth of 4.25m below mean sea level. The extraction depth is limited to protect the integrity of the underlying Hutt Aquifer.

Processing of the sediment involves the separation of coarse material (>5mm) consisting mostly of gravels, but including shells and wood. While some of this coarse fraction is sold as fill material, the remainder was initially stockpiled on the beach within the sand deposition bund (Figure 2.1). Since 1996 this coarse waste material has been dumped off-shore. Fine sediment from the settling ponds is also stockpiled within the bund area. Material from this deposit is then redistributed along the Petone Beach by wave action under southerly storm conditions (CER, 1995). The excavated product material is processed into different sand grades for wholesale to the construction industry. These sediment extraction activities have removed, and then prevented the build-up of, naturally forming bars across the river mouth. The area in the vicinity of the sand processing plant has been reclaimed by approximately 200m to the south (CER, 1995).

2.3 Petone Beach

Petone foreshore is a sand and gravel beach which extends in a northwest arc approximately 3.8km from the Hutt River mouth to State Highway 2 in the west. Petone Beach is not expected to be especially sandy. This is because high energy waves generated under southerly conditions erode any fine material from the beach, transporting it offshore. This leaves behind a 'lag deposit' of coarser gravel. The beach is mostly gravel at the eastern end; averaging 75% gravel within 500m of the Hutt River mouth. Immediately off the beach is a significant sand source, some of which is transported back onto the beach by waves under less energetic northerly conditions (CER, 1995). The main sediment source for Petone Beach is the Hutt River, with a minor amount of sediment entering the system from Korokoro Stream in the west. Sand and gravel is also transported through the heads and into Wellington Harbour during large southerly storms. Some of this may be deposited on Petone Beach.

The by-product of sediment extracted from the river mouth; consisting mainly of organic material, coarse sands to gravels, some finer sand, and shell, has been placed in a 120m bund on the high tide line of Petone foreshore. This is within Winstone's site (Figure 2.1). Material has been added at an average rate of 700m^3 per month. This material is then redistributed along the foreshore by coastal processes, generally driven by southerly storm waves. This practice was in place since the late 1970s. It contributed to significant accretion at the eastern end of Petone Beach. The extraction and redistribution of coarse material caused a lower proportion of sand at the eastern end of the beach. This practice was, however, altered in 1999. A new resource consent to dump the coarse waste material offshore then came into effect. From that time only fine sand and silt material has been deposited within the bund. This fine material was expected to be discharged into the beach/marine environment at an average rate of 8,800m^3/yr; and a maximum rate of 11,500m^3/yr (CER, 1998).

Petone foreshore accreted at an average rate of 2.33m/yr between 1840 and 1956 (Beca, 1996). This included a 30–100m shoreline advance associated with uplift caused by the 1855 earthquake (CER, 1995). Aerial photograph analysis shows 20–30m of beach accretion between 1939 and 1985. Accretion averaged 0.75m/yr and involved 10,000m^3/yr of material (O'Callaghan, 1996b). Throughout most of this period dredging operations have been active within the Hutt River mouth. From the early 1980s to mid-1990s the eastern end of the beach advanced at a greater rate than in the west; approximately 15m (~1m/yr) compared to 8m (~0.5m/yr) (O'Callaghan, 1996a).

2.4 Disposal Site

The characteristics of sediment offshore from Petone indicate a belt of sands, 0.016-0.075mm in diameter, out to approximately 300m. The sediment is finer the further offshore. Beyond 300m from the shore, harbour bed surface sediments are mainly silt and silty-mud (CER, 1995). The deposal site for coarse waste material since 1999 was initially composed of mainly very fine homogenous silt and clay. This is typical of other areas within the harbour at depths of over 10m (Wear, 1996).

The currently consented coarse by-product disposal site, a 400x150m north-south orientated rectangle, is situated approximately 700m southwest of the Hutt River mouth. It is located in an area where the water is about 10–14m deep (Figure 2.2). However, there is a proposal for the disposal site to be moved approximately 190m to the south (Figure 2.3). This should prevent any excessive build-up of sediment. The new site is at the same depth as the previous location so the processes and effects should be the same. The sea floor at this depth is a low kinetic environment with maximum current flows of only 1.5-2cm/s (O'Callaghan, 1996b). The flow of these bottom currents runs parallel to the sea floor contours, and consequently the beach. They travel northwards during incoming tides and southwards on outgoing tides (CER, 1998).

The depth of the waste dumping zone, and the low velocity and lateral currents, are sufficient to avoid the migration of sediment back onto Petone Beach, or into the river mouth

(O'Callaghan, 1996b). As will be discussed later, this has been confirmed by bathymetric surveys.

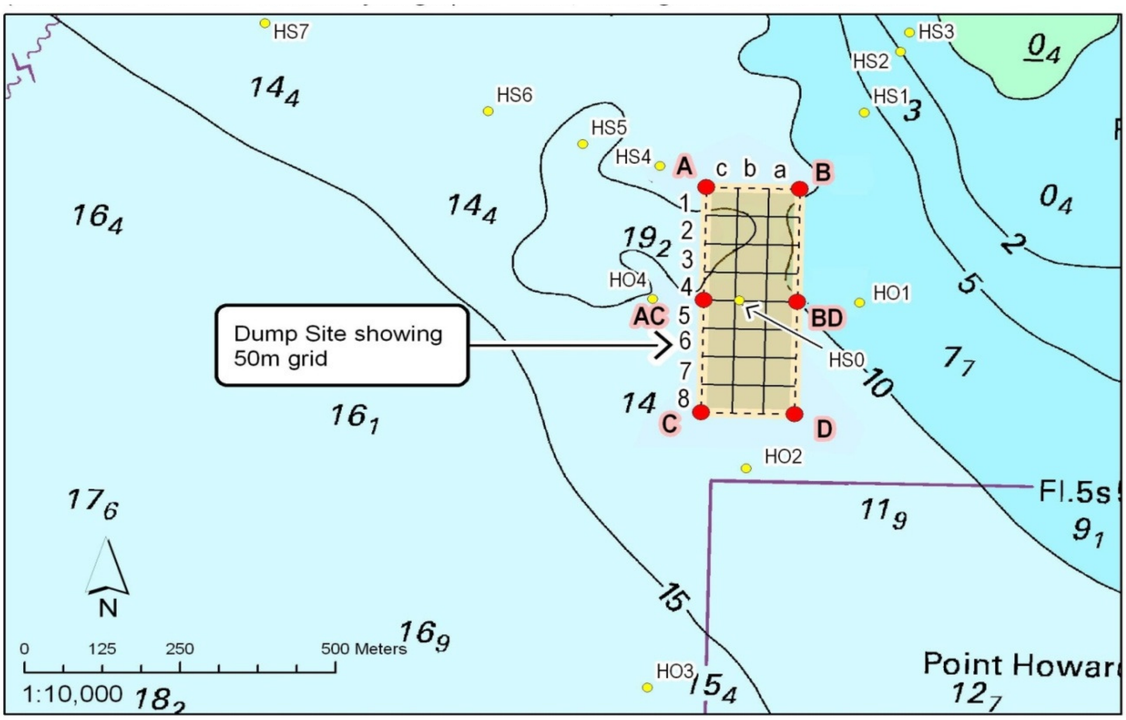

Figure 2.2: Location of current dump site in Wellington Harbour (Source GWRC).

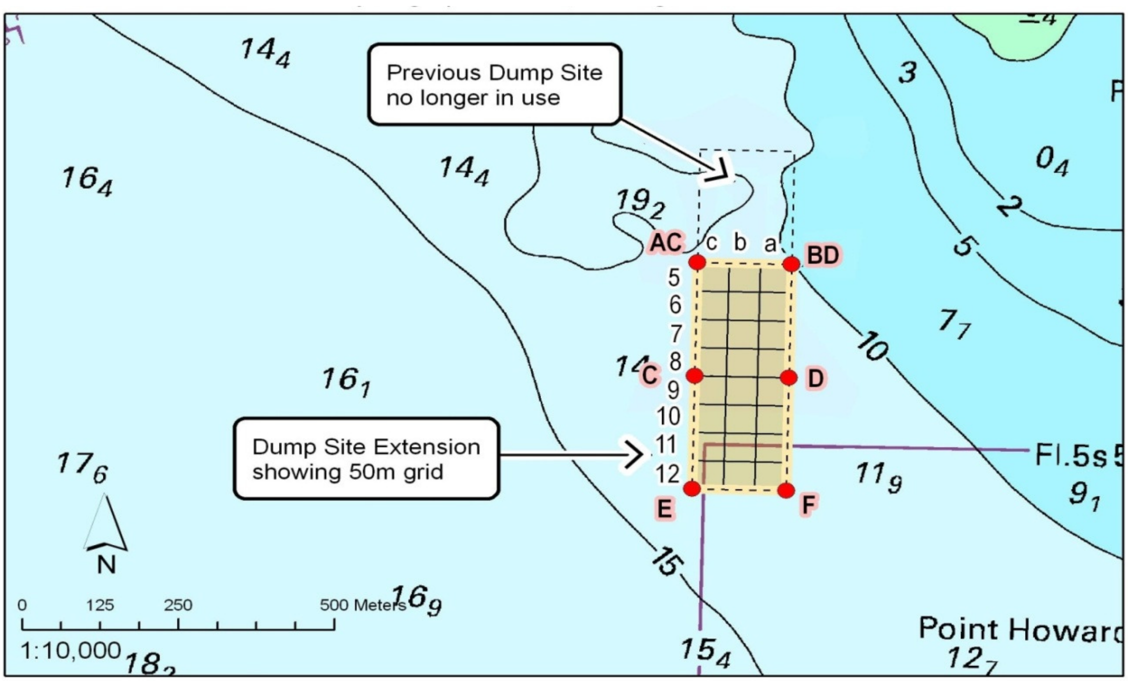

Figure 2.3: Location of proposed dump site in Wellington Harbour (Source GWRC).

3. Sediment transport

3.1 Wind and waves

Waves affecting the Hutt River mouth and Petone foreshore are mainly generated by winds from 190° to 290° within the fetch-limited Wellington harbour (Beca, 1996). The maximum fetch in this direction is about 10.5km; from the Hutt River mouth to Seatoun. A narrower band exists (195° to 205°) where waves approach directly through Wellington Heads from Cook Strait. Winds from this direction essentially have an unlimited fetch to the south, producing large waves at the harbour entrance. These waves diminish in height once they enter the harbour (Marico, 2006) but can still be up to 2.2m at the breaker zone off Petone Beach (O'Callaghan, 1996b). The Seaview Marina was designed using an estimated significant wave height of 2.0–2.5m which are expected about once every 20 years under south to south-westerly conditions (Beca, 1996).

3.2 Sediment transport processes

The majority of sediment supplied via the Hutt River arrives in pulses associated with discrete flood events (Opus, 2010). It is estimated that an average of approximately 10,000m^3 of sediment is accumulating on Petone Beach each year (O'Callaghan, 1996b).

Southerly generated ground-swell and wind-wave action is the predominant sediment transport process on Petone Beach. Waves of up to 2.2m are capable of moving sand out into the harbour to a depth of 4.5m. Coarser sediment can therefore only move at shallower depths, and in lesser volumes, because of the energy required to move the larger particles (O'Callaghan, 1996b). Silt and very fine sand within the by-product disposal bund is easily eroded from the beach by wave action and is lost offshore. This material can also be re-deposited further along the beach by longshore drift.

Trapped edge waves cause the longshore drift along the beach of both naturally occurring sediment, and that from the disposal bund. Stronger longshore drift occurs around the reclaimed land near Winstone's extraction processing plant than on the remainder of Petone Beach. This is because of the north-northwest alignment of this section of the coast relative to the southerly wave approach. Southerly waves can also push sediment back into the river mouth as the shoreline is aligned due north at the eastern end of the Winstone's plant.

These sediment transport processes are strong enough to move gravels west along the beach for approximately 500m (O'Callaghan, 1996a). This, combined with the material previously available from the disposal bund, has caused Petone Beach to be composed of mainly gravel in this vicinity. Sand is more predominant further west as the sediment transport processes lessen, and more offshore sand is available to the system. Very little of the larger-sized sediment is transported all the way to the western end of Petone Beach. This is because the short fetch within the harbour limits significant wave build-up, and therefore longshore drift from any direction other than the south.

Profiles measured on Petone Beach reflect the sediment composition, and also the dominant sediment transport processes. The eastern end of the beach is relatively steep compared to the flatter profiles further west where sand is more dominant. The eastern beach consists of more gravel, and therefore steepens to reflect energy during wave attack. Once the gravel is 'pushed' high up the profile it is only mobilised under the most severe storm waves. Any sand or silt within the profile is, however, likely to be removed more regularly.

4. Geomorphic change

In the past, concern has been raised about the effect of sediment extraction and by-product deposition activities on the nature of Petone Beach; particularly near the Winstone's plant. Concern related to increasing stoniness and the build-up of silt; the impact of this on the landscape and beach profile; and the adequacy of data to monitor of these effects.

The resource consents granted for both sediment extraction and the dumping of waste by-product included conditions requiring specific monitoring of the potentially affected environments. This included: cross-sectional surveys of the river bed at 5-yearly intervals; full hydrographic surveys of the greater river mouth area at 10-yearly intervals; aerial photography of the greater river mouth area at 2-yearly intervals; and six beach profile surveys, including photographs and sediment size analysis of samples from MSL on each profile at 6-monthly intervals.

4.1 River bed cross sectional surveys

Cross-sectional surveys have been undertaken along the length of the Hutt River. Thirteen of these are below the Waione Street Bridge and include the dredging area at the river mouth (Figure 2.1). These are numbered from: 1, surveyed from the southern point of the Seaview industrial area out into Wellington Harbour; to 90, just downstream from the Waione Street Bridge. Cross-section 100 is just upstream of the Waione Street Bridge. Although not within the dredging zone, this cross-section has been included for comparative purposes since it represents 'un-dredged' conditions. The majority of these surveys cover 1987, 1993, 1998, 2004, and 2009. Three of the surveys include the effects of river dredging under the current resource consent; granted in 1996. The 1987 and 1993 surveys reflect the bed levels 9 and 3-years prior to the granting of the current consents.

Cross-section 1 was only surveyed in 2004 and 2009. This section shows very little difference in bed level which is currently around -2.75m RL (Figure 4.1). Over the 450m surveyed in 2009, the bed shape has remained similar to that in 2004. This includes the steep eastern bank against the Seaview industrial area, and the flat river bed 100–400m from the survey origin. Beyond 400m the bed drops into Wellington Harbour itself. The bed lowered a maximum of 0.6m between 100-350m from the survey origin over this 5-year period. The western edge has risen by 0.7m between 450-350m, and the eastern edge bank has risen 0.4m over the same time. These differences are all very minor and are likely to be within the resolution of the measurement techniques adopted. Nevertheless, even if these changes are real their effect on the river and harbour is likely to be less than minor.

Cross-section 3 shows that the bed of the channel lowered by up to 1.4m between 1987 and 2009. The majority of this lowering (up to 1.3m) occurred between 1987 and 1998 (Figure 4.2). Since 1998 the bed has been lowered a maximum of 0.8m. The bed levels and overall shape remain very similar between the 2004 and 2009 surveys, with the bed at around -2.5m

RL. Differences range up to approximately 0.4m where the thalweg (i.e. the deepest part of the channel) moves from the eastern to the western side of the cross-section.

The river bed at cross-section 5 has fluctuated over the whole surveyed period. Much of this fluctuation is caused by the movement of the thalweg across the bed (Figure 4.3). While the 1987 surveyed bed was generally higher, at around -1.6m RL, the thalweg was at 2009 levels (between 220–270m from the survey origin). A decrease in channel depth over time is more evident at the eastern bank. This portion of the cross-section lowered by approximately 0.6m between 1987 and 1998; to -2m RL between 0–100m from the survey origin. The bed lowered a further 0.2m between 1998 and 2004, but seems to have remained fairly stable since that time at around -2.2m RL. The western ends of each survey finish at different points. It is therefore difficult to identify any definitive bed lowering that is not associated with the wandering thalweg. In general, bed levels within this area have remained within ±0.2m since 1998.

Cross-section 7 shows the bed levels to be similar in both shape and depth over all the surveyed periods (Figure 4.4). The later levels (2004 and 2009) fluctuate within ±0.2m of each other at around -2.1m RL. This is approximately 0.4m lower than during the earlier surveys (1998 and 1987) when levels were also within 0.2-0.3m of each other. Overall, this indicates a slight lowering of bed levels in the vicinity of cross-section 7 over the last decade.

The western end of cross-section 10 shows the most change (Figure 4.5). The river bed between 200–400m from the survey origin shows a lowering of the bed of 0.8m between 1998 and 2004. It was then at -2.2m RL. The “Hydraulic Line” (i.e. the true right bank of the river’s most efficient flow path) is situated around 250m from the survey origin in 1987 and 1998. The general lowering of the bed appears to be associated with erosion of the true right bank between 1998 and 2004. This section has then remained stable through to 2009. The depth on the eastern side of the cross-section has remained relatively constant since 1987; at approximately -2.1m RL. In 2004 the channel reached a depth of -2.6m RL, but it had returned to previous levels by 2009.

The eastern side of the river channel in cross-section 20, 50–175m from the survey origin, is higher in 2009, at around -2.1m RL, than in all the older surveys (Figure 4.6). In the 1998 and 2004 surveys the channel was approximately 0.5m lower, while in 1987 it was 0.2m lower. The “Hydraulic Line” is evident in this survey by the higher bed level 250m from the survey origin. This feature is maintained through the dredging activity for optimum flood mitigation. By the 250m mark the 2009 level is 0.50–0.7m lower than the 1998 and 2004 level.

Cross-section 30 is the first to extend across the entire river, and includes data from 1993 (Figure 4.7). The left bank is within a ‘No Extraction Area’ at the mouth of the Waiwhetu Stream (Figure 2.1). Little change is evident at this bank. The middle of the channel was at a depth of around -2.3m RL in 2009. This is a similar level to that in 1987. The area between 75–150m from the survey origin was approximately 0.4m lower in 1993, and 1m lower in 1998. This section has therefore aggraded despite the dredging operations, and the channel is now shallower than previously. However, a thalweg has developed towards the western bank lowering the channel to a depth of -3.2m RL. This allows larger flows to pass through this section even though it is generally shallower than it has been in the past.

The eastern bank of cross-section 40 is also within the ‘Waiwhetu Stream Mouth No Extraction Area’ (Figure 2.1). The minor changes observed 0–40m from the survey origin are therefore natural. The channel from around 50m has lowered approximately 1.6m from 1987/1993 levels (Figure 4.8). The 2009 channel is at about -2.6m RL 50–150m from the survey origin. Again, this is similar to the 1987 levels. The 1993, 1998 and 2004 levels were between 0.4–1.0m lower (1998 levels were the lowest). However, the channel has widened in the vicinity of the Winstone’s plant by approximately 20m (at 0m RL) since 1987, and 10m since 1998.

Cross-section 50 shows the channel in 2009 to be at approximately -2.4m RL. This is the shallowest of all the surveyed cross sections at this location (Figure 4.9). The deepest cross-section was surveyed in 2004. It was 0.8m lower than the other surveys at an average RL of -3.2m. The other cros-sections fluctuate around a mid-channel average of -2.8m RL. The banks at either side of the river have remained stable throughout all surveys.

Cross-section 60 also has stable banks (Figure 4.10). The 2009 and 2004 profiles are generally shallower than the earlier surveys up to 130m from the survey origin; at an average of approximately -2.4m RL. The thalweg has moved from the western side of the channel in 2004 to the east side in 2009. The previous surveys are generally deeper, fluctuating around a mid-channel average depth of approximately -3.5m RL. The channel along the western bank apparent in the earlier surveys has not been present since 2004.

The thalweg on cross-section 70 deepened by approximately 0.8m between 2004 and 2009 (Figure 4.11). This is still 0.4m shallower than it was from 1987 to 1998. Levels over this period were around an average of -3.5m RL at this point (approximately 65m from the survey origin). The western side of the channel has become deeper by approximately 0.6m since 1998 150–170m from the survey origin. The channel has also widened by about 20m at -1.5m RL.

The shape of the channel in cross-section 80 has generally stayed the same, and the banks have remained stable over the surveyed years (Figure 4.12). The bed levels of the western side, to around 100m from the survey origin, are very similar. Most fluctuation occurs within the thalweg, 20–100m from the survey origin. The depth of this fluctuates between -3.8m RL in 1993 to -2.6m RL in 2004. In 2009 the bed level is approximately -3.2m RL.

Cross-section 90 is the narrowest of all the river cross-sections. This is controlled mainly by the bridge a few metres upstream, and the ‘Hikoikoi Pa No Extraction Area’ on the western bank (Figure 2.1). The 2009 profile is the shallowest of all surveys with the main channel averaging around -1.8m RL (Figure 4.13). At 120-150m from the survey origin, just before the no extraction area, the thalweg extends down to -3.6m RL. This was deepest in 2009. In general, the river bed has progressively risen by around 1m, while the thalweg has deepened by 1.2m at this cross section since the 1987 survey.

Cross-section 100 is just upstream of the river dredging activity. The 2009 survey shows bed levels 30–100m from the survey origin being the highest of any survey; approximately -1.8m RL on average (Figure 4.14). This is 0.8m higher than the average bed levels during the 1987, 1993, and 1998 surveys which all fluctuate around -2.4m RL. The bed appears to have begun accreting after the 1998 survey. The bed level on the western side, between 100–130m, fluctuates around approximately -2.4m RL. The western bank has widened by approximately 10m at -1m RL, 135–150m from the survey origin after 1998. This allows larger flows to travel down the generally shallower channel.

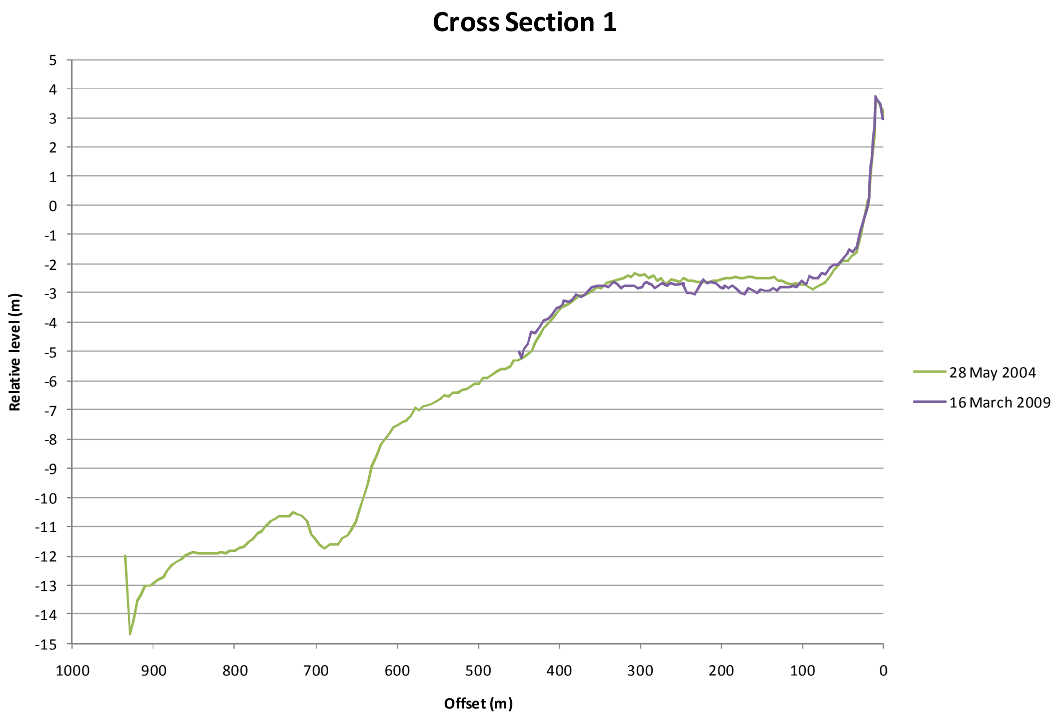

Figure 4.1: Hutt River bed at cross-section 1 looking upstream. The origin is on eastern bank of Hutt River.

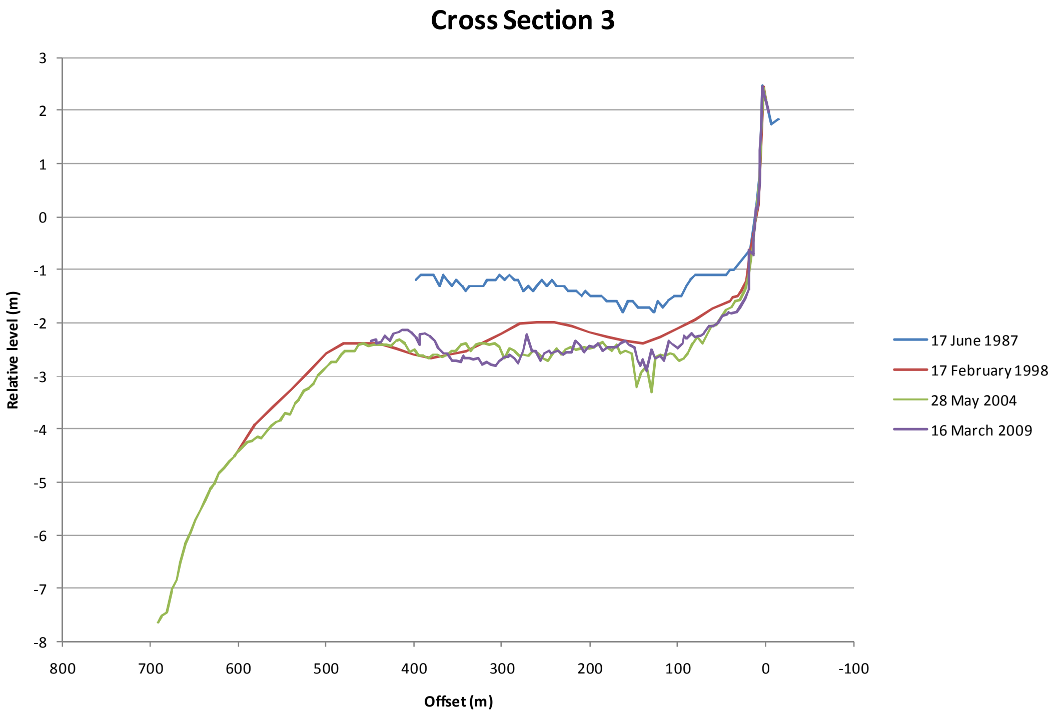

Figure 4.2: Hutt River bed at cross-section 3 looking upstream. The origin is on eastern bank of Hutt River.

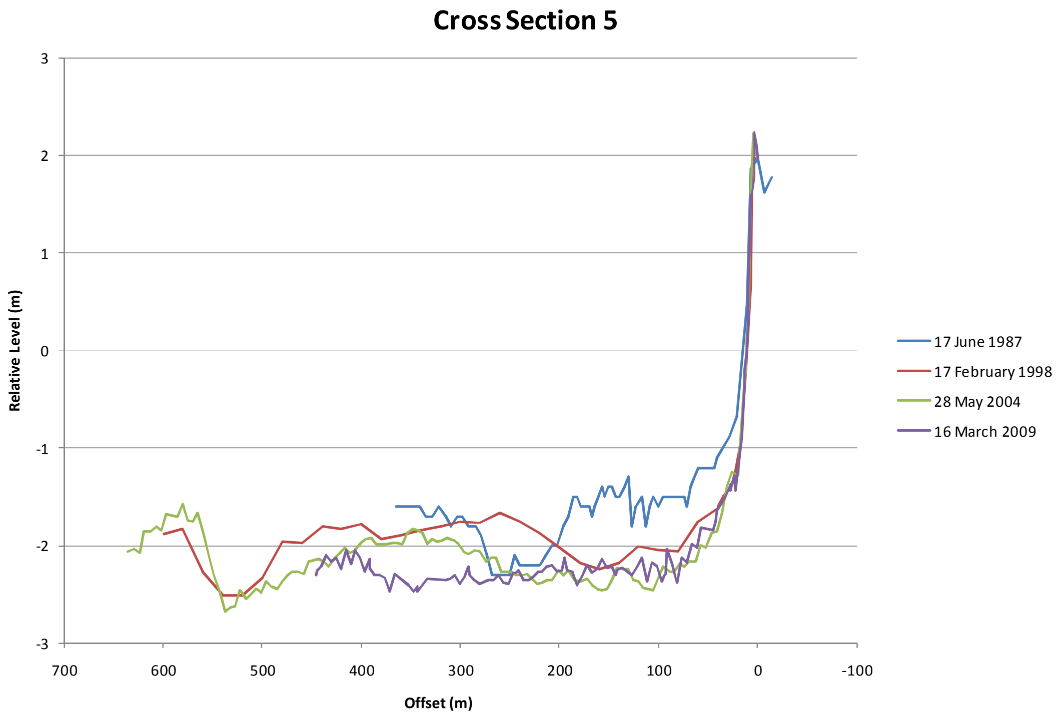

Figure 4.3: Hutt River bed at cross-section 5 looking upstream. The origin is on eastern bank of Hutt River.

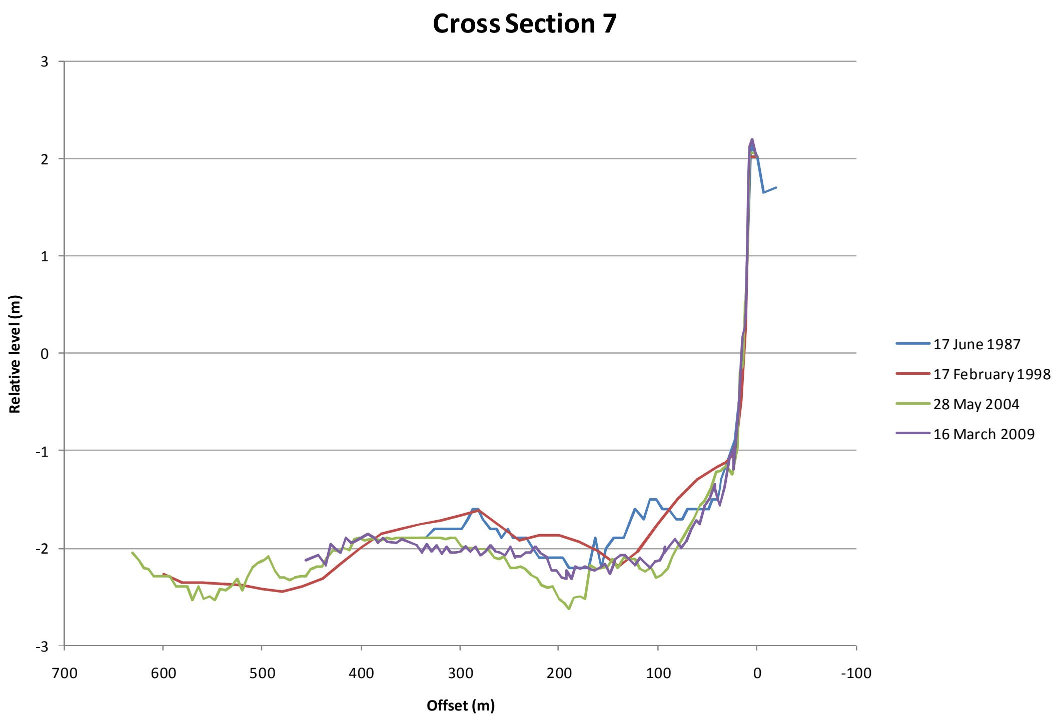

Figure 4.4: Hutt River bed at cross-section 7 looking upstream. The origin is on eastern bank of Hutt River.

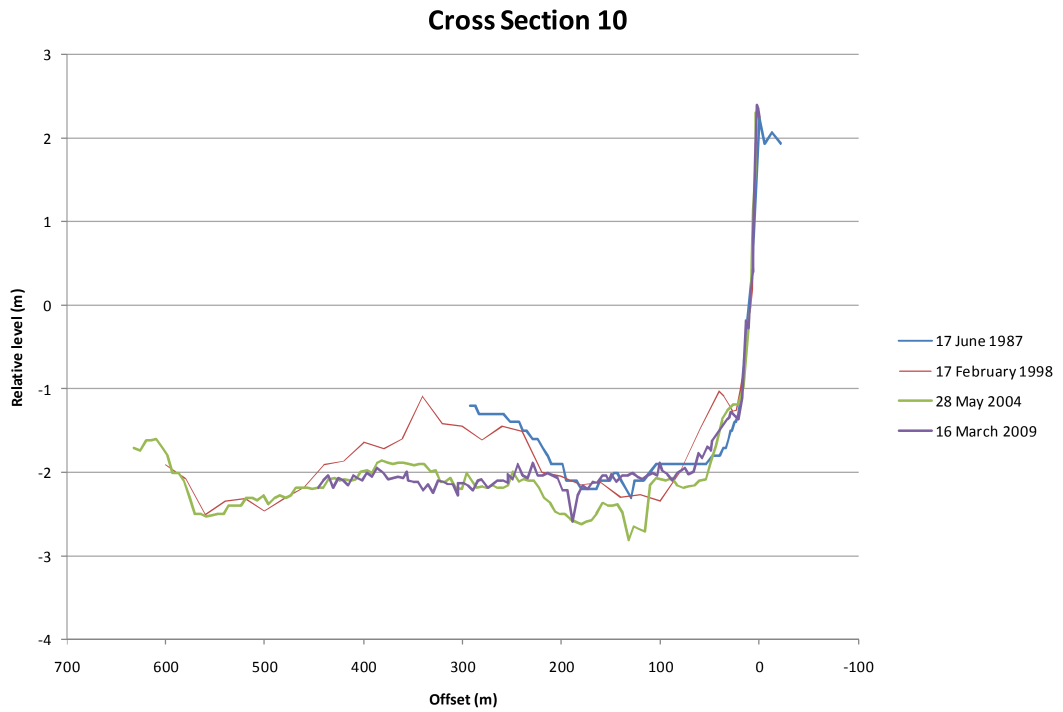

Figure 4.5: Hutt River bed at cross-section 10 looking upstream. The origin is on eastern bank of Hutt River.

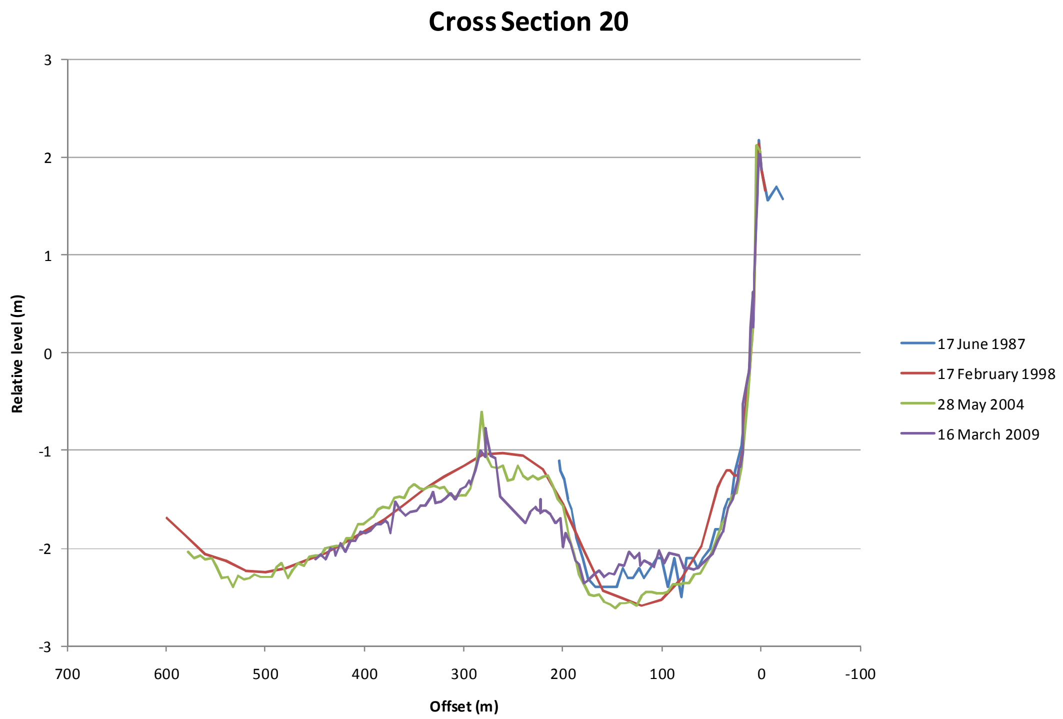

Figure 4.6: Hutt River bed at cross-section 20 looking upstream. The origin is on eastern bank of Hutt River.

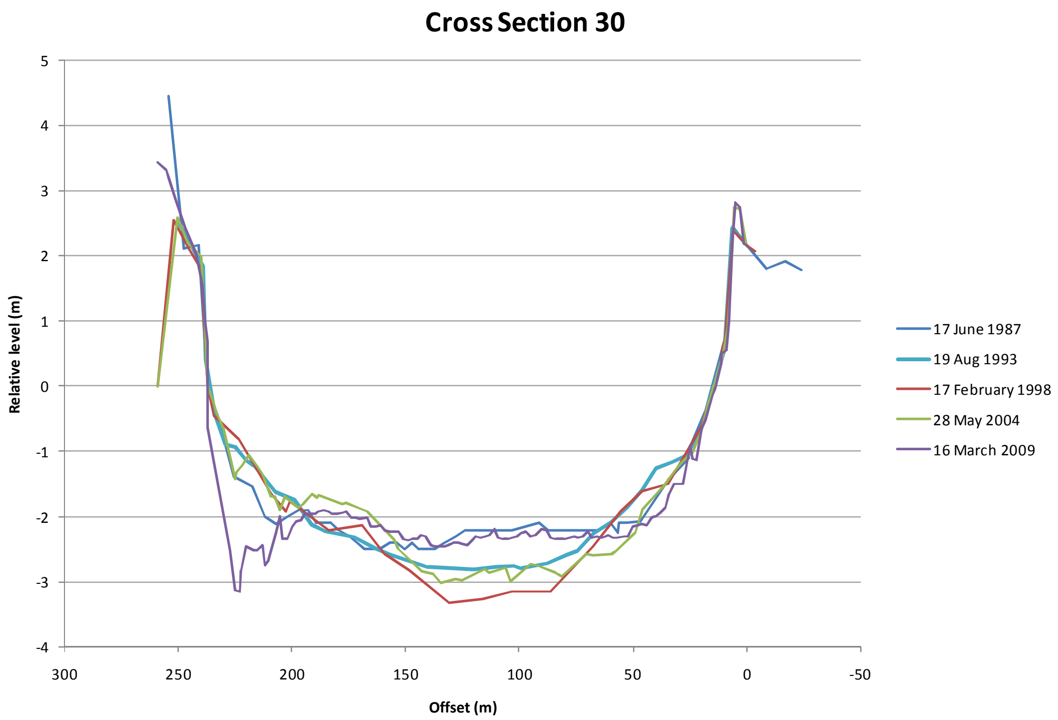

Figure 4.7: **Hutt River bed at cross-section 30 looking upstream. The origin is on eastern bank of Hutt River.**

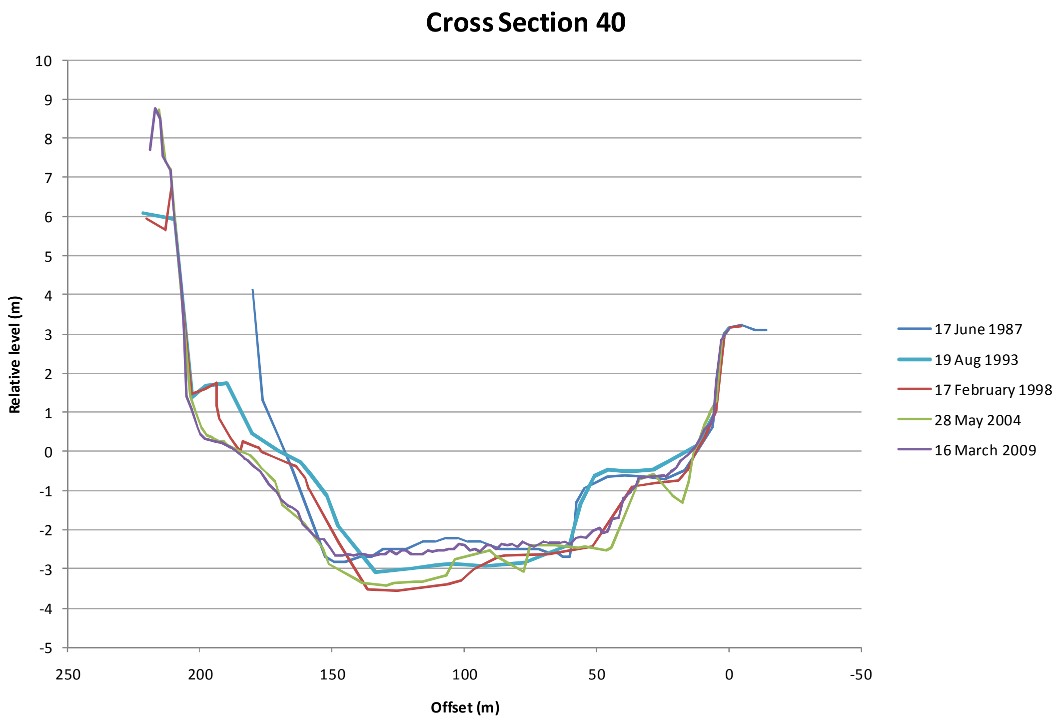

Figure 4.8: **Hutt River bed at cross-section 40 looking upstream. The origin is on eastern bank of Hutt River.**

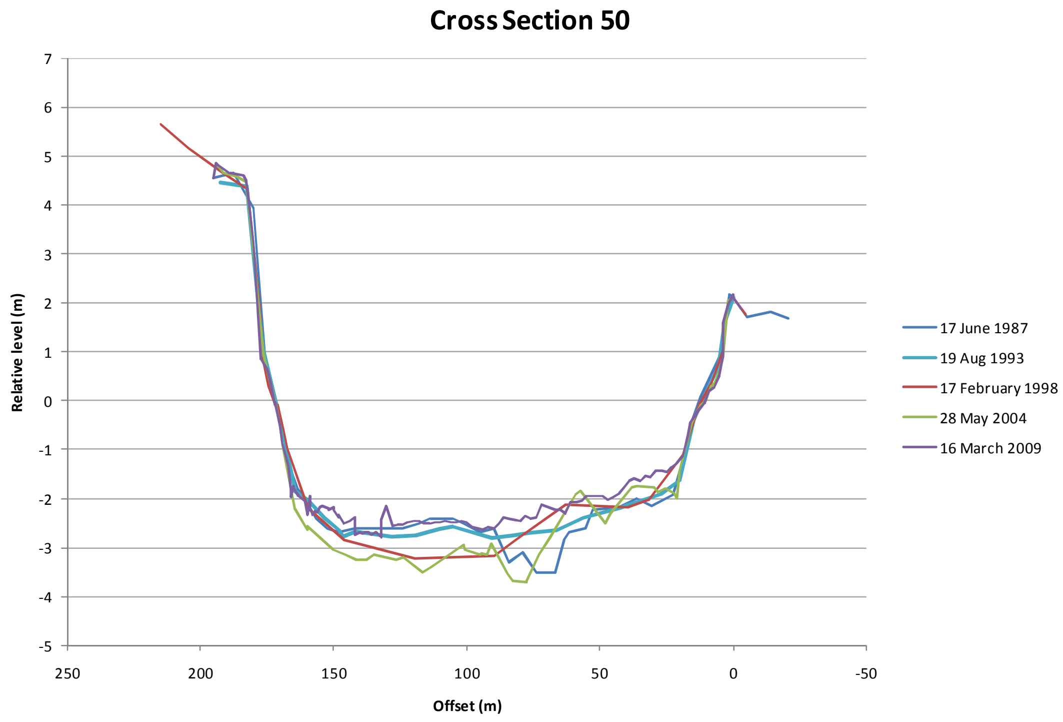

Figure 4.9: **Hutt River bed at cross-section 50 looking upstream. The origin is on eastern bank of Hutt River.**

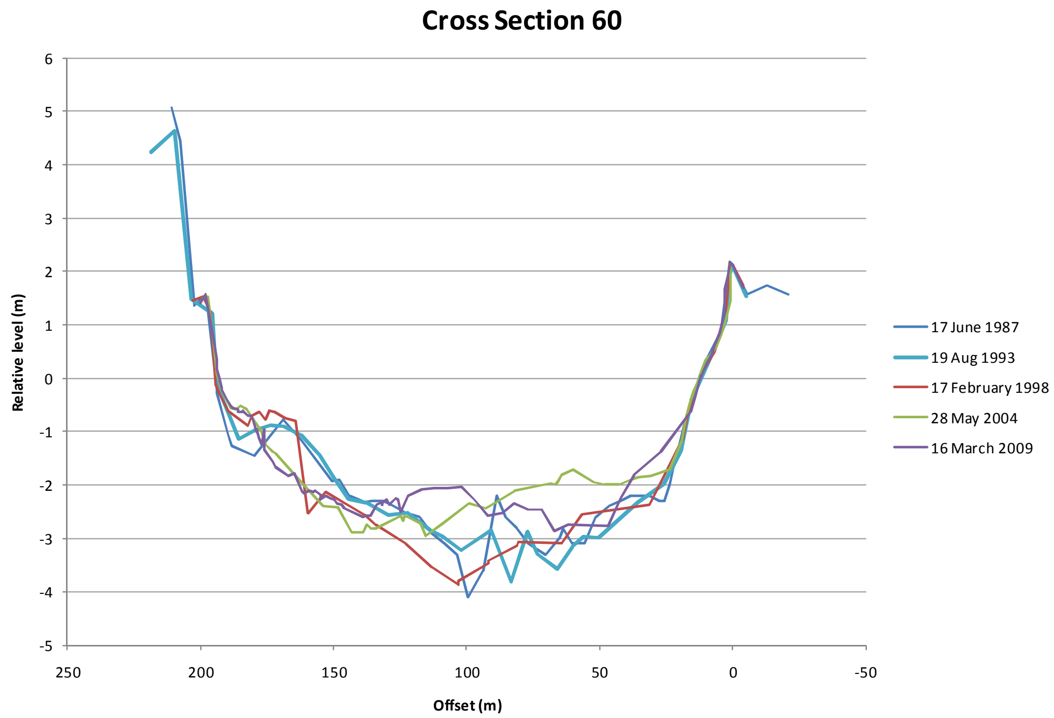

Figure 4.10: **Hutt River bed at cross-section 60 looking upstream. The origin is on eastern bank of Hutt River.**

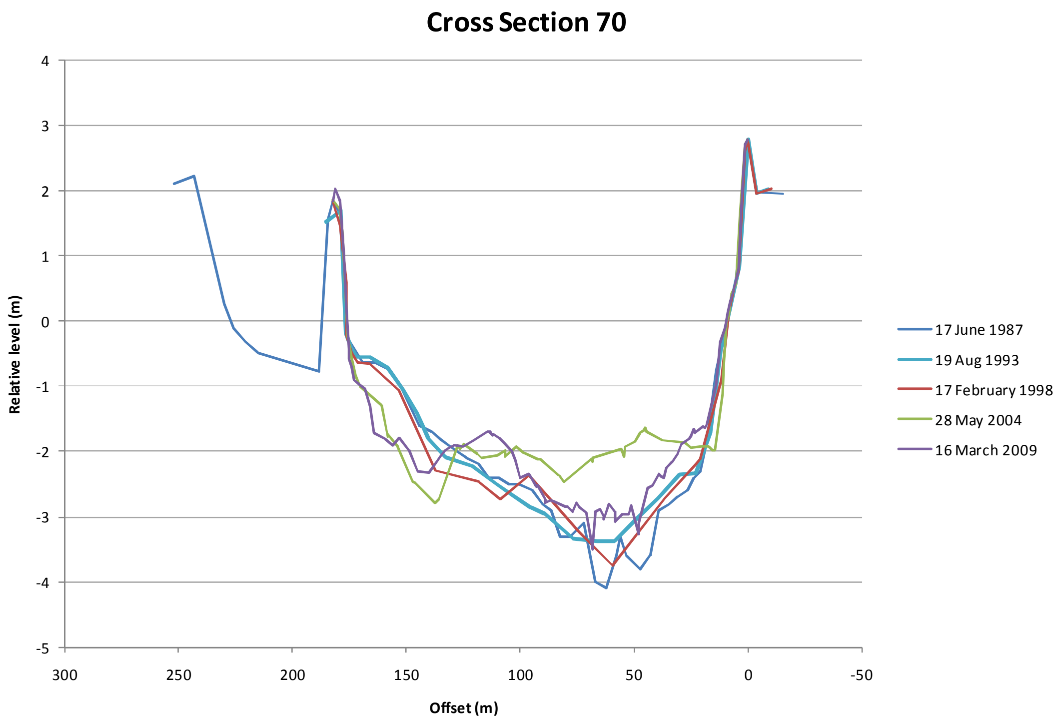

Figure 4.11: **Hutt River bed at cross-section 70 looking upstream. The origin is on eastern bank of Hutt River.**

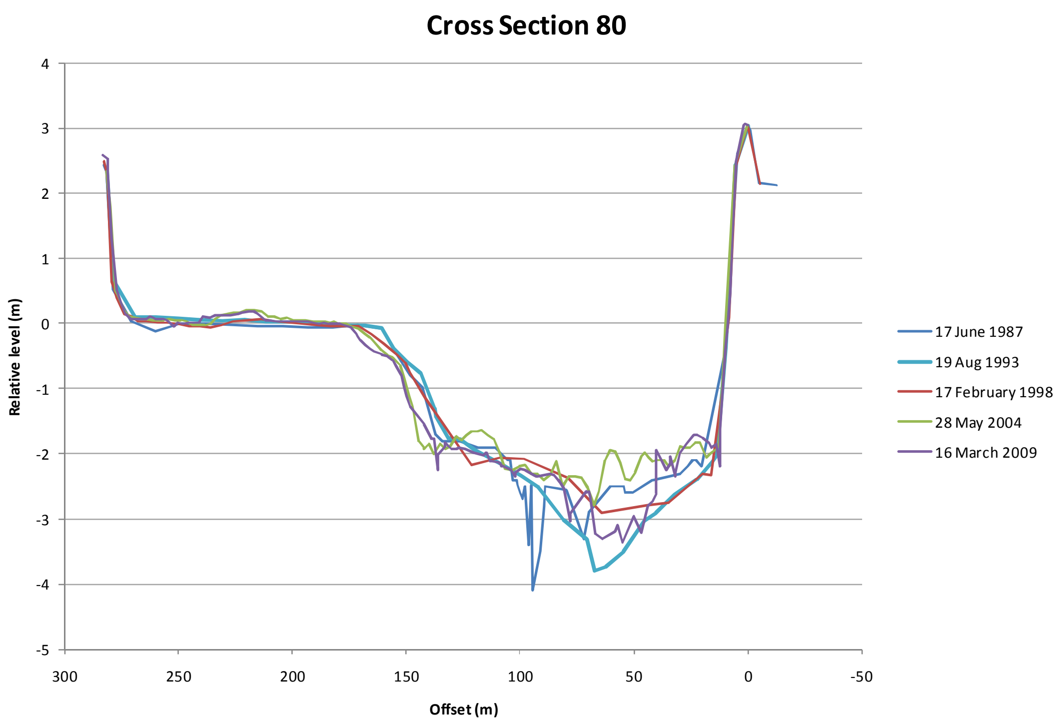

Figure 4.12: **Hutt River bed at cross-section 80 looking upstream. The origin is on eastern bank of Hutt River.**

Figure 4.13: **Hutt River bed at cross-section 90 looking upstream. The origin is on eastern bank of Hutt River.**

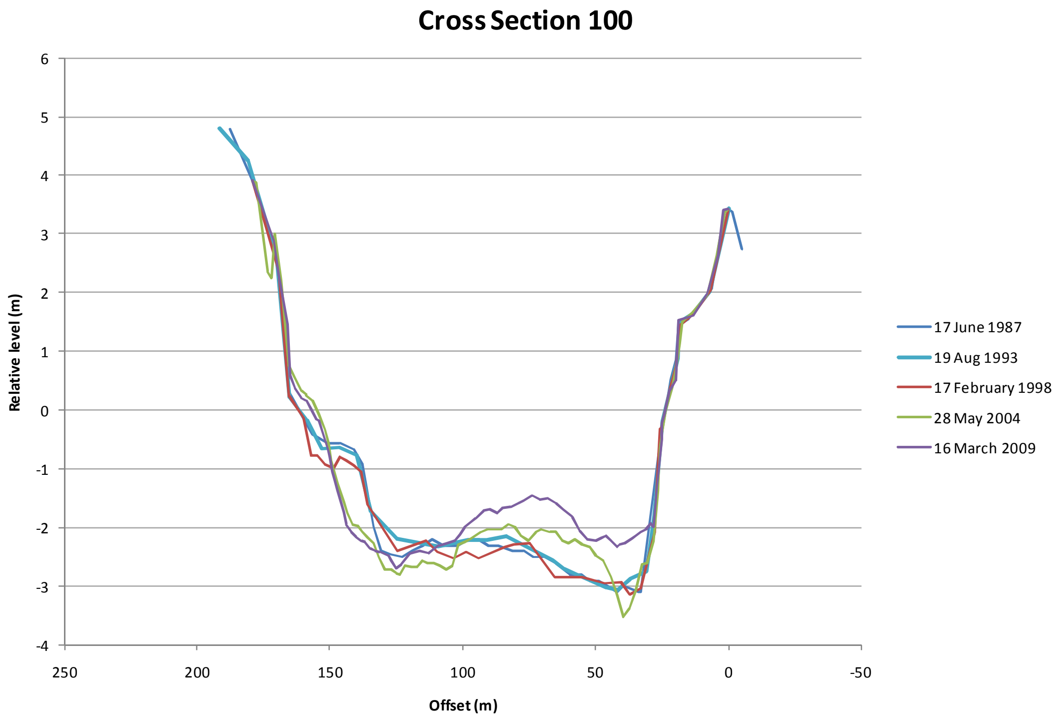

Figure 4.14: **Hutt River bed at cross-section 100 looking upstream. The origin is on eastern bank of Hutt River.**

The greatest changes to the river bed profiles occur between cross-sections 3 and 10. These are situated south of the Winstone's plant, and run from the Seaview industrial area out into Wellington Harbour. Even these cross-sections, however, have remained relatively stable since 2004. The levels in 2004 and 2009 are up to a metre below those surveyed in 1987. Much of this bed lowering occurred between 1987 and 1998. It is unclear if this occurred before, or as a direct result of, the 1996 sediment extraction consent. However, since the cross-sections have been stable since 2004 it is unlikely that sediment extraction was responsible. The true right bank of the Hydraulic Line has tended to flatten in later years (2004–2009) at cross-section 10. The Hydraulic Line had also been eroded at cross-section 20 by 2009.

A general rising of the bed level back to that surveyed in 1987 is shown from cross-section 10 up to the Waione Street Bridge (cross-section 90). This has been associated with some widening of the channels and/or deepening of thalwegs, which helps to accommodate higher flood flows. This pattern is also evident above the extraction area on cross-section 100. It must therefore reflect effects other than sediment extraction. Where the earlier surveys fluctuated around a general mean (i.e. in cross-sections 50, 80, and 100) the pattern is similar. The 1987 bed level is the lowest; the 1993 level the highest; and the 1998 survey in the middle.

Dredging of the channel has occurred over a long time span. Changes within the catchment that affect sediment supply have also been continuous. Consequently there is no base-line information. The lack of this base-line data makes it impossible to determine the specific effects of the most recent abstraction. This is compounded by the fact that overall the changes have been small. However, it appears that the bed levels in the upper extraction zone are actually higher than those in 1996; when the consents were granted.

The bed levels may correlate with the pattern of annual and monthly sediment extraction from the river mouth. Annual extraction rates prior to 1996 fluctuated widely but were generally higher than in later years (Figure 4.15). Monthly extraction rates continued to fluctuate between 5320m^3 and 1345m^3 until late 2001. Since 2002 the fluctuations have lessened, and since mid-2005 extraction rates have fallen (Figure 4.16). These reduced extraction rates have likely resulted in a slight rising of the overall bed level i.e. there has been a net surplus of sediment at the river mouth. The 12-month moving average shows that as well as extraction decreasing since 2005, monthly extraction averages around 3700m^3. The widening of the channel, and deepening of the thalweg, is a result of the higher bed levels and the consequential changes necessary for the channel to convey flood events.

Overall, there is no evidence in the analysis of the cross-sections to suggest that sediment extraction has had a significant effect on the character and dimensions of the channel. The fact that the bed has generally risen over recent years indicates a net surplus of sediment, even after the extraction of about 35,000m^3 of material each year (Figure 4.17)

Figure 4.17 shows that total annual extraction has varied between about 35,000 and 51,000m^3 over the past 10 years. It would appear that there has been a slight reduction in total abstraction, particularly since 2005. What is perhaps of more significance is that the total volume of 'product' appears to have decreased markedly over the past 10 years, and particularly since 2005. The volume of waste by-product has consequently increased significantly; particularly the finer fraction. This may reflect a reduced level of flood activity over recent years. This would lead to less sand and gravel and more silt deposition as discussed in Opus (2010).

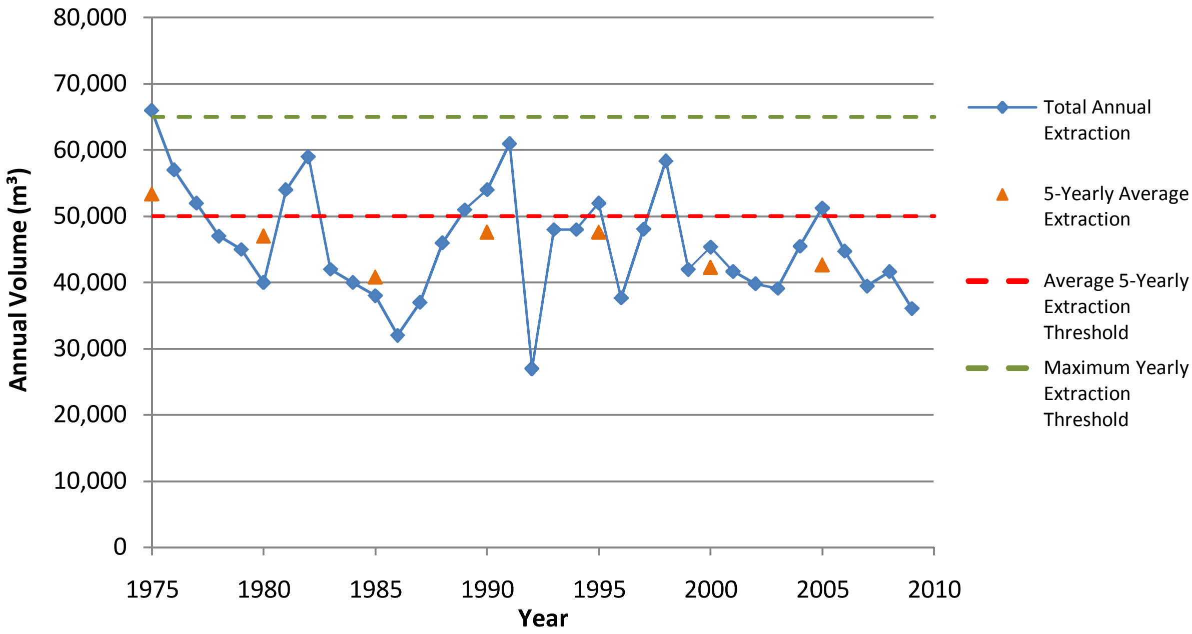

Figure 4.15: Annual river dredging extraction rates at the Hutt River Mouth 1975 to 1999.

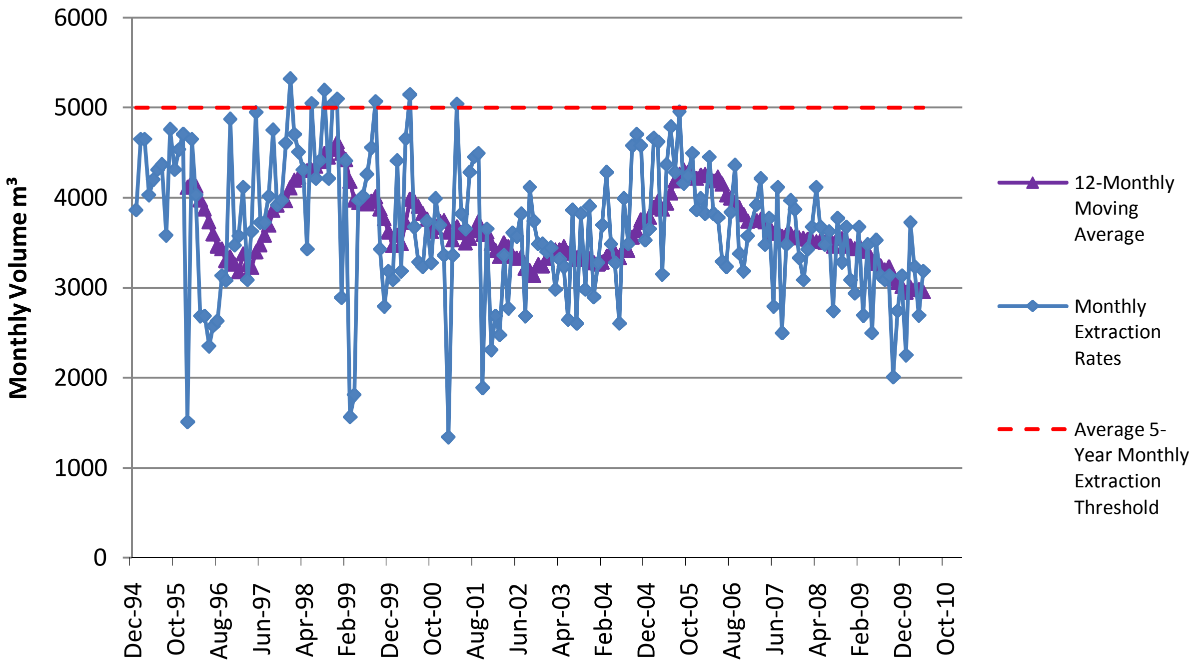

Figure 4.16: Monthly river dredging extraction rates at the Hutt River Mouth 1995 to 1999.

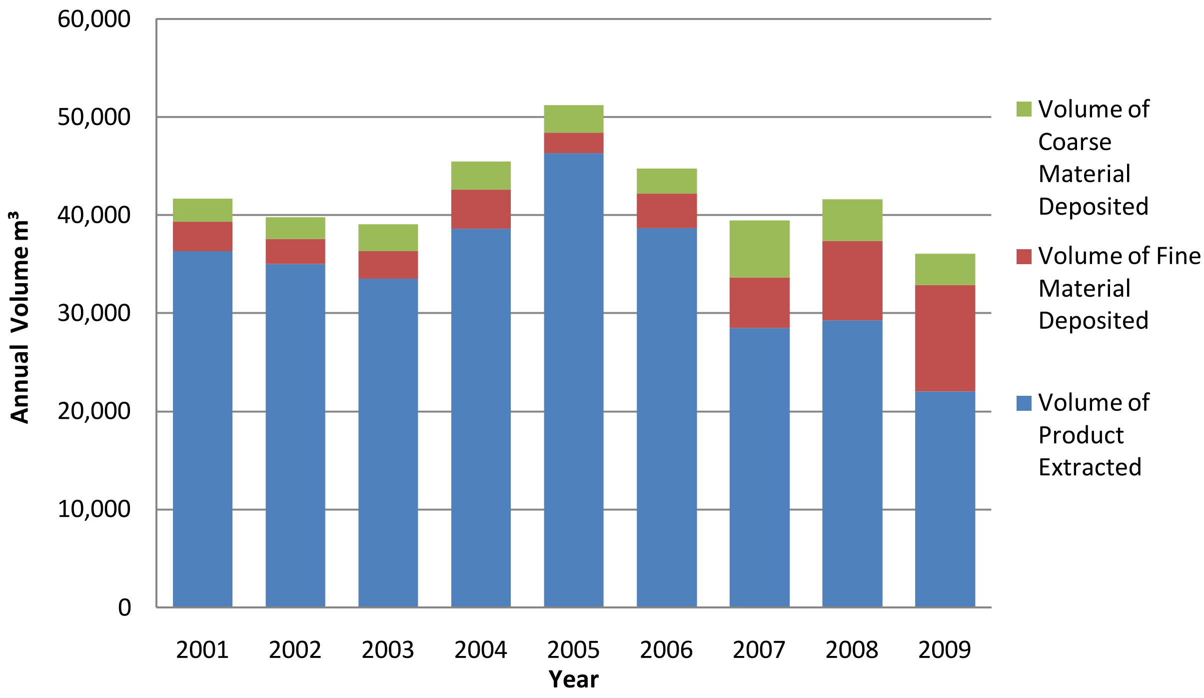

Figure 4.17: Annual extraction and deposition volumes 2001–2009; including the volume of both coarse and fine fractions deposited. Note: Total extraction is the sum of all three volumes each year.

4.2 Hydrographic analysis

Hydrographic surveys to monitor potential changes over the wider Hutt River mouth and offshore deposition zone were taken in 1989, 1993, 1998, 2004, and 2009. The 1993 survey was, however, only a partial survey. It also did not follow the established grid of the other surveys and so it has been omitted from this analysis. Digital Elevation Models (DEM) from these surveys were created and the differences between successive surveys analysed by Gardner (2010). The study area depicted in these surfaces is 1.61km². Areas of aggradation (i.e. where the level has risen) are shown in green, and areas of degradation (i.e. where the level has lowered) are shown in blue in the figures below.

Figure 4.18 shows the differences in the surfaces from 1989 and 2009. This covers the period of the most recent consent, as well as earlier dredging activity. Much of the aggradation over this time is south of the river mouth, past the Seaview industrial area. Degradation is apparent in the northern areas. The patches of high aggradation (1-2m and >2m) are found within the offshore deposition zone, and also in a larger area further to the east. This shows that the material deposited in these areas is not moving. The eastern-most aggradation of >2m was most likely caused by the construction of Seaview Marina. Slight aggadation is found along the eastern bank at the river mouth. This is potentially related to the 'Waiwhetu Stream No Extraction Zone'. Aggradation also occurs south of the Winstone's plant where the land based deposition is situated. Only minor patches of high degradation (up to 2m) are present. Gardner (2010) found that the average overall change in bed level from 1989 to 2009 was 0.29m of aggradation over the study area (Table 4.1). This shows a slight net surplus of material arriving at the river mouth, even after meeting extraction requirements.

Figure 4.19 shows the differences between the 1998 and 2009 surfaces. This period covers much of the current dredging and offshore deposition activities (consents granted 1996 and 1999 respectively). The pattern of northern degradation and southern aggradation continues. There is also an area of slight, 0–1m, aggradation at the river mouth. This may represent a sediment pulse coming out from the river during one of the major floods over this period. Patches of high aggradation (1-2 and >2m) are evident around the offshore deposition zone. Again, this confirms a net surplus of material and the relative stability of material within the deposition zone. High degradation is present in the area around the Winstone's plant and the beach. This is unexpected given the by-product disposal bund is situated here. It is believed that this is actually an artefact of the 'edge effect' of the surface modelling. Only the 2009 survey came within 20m of this point. Gardner (2010) calculated the average overall change in bed level for this period to be aggradation of 0.13m (Table 4.1).

Changes in bed level over the past 5 years (i.e. from 2004–2009) have been very small. The study area shows continued minor aggradation (0-1m); especially around the river mouth, and between Winstone's plant and Petone Beach. There are small patches of minor degradation (-1-0m) throughout the study area (Figure 4.20). Patches of high aggradation (1–2m and >2m) are still evident in and around the offshore deposition area. There are also some small patches of high degradation (-1 - -2 and <-2m). The average bed level change over this period was determined by Gardner (2010) to be aggradation of 0.25m (Table 4.1). This result is likely to be skewed by the large area of aggradation near the newly constructed Seaview Marina.

It is considered that much of the apparent change discussed above might actually be simply a function of the accuracy and resolution of the bathymetric surveys and the surface modelling techniques.

Notwithstanding the above, it would appear that the extraction of sediment from the river mouth, and the dumping of waste offshore, have had very minor effect on the environment. Despite the extraction of over 30,000m^3 of material each year there still appears to be a net surplus of material arriving at the river mouth. This is shown by the continued net aggradation over recent years.

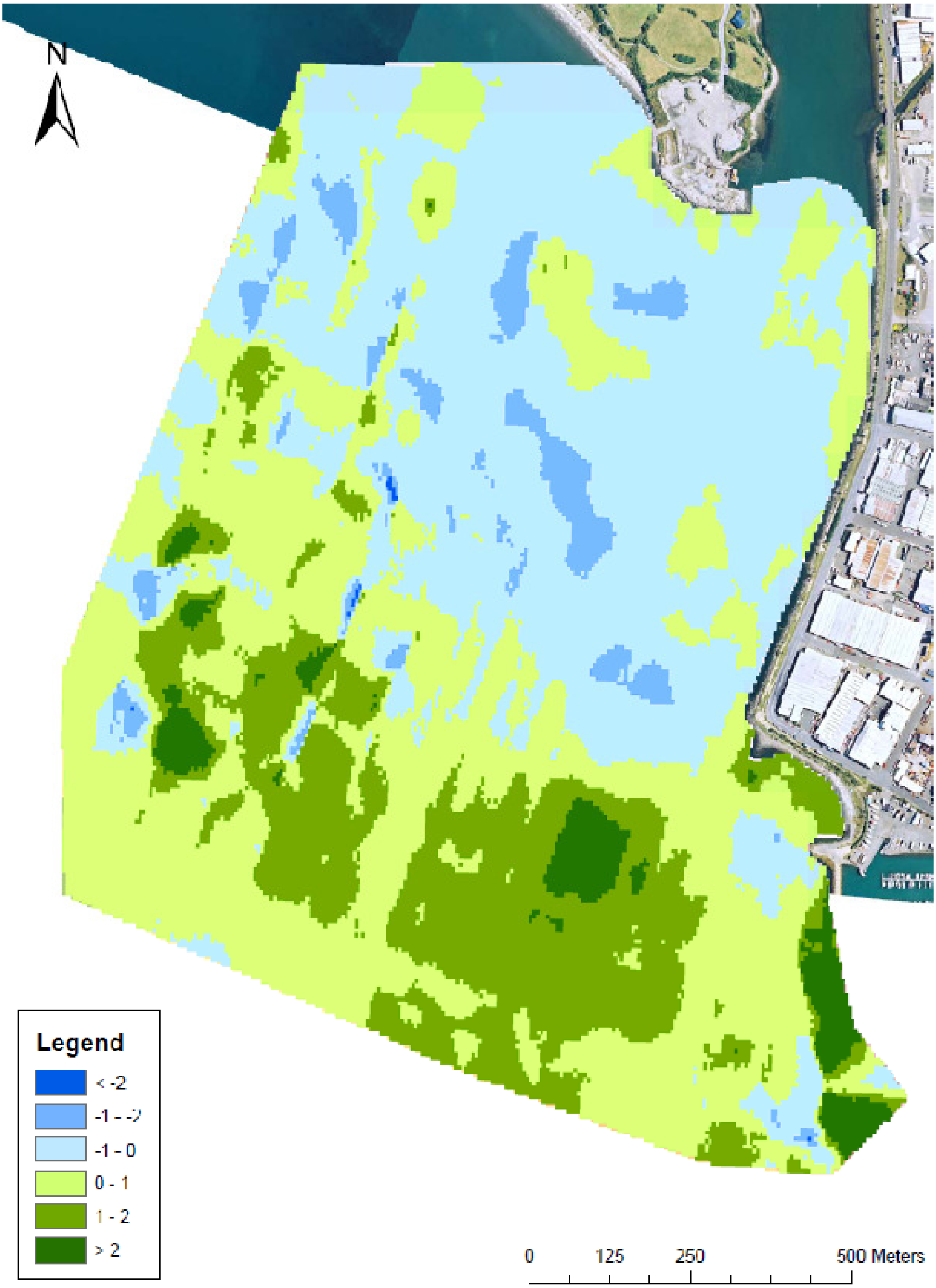

Figure 4.18: Differences in Hutt River mouth surfaces 1989–2009 (From Gardner, 2010).

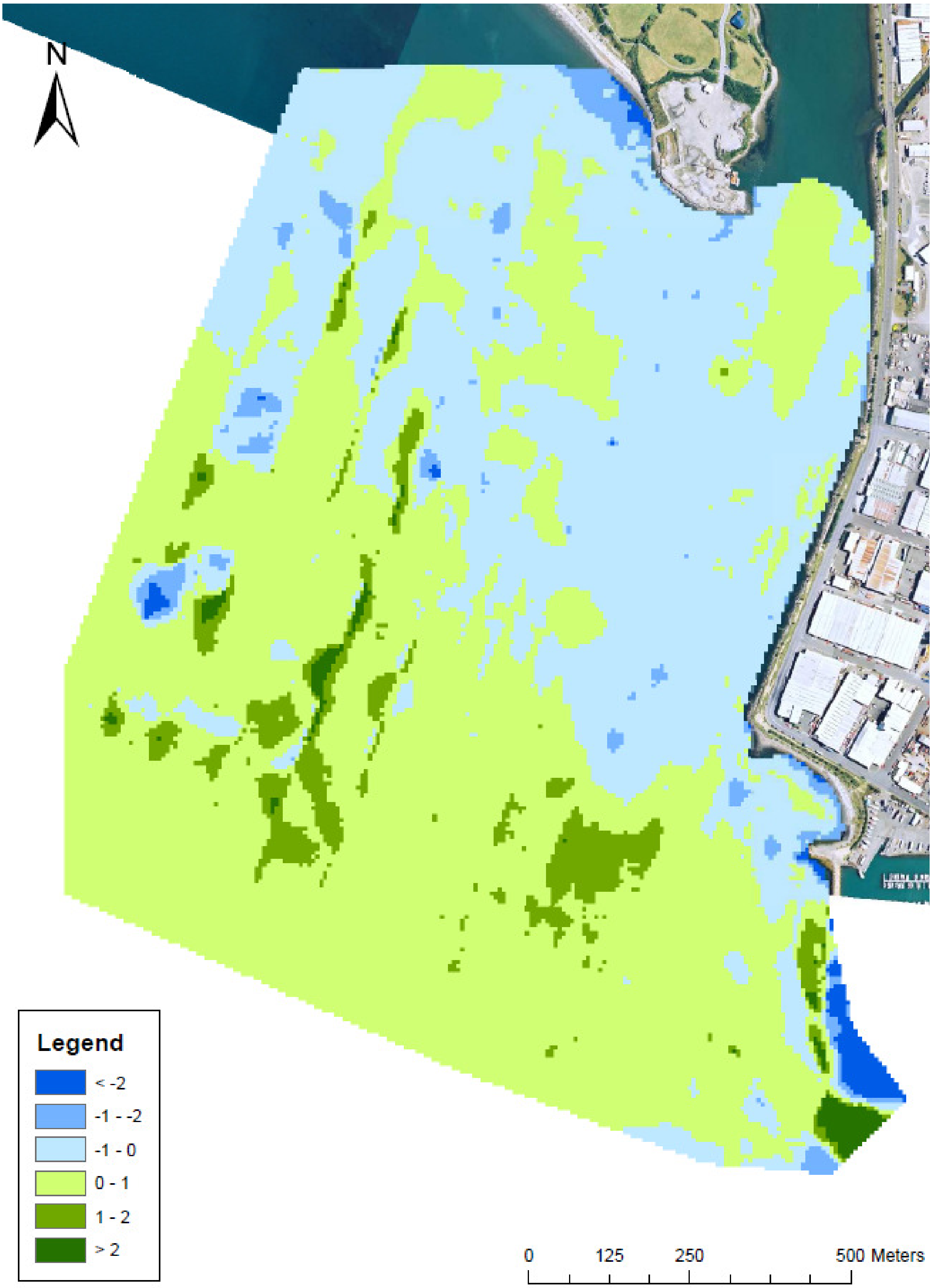

Figure 4.19: Differences in Hutt River mouth surfaces 1998–2009 (From Gardner, 2010).

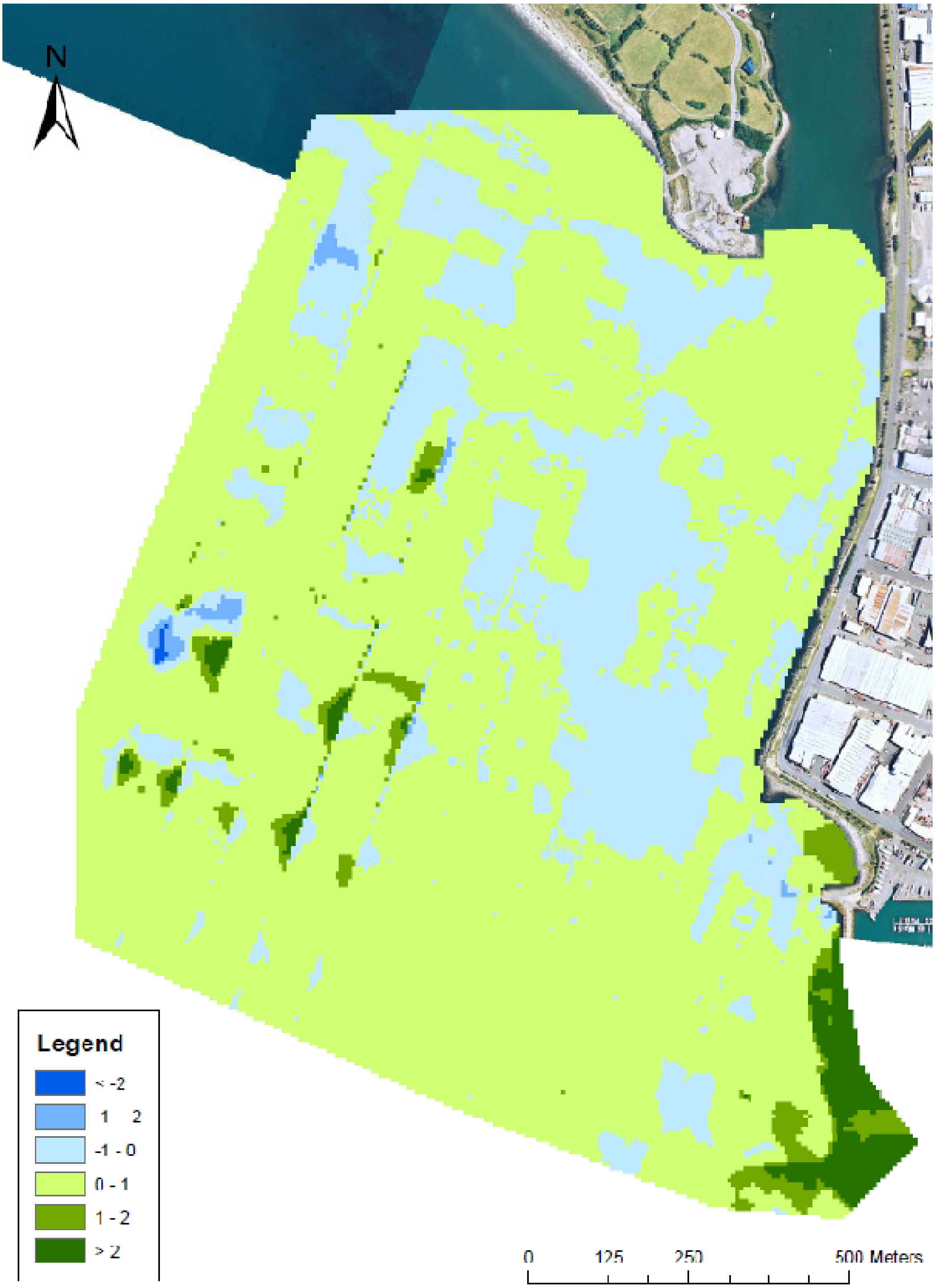

Figure 4.20: Differences in Hutt River mouth surfaces 2004–2009 (From Gardner, 2010).

Table 4.1: Average changes in bed level over the wider Hutt River mouth area (Gardner, 2010).

Period	1989-2009	1998-2009	2004-2009
Average change in bed level	+0.29m	+0.13m	+0.25m

4.3 Shoreline change

AERIAL PHOTOGRAPHS

A series of aerial photographs were overlaid with the current property boundaries to highlight shoreline change over various time periods (Figure 4.21). These photographs include images from 1939, 1998, 1999, 2002, 2004, 2007, and 2009. The black lines across the beach in these photos indicate the position of the beach profile surveys discussed in the next section.

The bars at the river mouth caused by the deposition of sediment are evident in the 1939 aerial photograph. These were subsequently removed as part of flood mitigation strategies. The reclaimed land in the vicinity of Winstone's plant, and for approximately 200m south into Wellington Harbour, is also apparent. In the more recent years the most obvious changes occur along the right bank of the river mouth. These changes are associated with activities within the Winstone's plant.

A small north-trending spit directly opposite the Waiwhetu Stream mouth is visible in the 1998 photograph. This is also visible in a separate image from 1996. However, by 1999 this spit had been incorporated into the western bank forming a bulge at this point.

Other minor changes occur around the land based by-product disposal bund. These most likely relate to the bund size, and wave action prior to the taking of the photograph. The line of the bund remains within approximately 10m over the time frame of the photographs. Much of the apparent change observed in the photographs is likely to be the result of different photograph quality, shadow effects, the tide level, and erosion of the bund at the time of the photograph. There may also be some systematic error inherent in the 'rubbersheeting' (i.e. overlaying of the photographs on top of each other using common reference points).

Overall shoreline accretion is apparent between 1939 and 1998. This reflects the long time span between photographs. Accretion was at a rate of 0.75m/yr between 1939 and 1985; increasing to 1m/yr at the eastern end of the beach between early 1980's and mid 1990's (O'Callaghan, 1996a). Again, this indicates a net surplus of material being added to the coastal sediment budget.

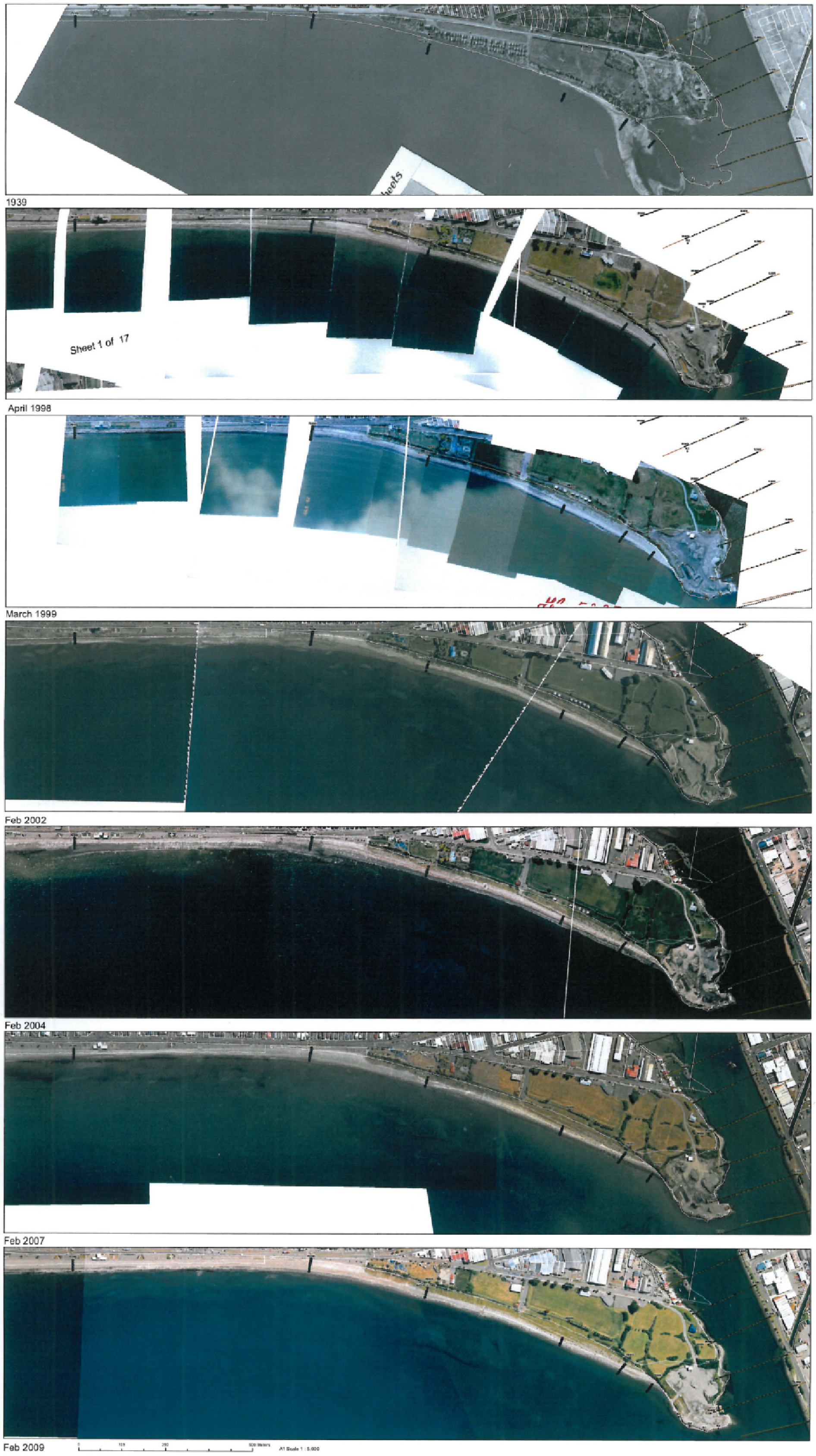

Figure 4.21: Aerial photographs of the Hutt River mouth and eastern Petone Beach.

BEACH PROFILE SURVEYS

Dick (1996) stated that southerly-generated wave action actively erodes the foreshore at the point where the extraction by-product is placed in the bund. He concluded that the rate at which the by-product was placed was causing neither accretion nor erosion in 1996. There was, however, still concern expressed about accretion, and also the potential change in the character of Petone Beach. To investigate any changes that might result from continued sediment extraction and dumping activities a series of beach profiles was established.

Beach profiles at 200m, 300m, 500m, 800m, 1200m and 2000m from the Winstone's plant have been surveyed every six months since October 1996. Results of these surveys are presented in Figure 4.22 to Figure 4.27. In general, the profiles become flatter the further they are from the river mouth (i.e. west). This is a result of the reducing effect of wave energy further along the beach, and the increasing presence of finer particles.

The closest profile to the river mouth, 200m west of the deposition bund (PB0000), shows the greatest variation over time (Figure 4.22). This is expected because of the high energy environment, and oblique angle at which the southerly waves approach the shoreline. The steepness of the beach at this location remains generally the same throughout the various cycles of erosion and accretion. The fluctuation of the upper profile storm berms, which indicate the level at which storm waves are acting on the beach, remain within ±0.5m throughout the entire time series; generally between 1.65–2.2m RL. The October 1996 profile is the most shoreward. It extends out to approximately 39m from the survey origin at the mid-profile (1m RL), and 47m at 0m RL. The mid-profile (1m RL) steadily eroded back 3.5m until August 1999; at an approximate rate of 1.3m/yr. This rate then increased dramatically, to approximately 5m/yr, between August 1999 and August 2002. The period since August 1999 is when only fine material has been deposited into the beach sediment system via the by-product disposal bund. From 2003 onwards the mid-profile fluctuated ±3m around 18.5m from the survey origin, and ±3m around 29m from the origin at 0m RL. Overall this profile has experienced a net loss of around 21m at mid-profile, and 17m at mean sea level; averaging 1.6m/yr and 1.3m/yr respectively since 1996. However, since 2003 this profile has stabilised and appears to have established a new equilibrium.

Profile PB0010, 300m from the by-product deposition bund, appears to have been more stable than PB0000 (Figure 4.23). The October 1996 mid-profile reaches to 45m from the survey origin, and the profile fluctuated ±2m around this position until November 2001. The 0m RLs over this period are all between 54 and 56m. The top of the beach over this period remains fairly stable; averaging around a mean of 1.75m RL. The storm berm reaches 2m RL. The general profiles from August 2001 tend to be steeper and fluctuate ±2m around 41m from the survey origin at 1m RL. The storm berms reach 2.3m RL (averaging approximately 2.2m RL). This profile has experienced net erosion of approximately 4m (averaging approximately 0.3m/y). However, since 2001 this profile has stabilised and appears to have found a new equilibrium.

Profile PB0020, 500m from the Winstone's plant, appears to have two distinct time series (Figure 4.24). The profiles between October 1996 and July 1998 have storm berms around a steady height of approximately 1.75m RL. The mid-profile (1m RL) fluctuates ±1.5m around 63m from the survey origin, and the lower profile remains around 72m at 0m RL. By August

1999 the mid-profile has accreted 3m in just over a year; out to 66m from the survey origin. From this point, the profile fluctuates out to 69m by May 2006. By May 2010 the profile has receded to approximately 67.5m. During this time the storm berm increased in height up to an average of 2m RL, and a maximum of 2.3m in May 2004. This may have been the result of a major storm event. Profile PB0020 has fluctuated by a total of 7.4m in 13.5 years. It shows an overall net accretion of approximately 6m, averaging at 0.4m/y since 1996.

Profiles PB0030, PB0040 and PB0050 (800m, 1200m and 2000m from the Winstone's plant respectively) all behave in a similar manner. These profiles all show very similar slopes throughout the time series presented for each profile. However; PB0030 has more pronounced storm berms in November 2006 and 2007 (both up to 1.8m RL) and December 2009 and May 2010 (both up to 1.6m RL) (Figure 4.25). All these profiles fluctuate between erosion and accretion over time scales of months. The overall net seaward mid-profile accretion of PB0030 is approximately 12m (averaging 0.9m/yr), and it has increased 0.5m in height (Figure 4.25). The net seaward mid-profile accretion of Profile PB0040 is approximately 9m (averaging 0.7m/yr), and it has increased approximately 0.4m in height (Figure 4.26). The net seaward mid-profile accretion of Profile PB0050 is approximately 5m (averaging 0.4m/y), and it has increased approximately 0.3m in height (Figure 4.27). This shows that the rate of accretion is decreasing in a westward direction.

Overall, the various profiles show changes at various temporal scales, largely as function of the wave and energy conditions. Most of the profiles show net accretion over the longer term. This indicates a net surplus of sediment arriving on the beach.

The two profiles closest to the river mouth show the most dynamic behaviour. While coarse material was being dumped into the bund these profiles were eroding slowly. Since the dumping of coarse material stopped in 1999 these two profiles have eroded more rapidly, most likely back towards their initial position. The erosion was relatively rapid over the first few years. More recently erosion of these profiles appears to have stopped, or at least slowed significantly. It is likely that these profiles have now reached new equilibrium conditions. The material that has been eroded from these profiles has likely been redistributed west along Petone Beach leading to the accretion seen in that area.

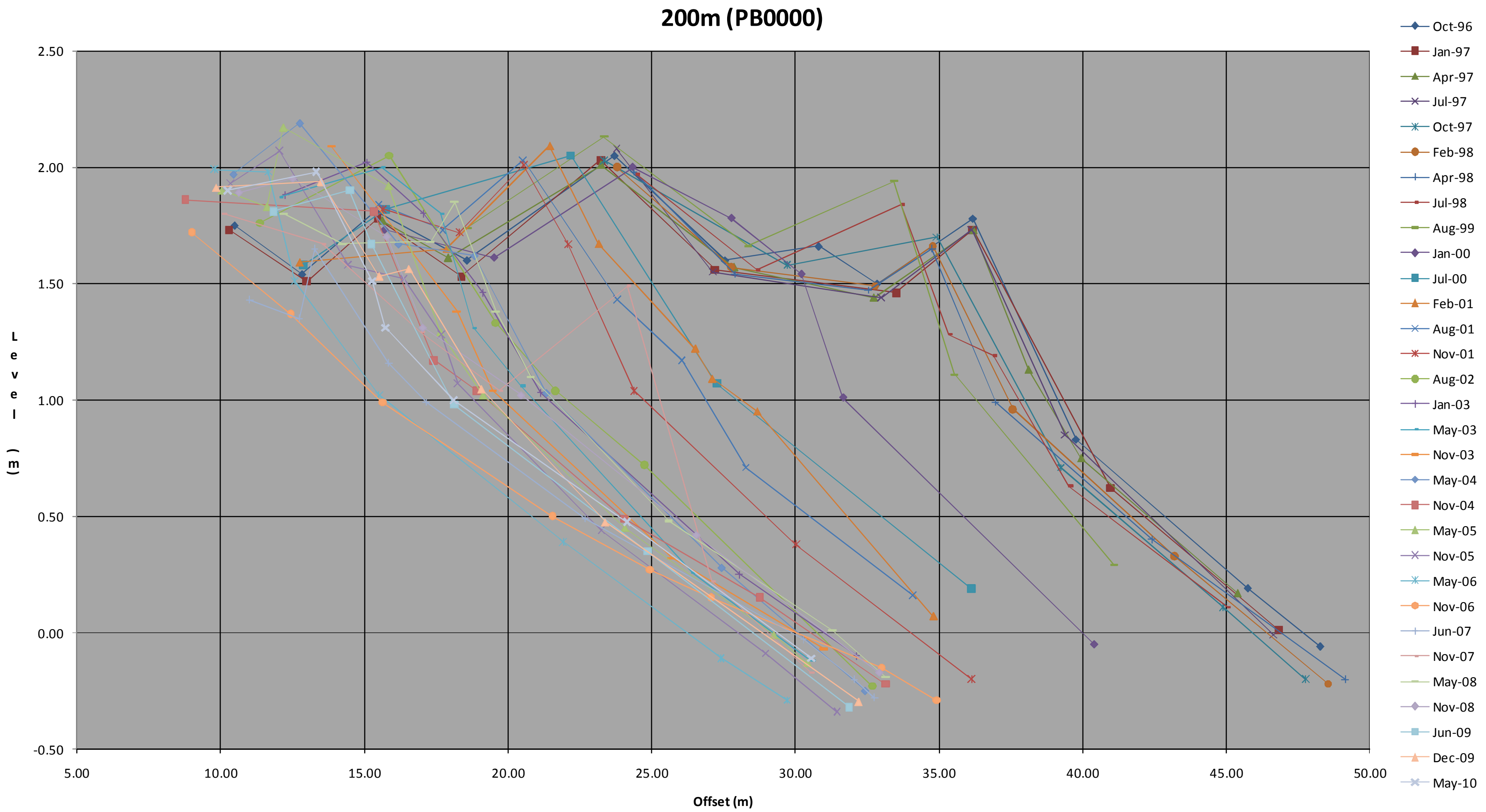

Figure 4.22: Petone Beach 6-monthly profiles at PB0000, 200m from extraction site.

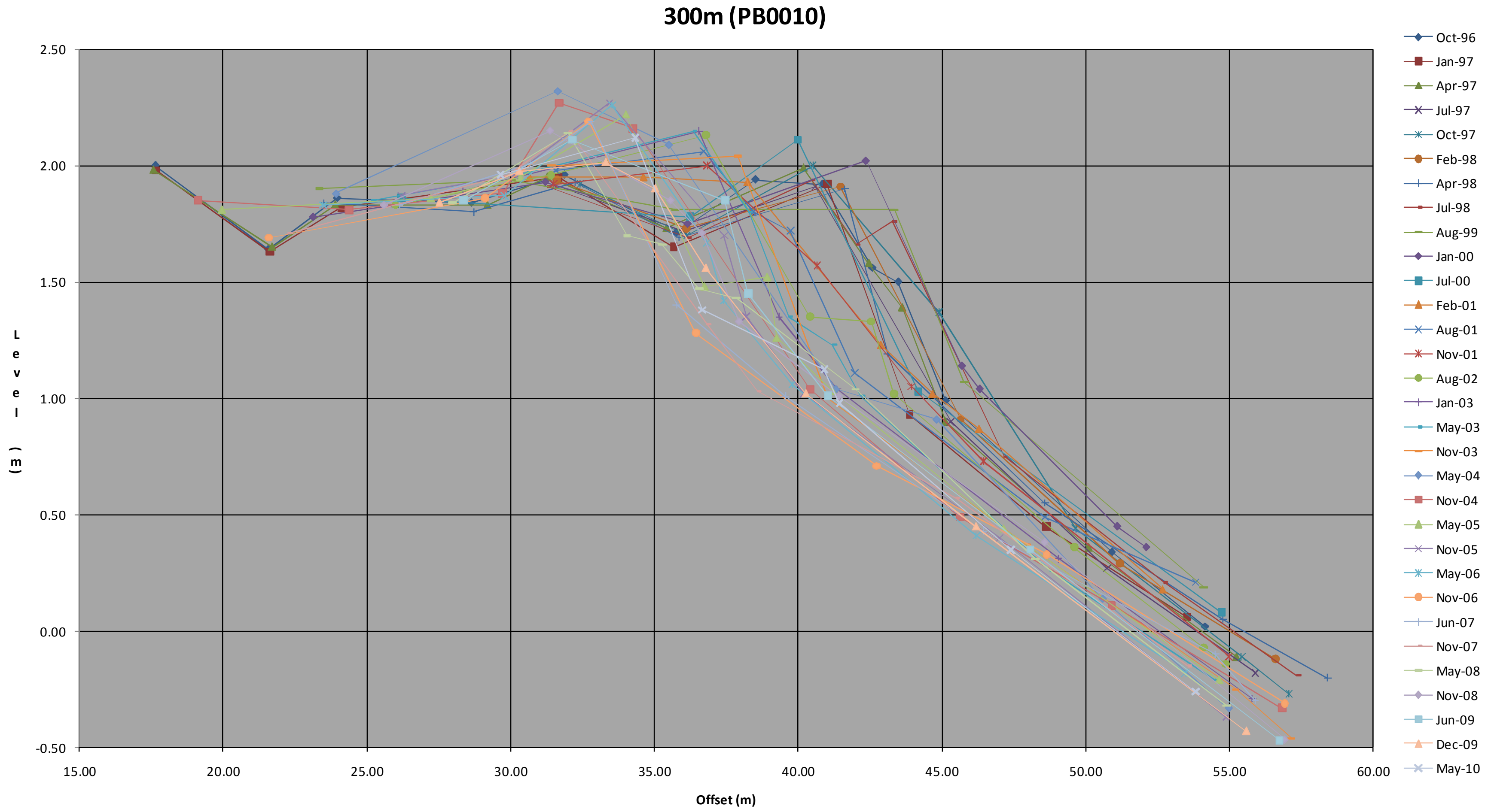

Figure 4.23: Petone Beach 6-monthly profiles at PB0010, 300m from extraction site.

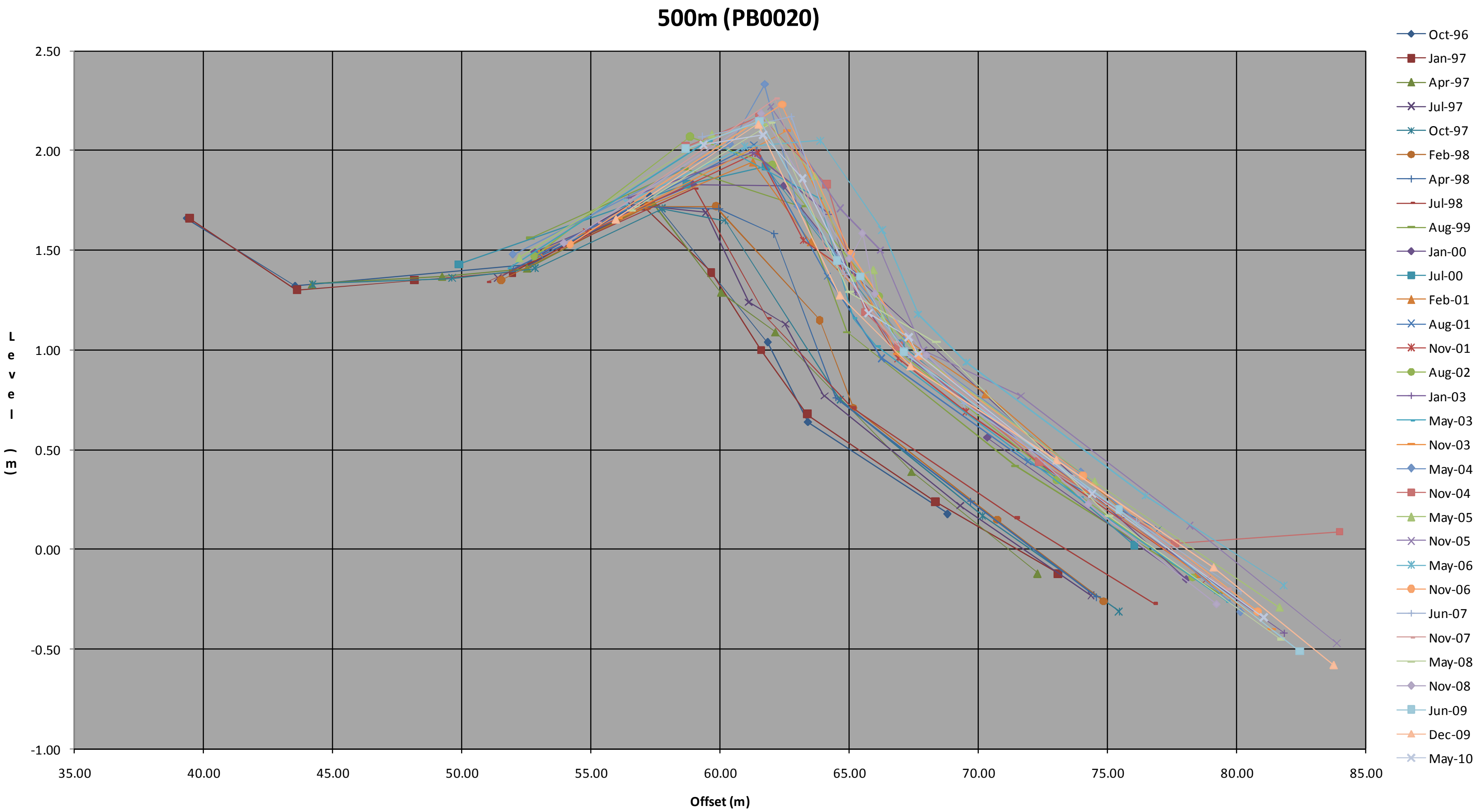

Figure 4.24: Petone Beach 6-monthly profiles at PB0020, 500m from extraction site.

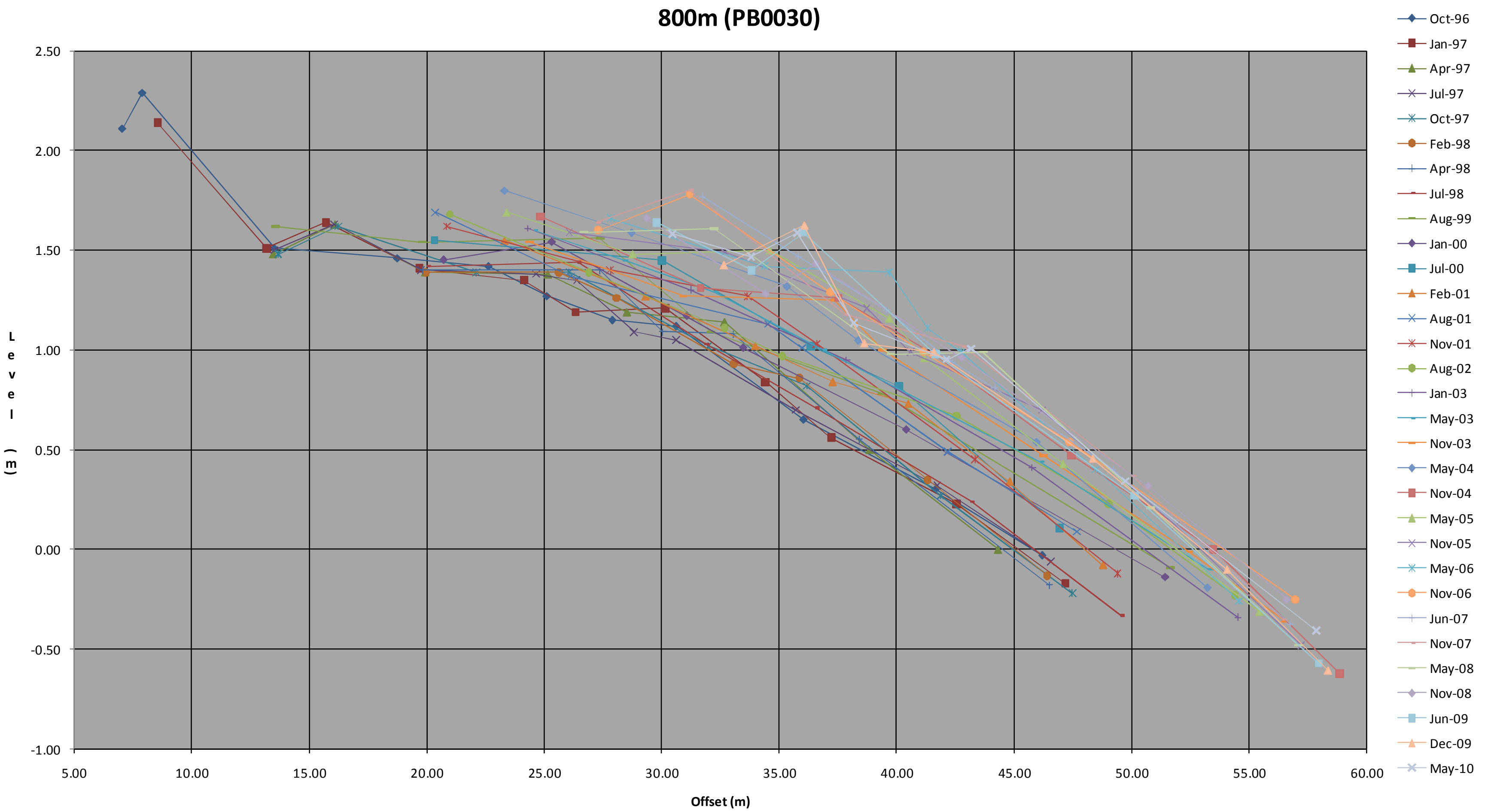

Figure 4.25: Petone Beach 6-monthly profiles at PB0030, 800m from extraction site.

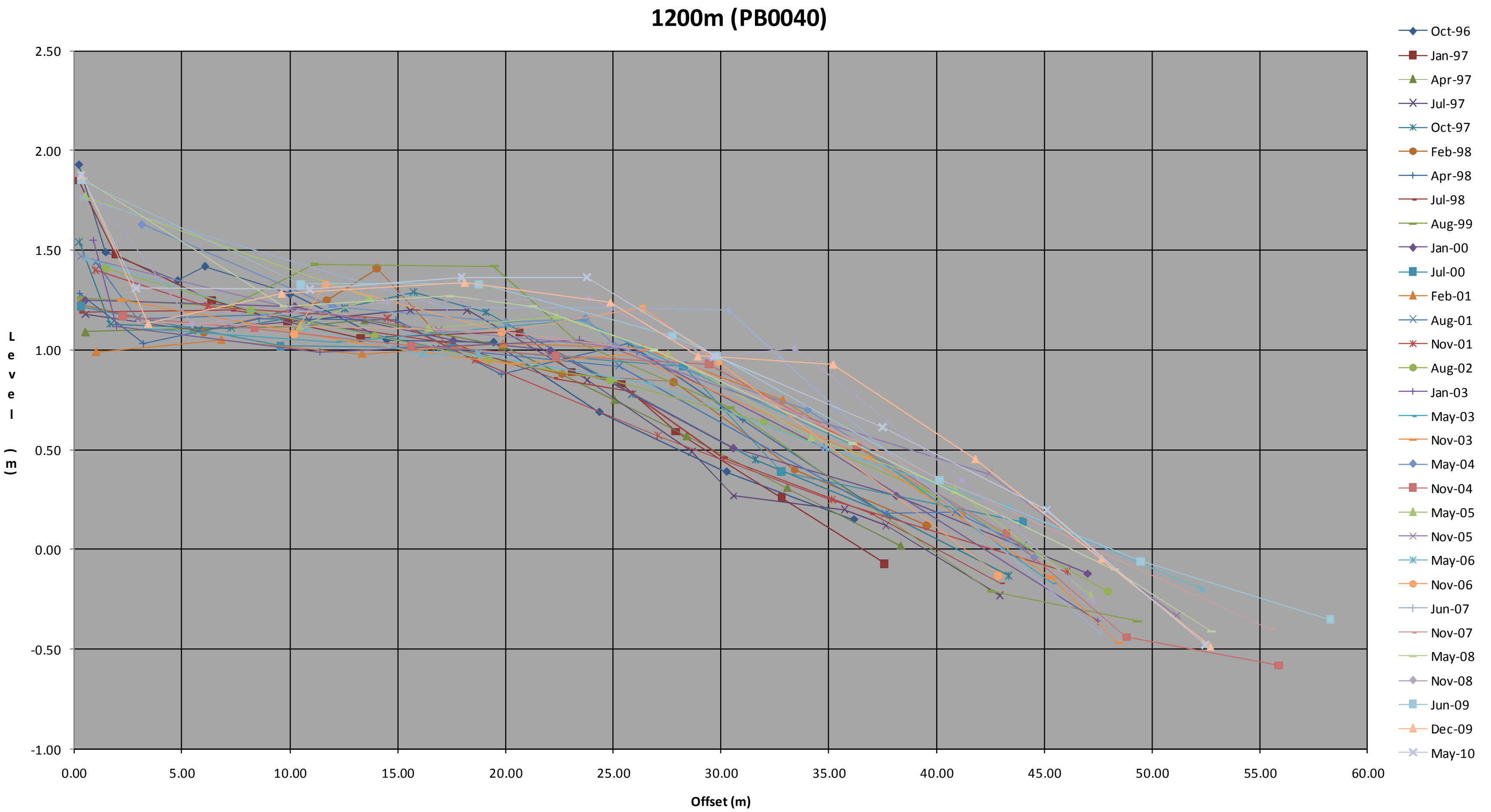

Figure 4.26: Petone Beach 6-monthly profiles at PB0040, 1200m from extraction site.

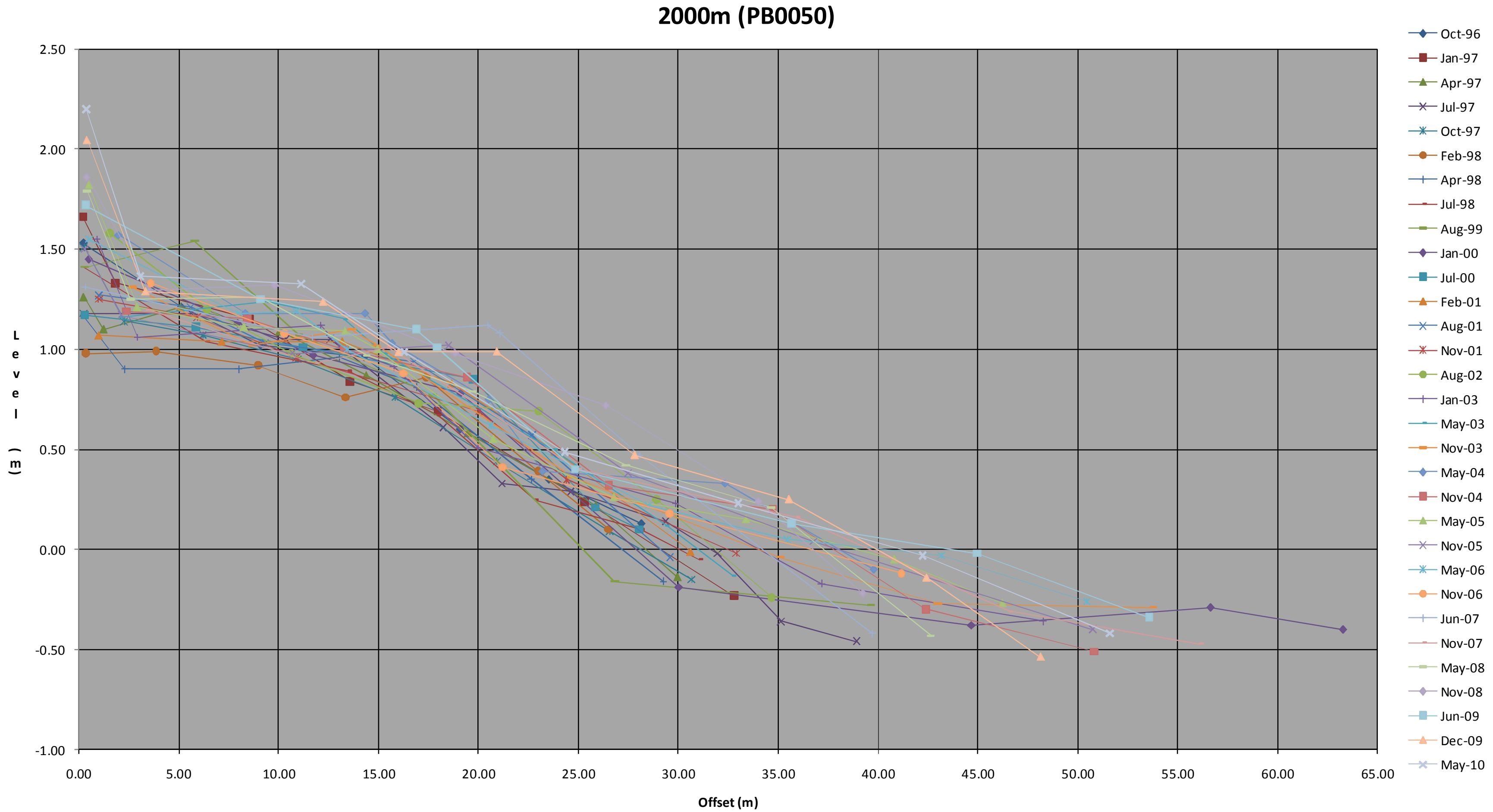

Figure 4.27: Petone Beach 6-monthly profiles at PB0050, 2000m from extraction site.

4.4 Sediment size analysis

In 1996, when the course sediment bund was still operational, the sediment along Petone Beach was typically within the range of 10–40mm around the stockpile area, with a high proportion of shell. The distribution of gravels and shell along Petone Beach progressively lessened towards the west. Approximately 1km west of the stockpile, the beach was predominantly sand (BECA, 1996). By Petone Wharf (approximately 2.5km west of the river mouth) stones larger than 2mm made up only 3% of the total sediment (BECA, 1996). The silt portion of the bund was eroded offshore to a depth of 7m where wave and current energy is low. The proportion of silt in the beach sediment at low tide was less than 10%, and less than 1% above the high tide line (O'Callaghan, 1996b). Since 1999 only fine material has been included in the sediment by-product bund. The coarse waste material has been dumped offshore.

Sediment samples have been collected along Petone Beach at 0m RL (Mean Sea Level) during each profile survey between October 1996 and May 2010. These samples were analysed by Materials Advisory and Testing Service Ltd (MATS). MATS divided the sediment into the following classes: gravel >2mm; sand 2mm–0.075mm; and silts <0.075mm. Results from MATS gave the percentage passing through sieves of the following sizes 37.5mm, 26.5mm 19mm 13.2mm, 9.5mm, 4.75mm, 2.36mm, 1.18mm, 600µm, 300µm, 150um and 75µm. Further analysis identified the 25%, 50% and 75% percentiles; being the lower and upper quartiles, and median of each sample.

The sediment samples from PB0000, 200m away from the Winstone's plant, have the greatest proportion of large material. Several surveys (August 2001, May 2003, May 2005, May 2006 January 2007 and January 2009) recorded sediment larger than 37.5mm (Figure 4.28). However, two samples (November 2006 and November 2008) were composed of particularly fine sediment, with both the lower and upper quartiles between 0.2mm–0.3mm (Figure 4.29). These two samples are anomalous when compared to the rest. Nothing out of the ordinary is recorded against these samples from this site. Photographs, however, indicate that there was a band of sand at MSL during these times. It is this fine material that is dominating the sample, and not necessarily a lack of coarse material. The usual coarse material was still present higher up the profile. The lower quartile of all the samples have a very wide range; from sand 0.2mm to gravel 7mm. This indicates the highly variable nature of sediment within the MSL environment. Since 1999, finer sediment sizes have been recorded within the lower quartile range, from sand 0.2mm to gravel 0.8mm; although the median still remains between 5mm and 13.5mm (i.e. gravel). The upper quartile ranges between 8mm and 26.5mm, with larger sediment more prominent since 1999 (Figure 4.29).

The sediment samples from PB0010, 300m away from the Winstone's plant, have a similar range as those from profile PB0000. Sediment larger than 37.5mm occurred on August 2001, November 2003, November 2005, and December 2009 (Figure 4.30). The MSL sand band associated with the anomalous fine sediment recorded during November 2008 is also apparent at this site. The sand that was present during November 2006 at PB0000 was not at this site. There is a high degree of variability in the lower quartile sediment range; from sand 0.2mm to gravel 9.7mm (Figure 4.31). The majority of median range is gravel; generally from 3.6mm–7.5mm, although some larger and smaller values occasionally occur. The upper quartile range is generally gravel, from 7.4mm–14.79mm, also with the occasional larger and smaller value. There is more variability in the sediment sizes after 1999, including both smaller material and larger clasts.

Profile PB0020, 500m away from the Winstone's plant, also has sediment larger than 37.5mm on August 2001, November 2004, May 2005, and December 2009 (Figure 4.32). In general, this profile also has high gravel content at MSL; this is particularly noticeable in the median and upper quartile figures (Figure 4.33). The majority of the gravels within the median range lie between 5.2mm and 14.2mm. The upper quartile is between 7.8mm and 29mm. The lower quartile has a wide range of sediment sizes; from sand 2mm to gravel 6.2mm. November 2006 provided a sample that was notably sandier than the rest. The significant sand band observed at MSL was also affecting this sample. Both larger gravel sizes and smaller sand sizes are represented in the post 1999-samples (Figure 4.33).

Profile PB0030, 800m away from the Winstone's plant, has the widest range of sediment size data of all the surveyed profiles (Figure 4.34). This includes a reasonably even spread within the ranges of the lower and upper quartiles, and the median (Figure 4.35). Samples show that the lower quartile and median mainly consist of sand, and the upper quartile of gravels up until 1999. The exception is April 1997 which has the coarsest median and upper quartiles at 2.6mm and 9mm respectively. Post-1999 samples include more sand, most likely indicative of bands of sand along the MSL during these surveys. Also present are larger gravels reflected in the median and upper quartile measures; up to 12.4mm and 26.5mm respectively for November 2006.

Profile PB0040, 1200m away from the Winstone's plant, shows clearly that this part of Petone Beach is much sandier than the profiles to the east (Figure 4.36). The majority of the samples have their lower quartile, median and upper quartiles all within the sand range, varying from 0.17mm to 0.45mm (Figure 4.37). Gravel is more apparent in the samples post-1999, but gravel was also present in July 1998. This gravel ranges in size from 4mm to 14.5mm. November 2006 and November 2008 are noted as producing some of the most gravelly samples from the MSL on this profile.

The samples from site PB0050 have the narrowest range of sediment sizes of all sites surveyed. This is also the sandiest site, with the majority of material being smaller than 0.2mm (Figure 4.38). The median of the samples ranged only between 0.21mm and 0.26mm (Figure 4.39). November 2006, November 2008, and July 1998 stand out as having slightly coarser samples within the upper range at this profile. Material as large as 26mm was present within the samples (Figure 4.38). However, these particles do not affect the upper quartile statistics significantly. The sample from November 2008 had the largest upper quartile (i.e. 0.38mm).

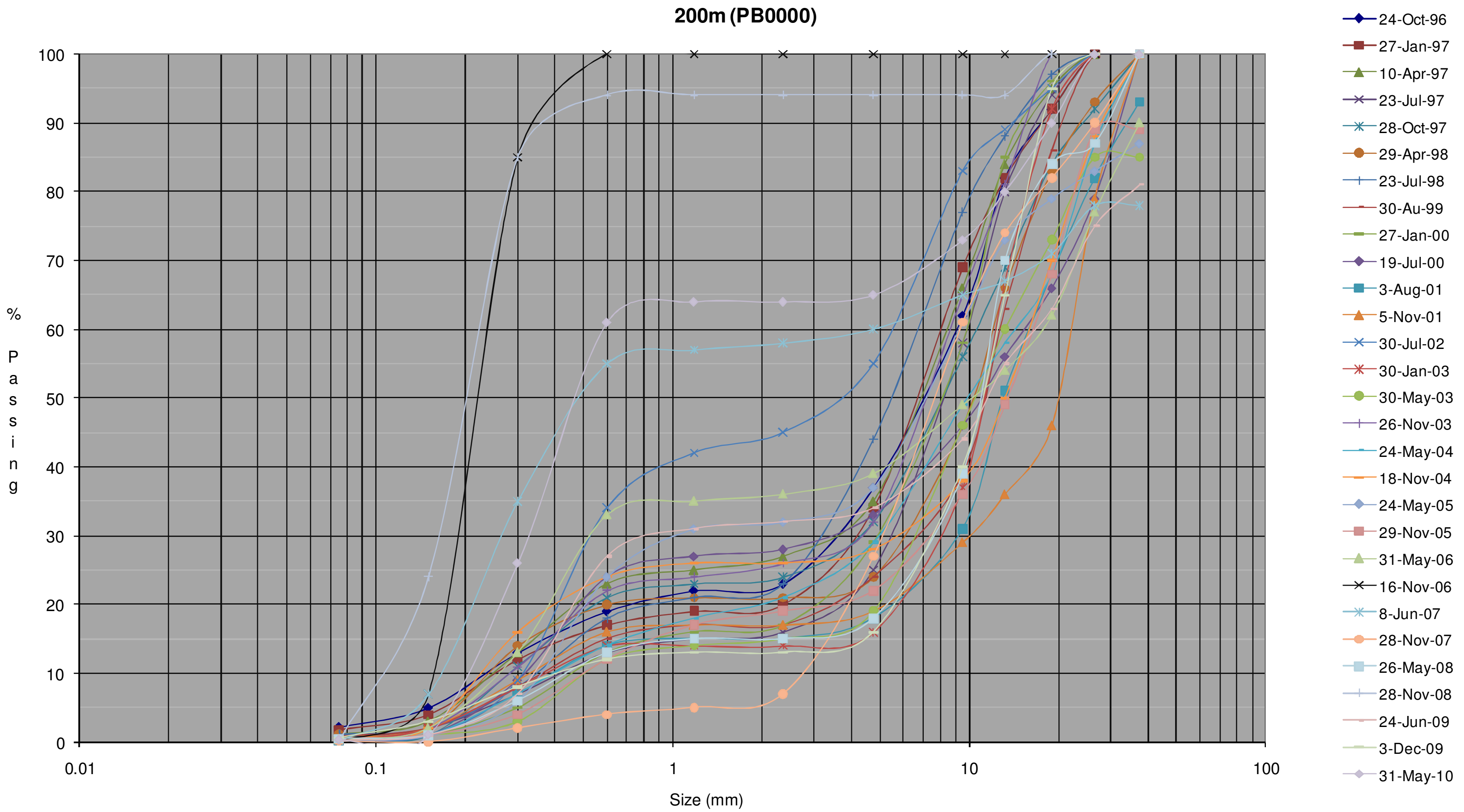

Figure 4.28: Petone Beach 6-monthly sediment analysis. Samples taken at MSL of PB0000, 200m from extraction site.

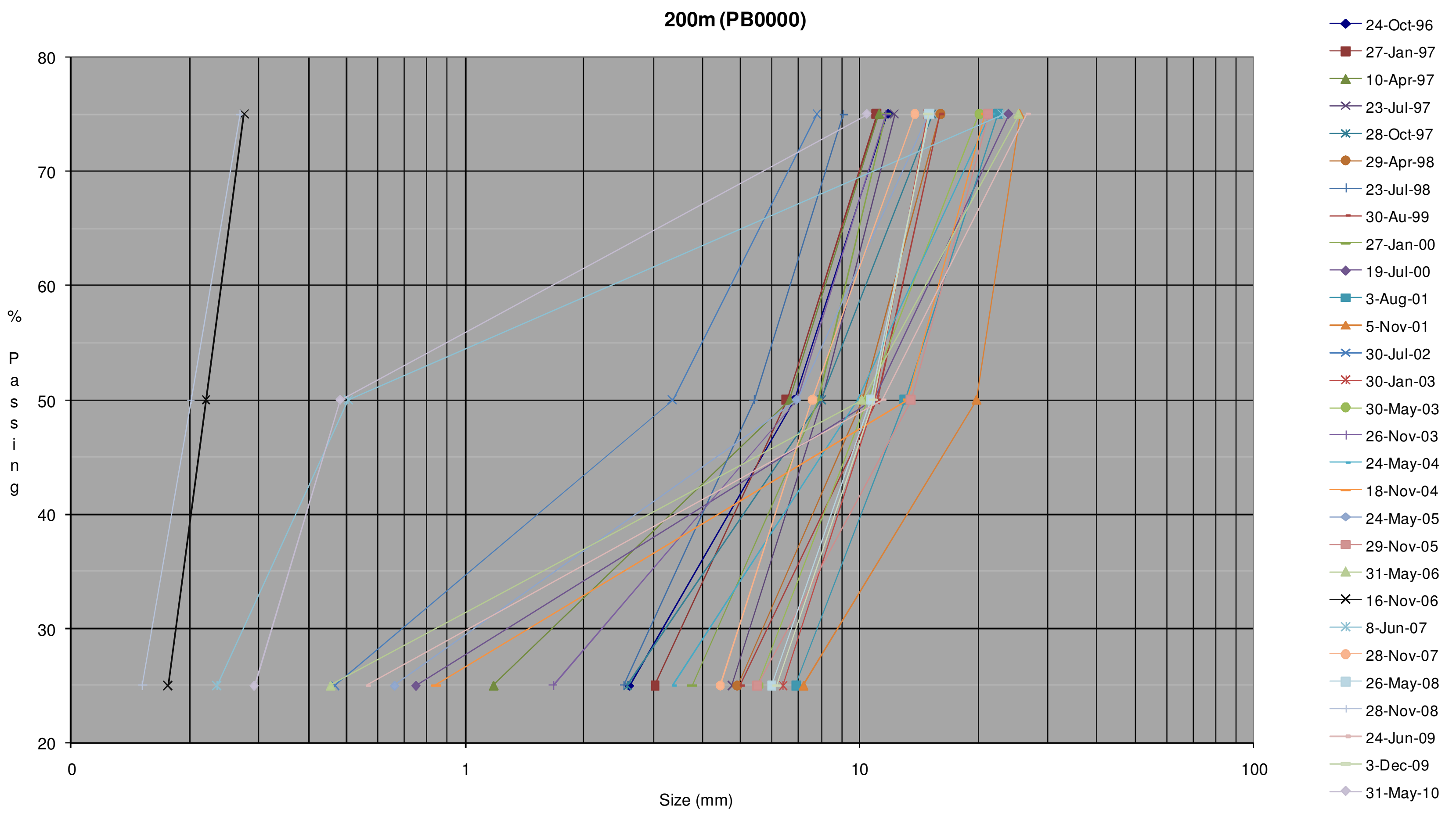

Figure 4.29: Site PB0000 sediment size median, upper and lower quartile.

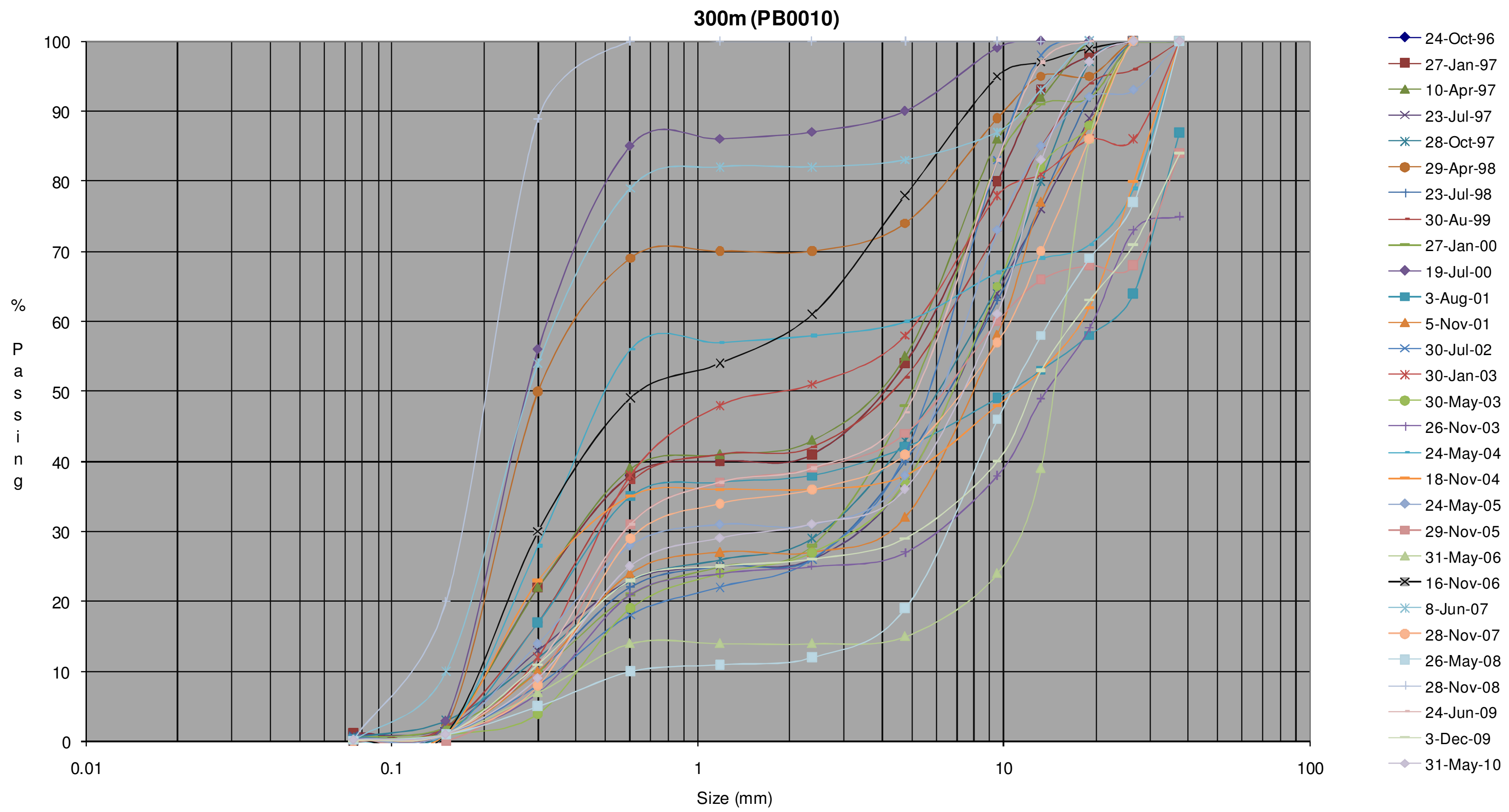

Figure 4.30: Petone Beach 6-monthly sediment analysis. Samples taken at MSL of PB0010, 300m from extraction site.

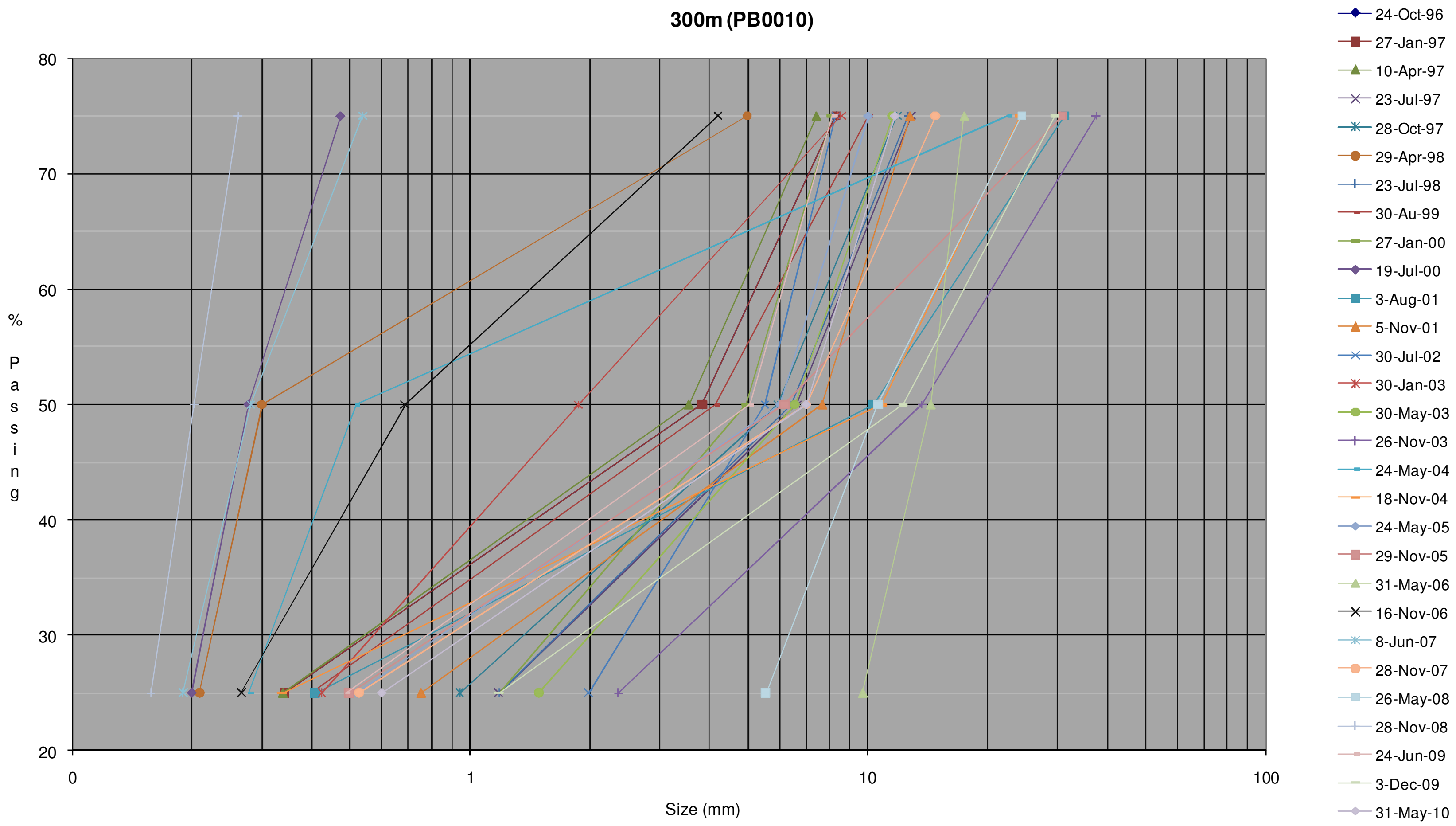

Figure 4.31: Site PB0010 sediment size median, upper and lower quartile.

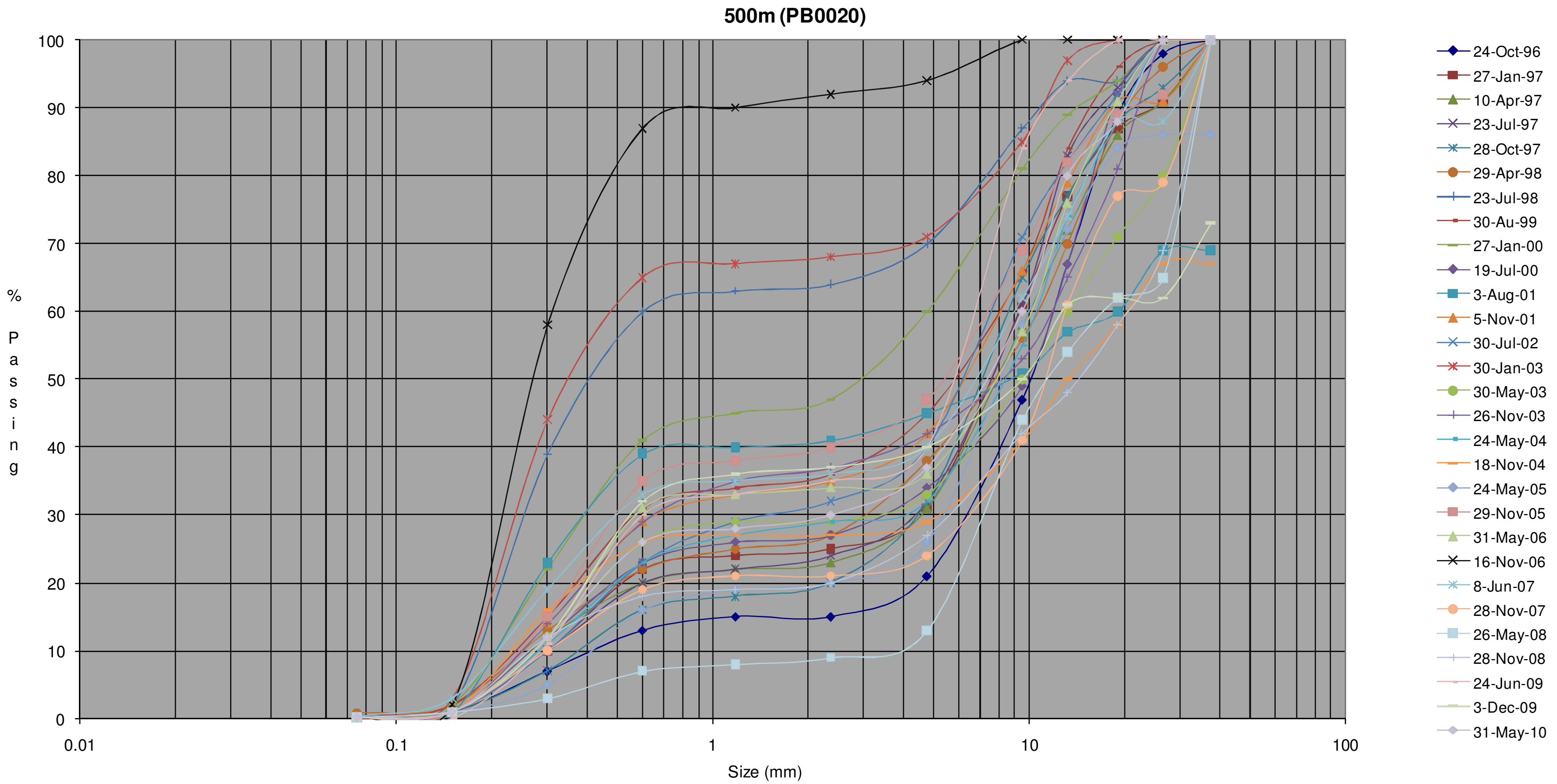

Figure 4.32: Petone Beach 6-monthly sediment analysis. Samples taken at MSL of PB0020, 500m from extraction site.

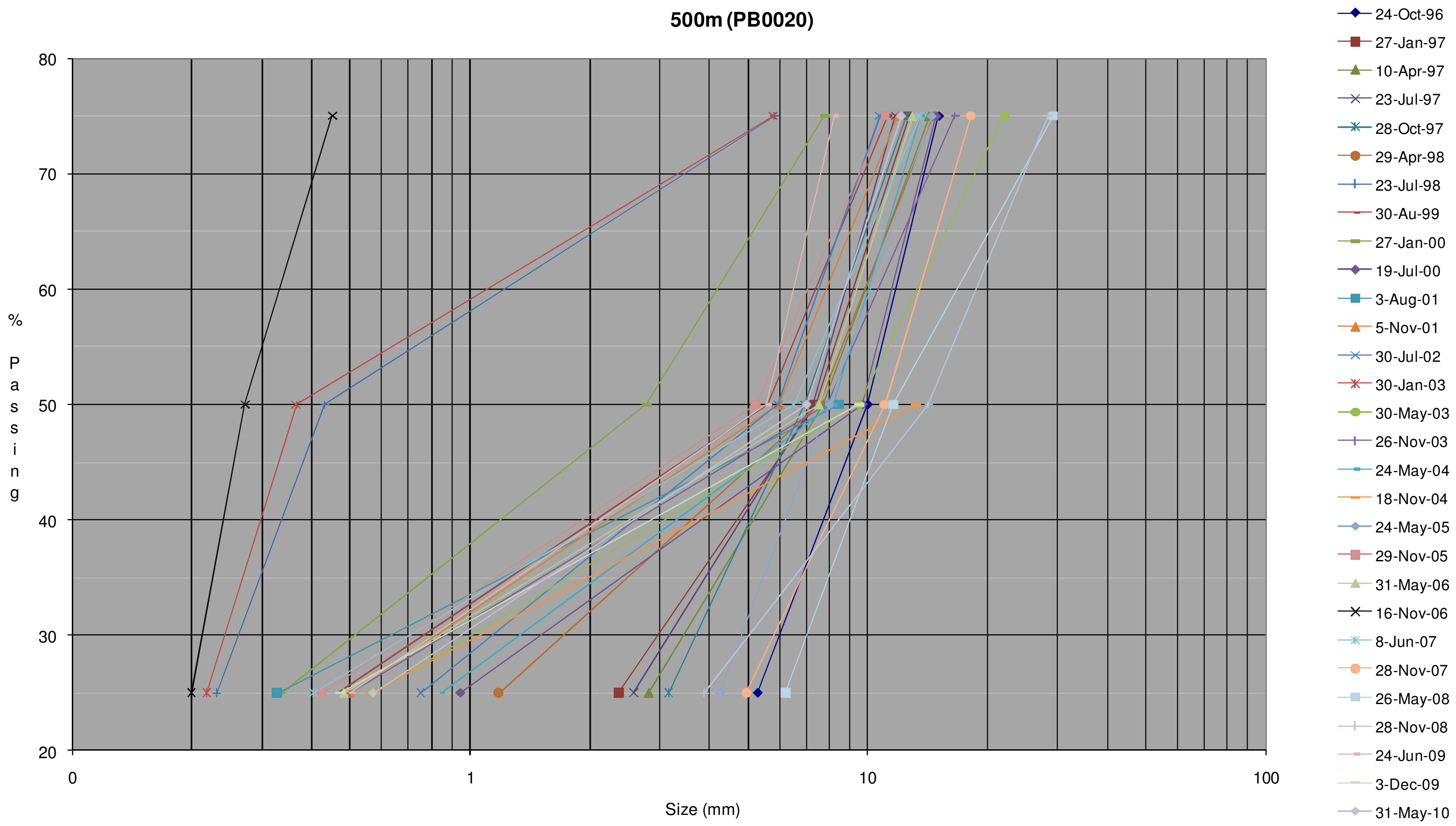

Figure 4.33: Site PB0020 sediment size median, upper and lower quartile.

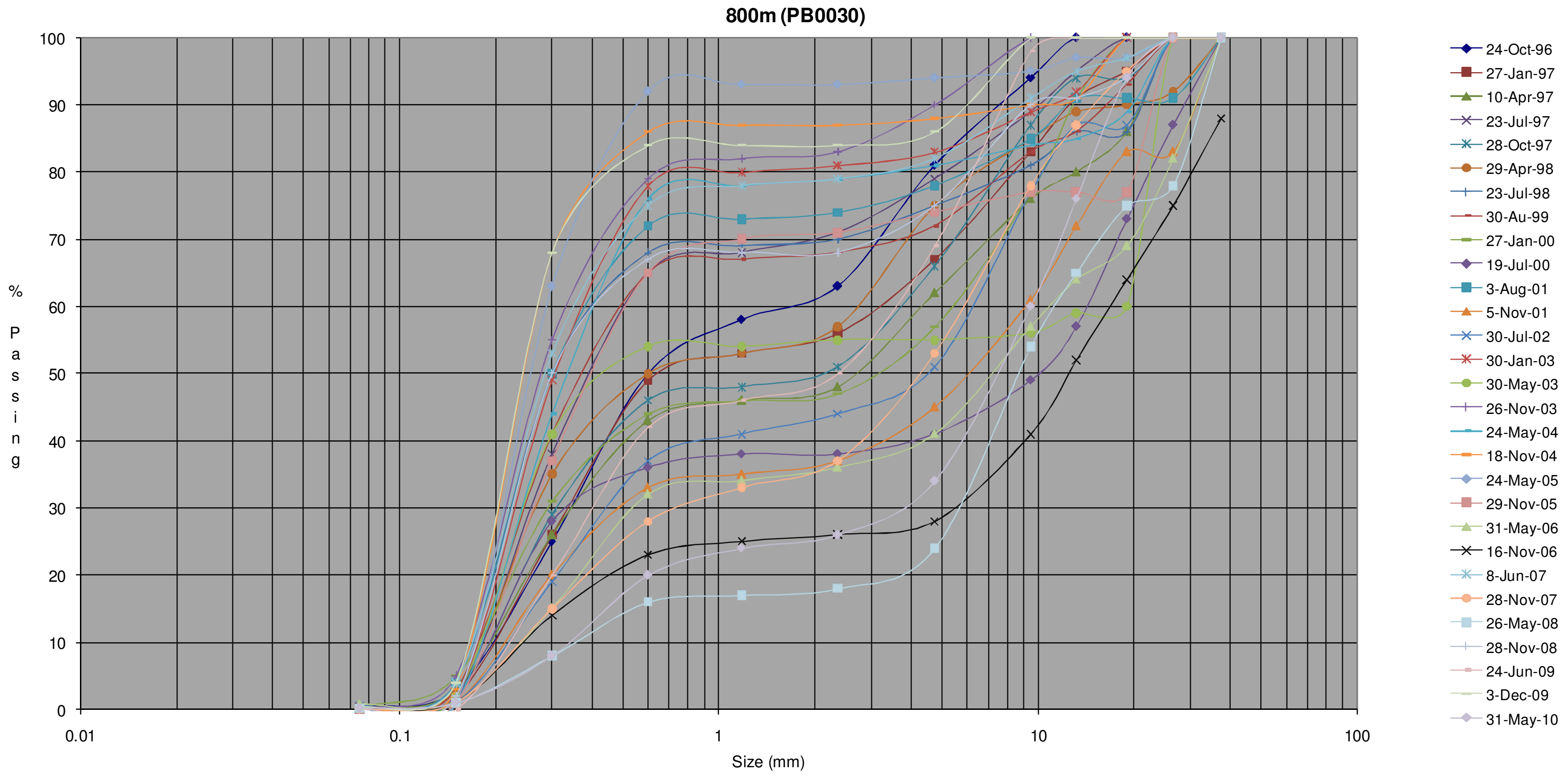

Figure 4.34: Petone Beach 6-monthly sediment analysis. Samples taken at MSL of PB0030, 800m from extraction site.

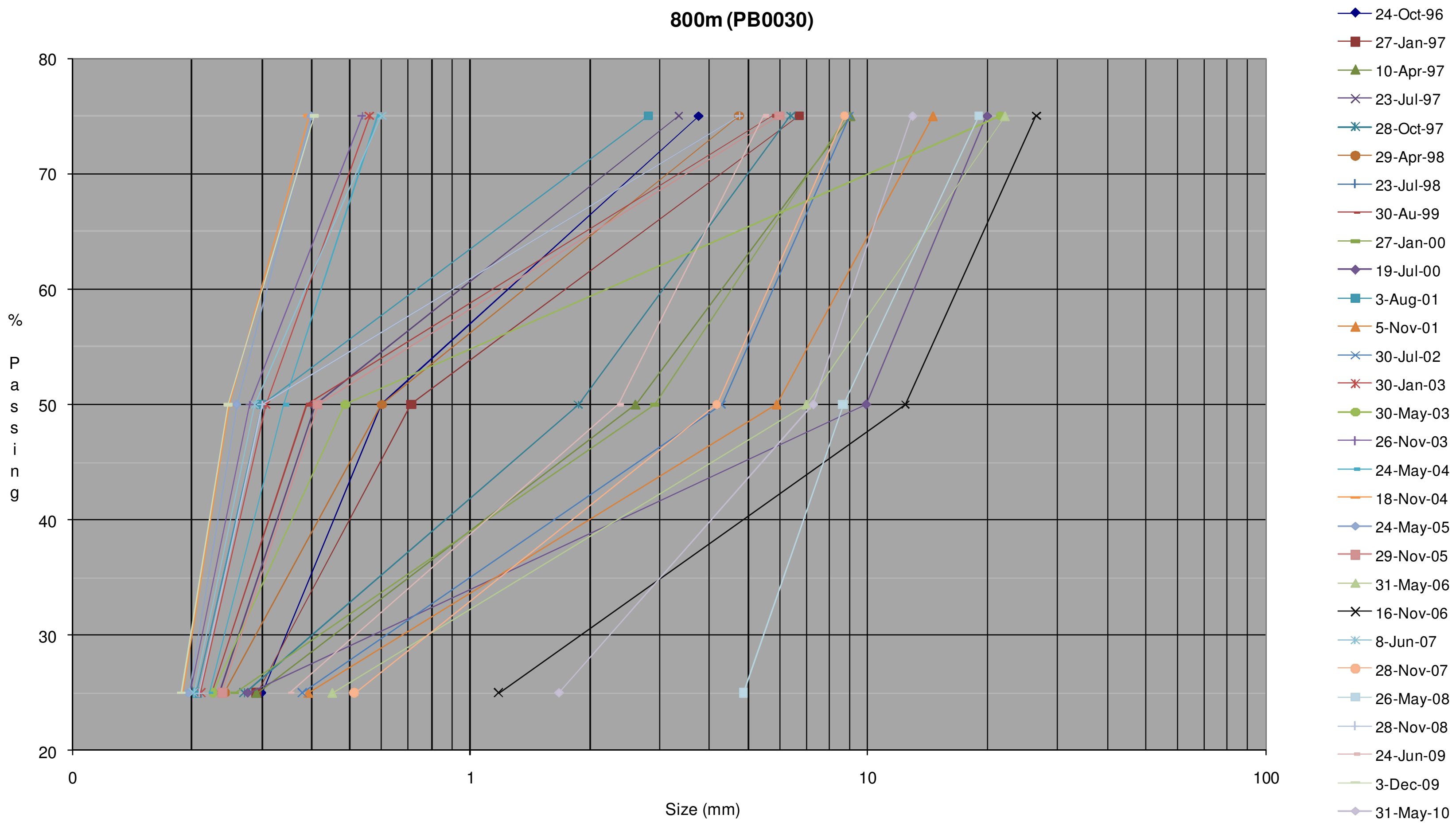

Figure 4.35: Site PB0030 sediment size median, upper and lower quartile.

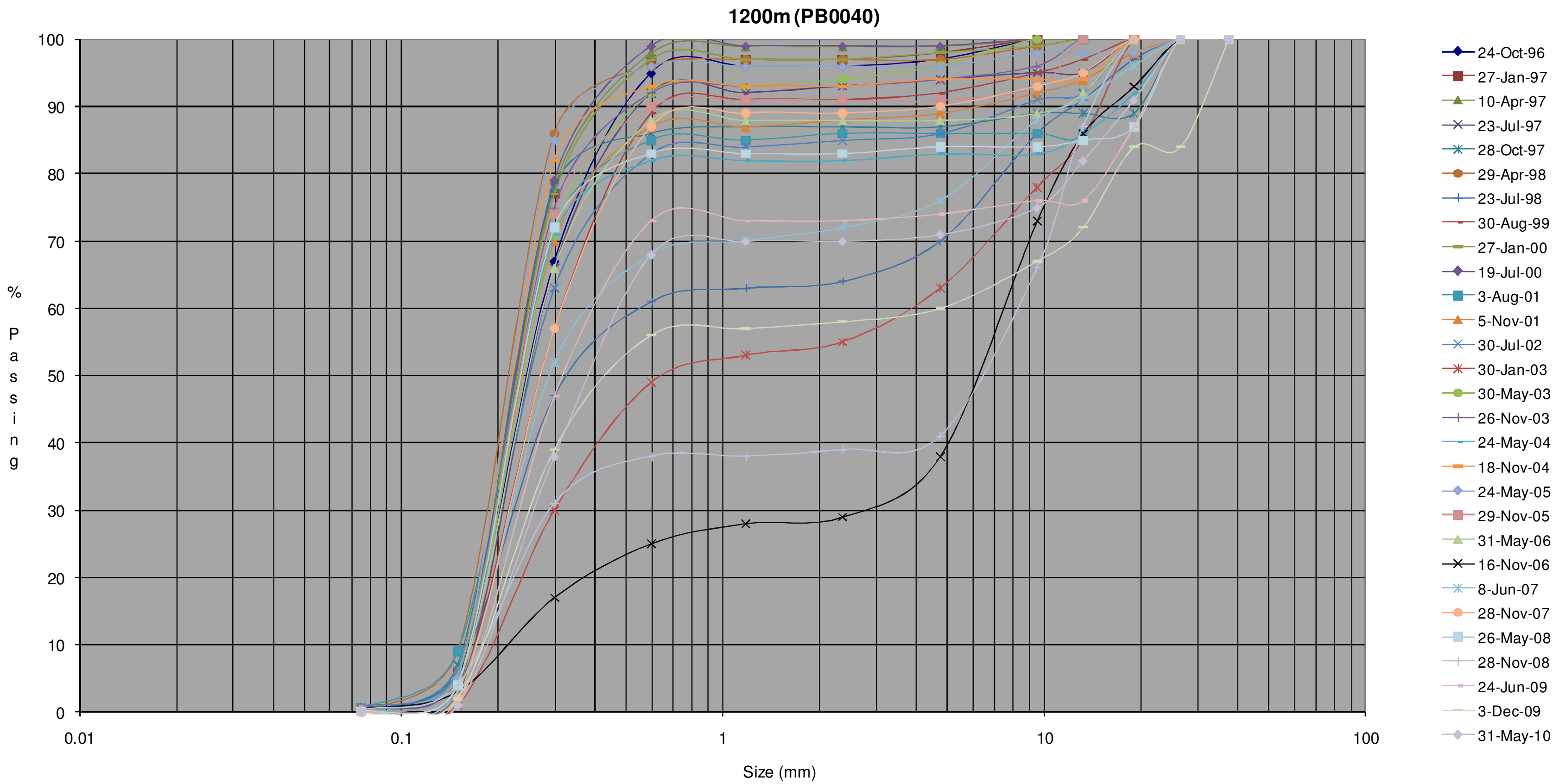

Figure 4.36: Petone Beach 6-monthly sediment analysis. Samples taken at MSL of PB0040, 1200m from extraction site.

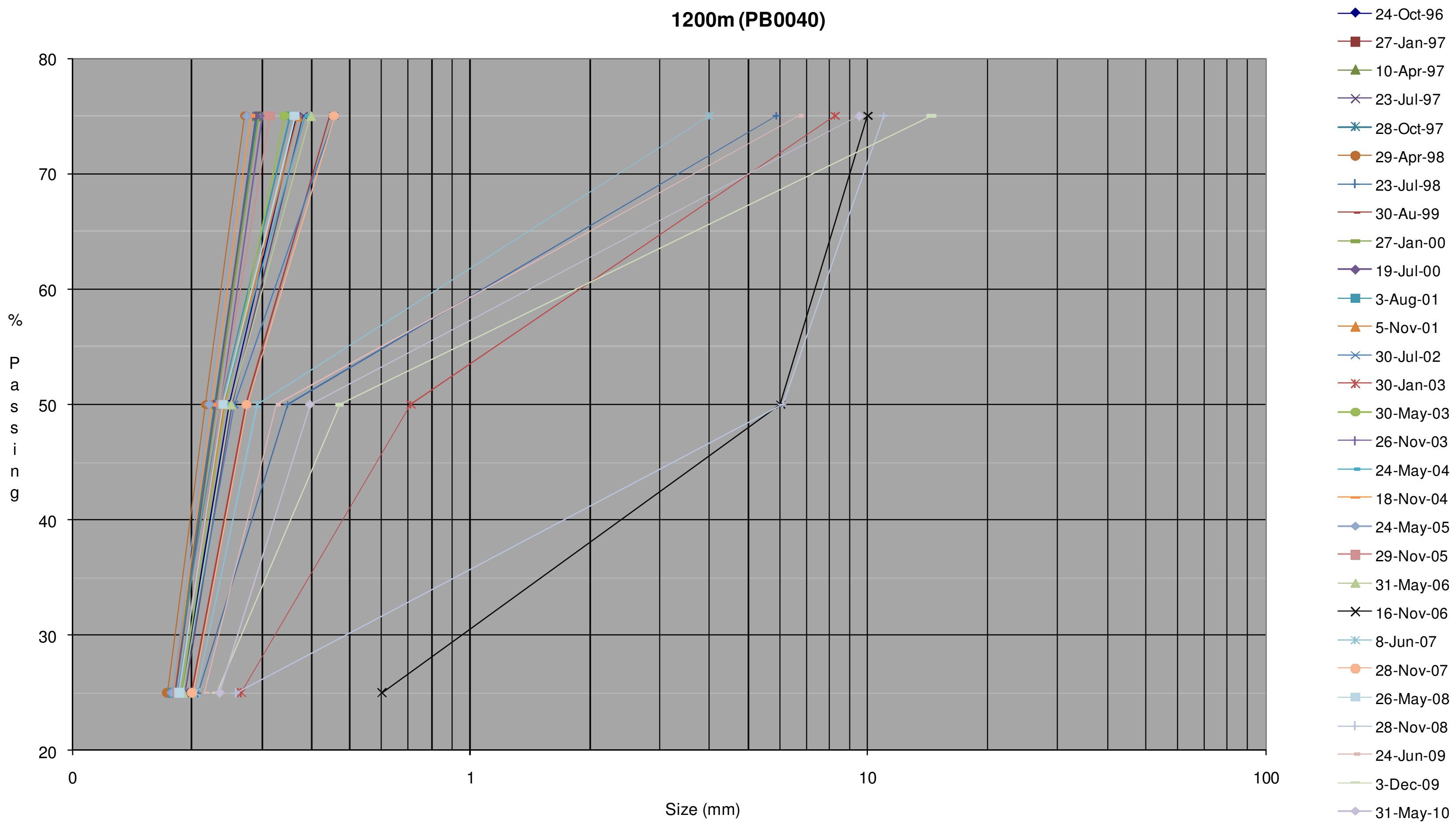

Figure 4.37: Site PB0040 sediment size median, upper and lower quartile.

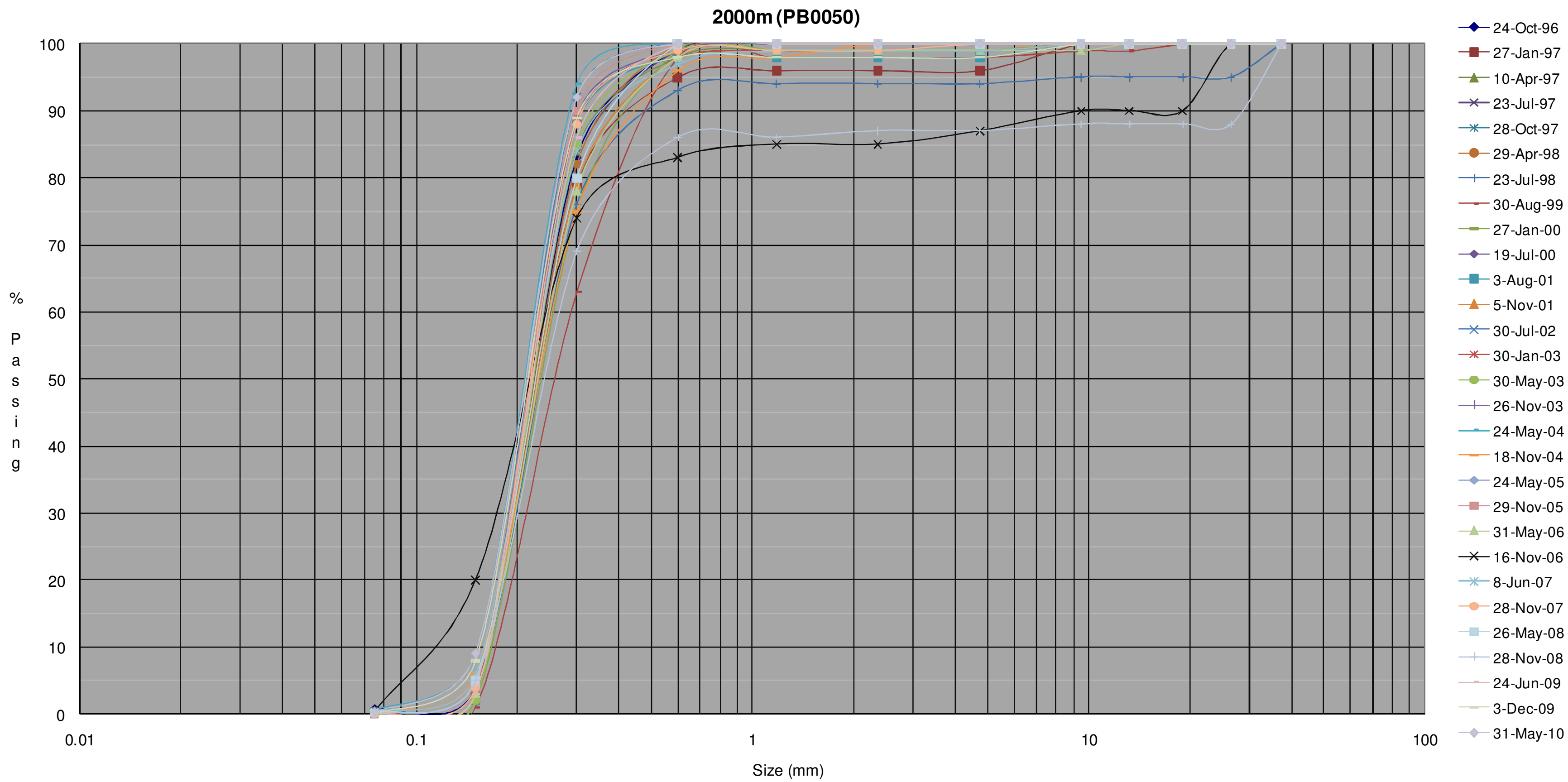

Figure 4.38: Petone Beach 6-monthly sediment analysis. Samples taken at MSL of PB0050, 2000m from extraction site.

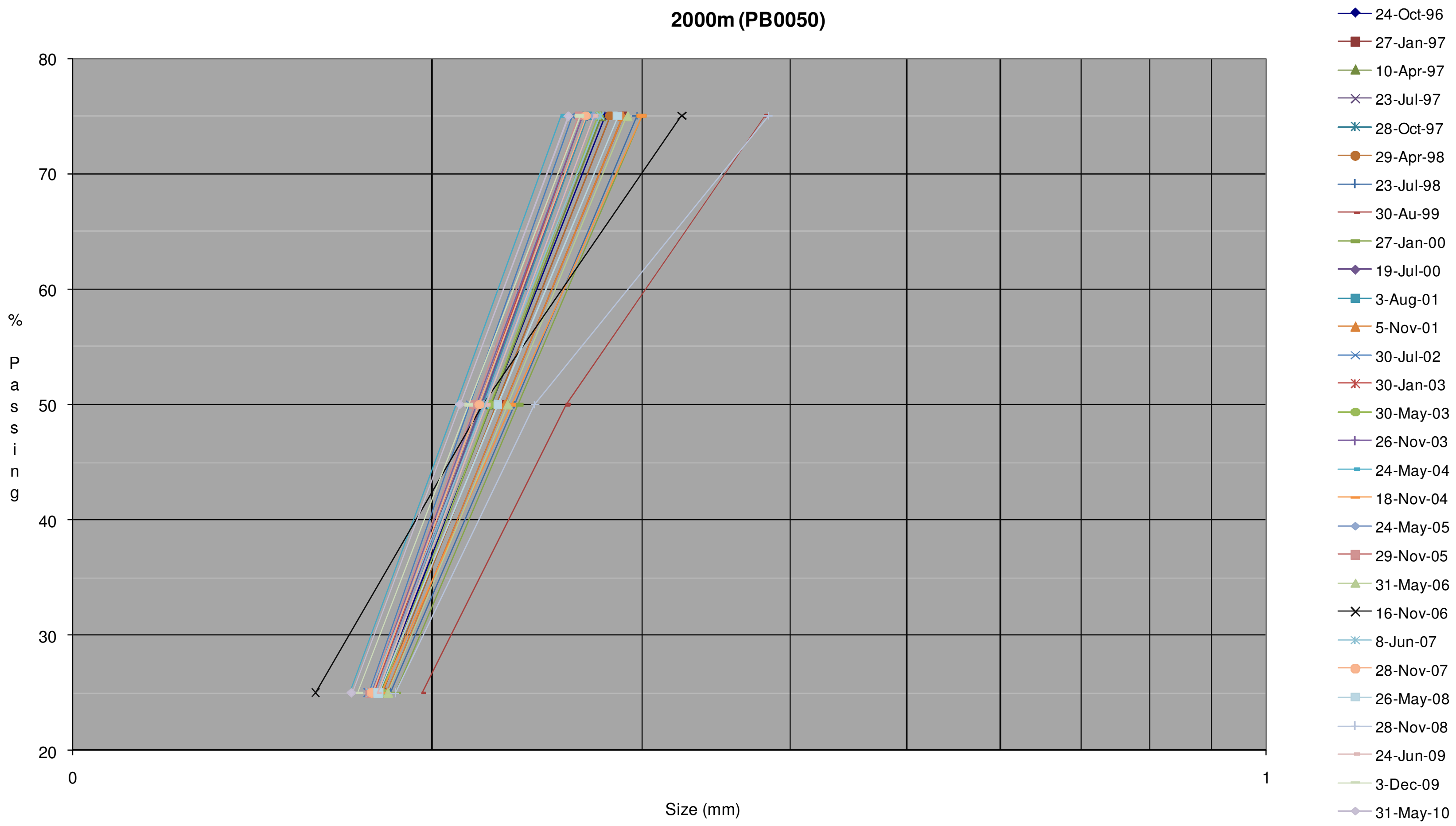

Figure 4.39: Site PB0050 sediment size median, upper and lower quartile.

5. Conclusions

5.1 Validity of previous conclusions

Past AEEs and evidence presented to the Environment Court have assessed the effects of continuing sediment extraction and disposal as minor. However, in many cases these conclusions were based on limited data and analysis. Since the current consent was granted regular beach profile measurements, river bed and hydrographic surveys, and sediment analysis have been undertaken. Ground and aerial photographs have also been taken.

There is a lack of baseline information showing what the local environment was like prior to any catchment modification, or excavation and beach disposal of sediment. This makes it difficult to assess the exact effects of the extraction and dumping activities relative to the natural environment.

Based on a review of all the information now available, the Hutt River mouth displays a high degree of variability, especially towards Petone Beach. This is to be expected given the natural dynamics of this high energy environment. Changes have occurred within the river bed cross-sections south of the Winstone's plant. Much of the bed lowered between 1987 and 1998, although the bed has now stabilised and even aggraded slightly. The rest of the channel up to the Waione Street Bridge is now generally at levels higher than in the past. This indicates a net surplus of sediment. The monthly sediment extraction rates have fluctuated less, and within a narrower band, since around 2003. Overall extraction appears to have reduced since 2005.

The hydrographic surveys show degradation near the river mouth. The river flows into the harbour scouring the bottom sediments and depositing them further offshore in an area of aggradation. Offshore there is a general pattern of minor aggradation (0-1m) or degradation (-1–0m). It is likely that this apparent change is within the accuracy limits of the survey and modelling. The overall average change in bed level of this area (Table 4.1) is minor aggradation. This is likely to be influenced strongly by anomalies such as around the Seaview Marina, the inherent error of the hydrographic survey, and any error associated with modelling the data. There is a greater aggradation around the offshore coarse sediment disposal site which is to be expected. This also indicates that this coarse material essentially remains where it is deposited. The disposal site would therefore appear to be working as intended.

The beach profile surveys represent a snapshot of the effect of various processes acting upon the beach. It is impossible to isolate the role or effect of a single factor. The deposition of the coarse waste material within the offshore disposal area, and the continued disposal of very fine sand and silt onto the beach since the 1999 consent, was thought by O'Callaghan (1996b) to cause little effect on the beach characteristics. The only effect predicted was a slowing of beach accretion towards the river mouth. Net erosion in this area was not predicted.

The profiles along the eastern section of Petone Beach all show a high degree of variability. This is expected because of the high energy nature of this environment. The profile closest to the Winstone's plant (PB0000) appears to have already been in a phase of slight erosion from 1996 to 1999. The erosion accelerated between 1999 and 2003. Since 2003, however, a new equilibrium appears to have been reached on this section of the beach. Successive profiles now tend to fluctuate around a relatively stable mean condition. The next profile (PB0010) underwent similar, though less extreme, net erosion and appears to have now also reached equilibrium.

Profiles PB0020 to PB0050 all display net accretion, the rate of which decreases in a westward direction. The storm berms on the last three profiles have also risen between 0.3m and 0.5m. This may have been the result of storm action immediately prior to the surveys.

The disposal bund has been used by the various companies involved the river dredging since around 1975. Up until 1999 this bund also included coarse material. The expectation that the removal of the coarse sediment from this bund would not cause significant erosion may have been optimistic. The coarse sediment does not move from the offshore dumping area and certainly does not move back onto the beach. This means that high energy southerly wave action is now working on much smaller sediment at the disposal bund site. Some erosion could therefore be expected until the beach in this area reaches some form of equilibrium. The latest data from the two profiles closest to the disposal bund shows that these may now have reached equilibrium.

The sediment size analyses are limited in their use. Samples were only taken at MSL and the measurement resolution is coarse. No information is available on what is happening higher or lower on the beach profiles. Those data that are available show a high degree of variability. This reflects the highly variable nature of sediment found on the beach and wave conditions. In general, more sand-sized material is present within the sediment on profiles at the eastern end of Petone Beach. The amount of sand in the samples appears to have increased since 1999, when the dumping of coarse sediment within the bund ceased. There is, however, no consistent trend showing that the beach is getting progressively stonier or sandier. The data fluctuates widely over time. The sediment analysis provides more of a measure of wave conditions prior to sampling than trends in sediment character over time. The variations in sediment distribution at MSL during November 2006 highlight the effect of the bands of sand and gravel that alternate along the beach. This could indicate that particular sediment sizes move along the beach in ‘pulses’ associated with particular storm events.

Notwithstanding the above, there is no evidence of the extraction of sediment and dumping of waste material affecting the character of the beach.

5.2 Assessment of the suitability of the proposed marine disposal site

Wear (1996) thought that disposal of coarse gravels offshore would increase the heterogeneity of the substrate in this area. The substrate would not be new or unique to the harbour floor as such substrate is found elsewhere. The dumping of coarse waste material, however, creates a substrate that is different to the usual silt and clay in this area. As there is little energy or sediment movement at this depth, the dumped material remains largely where it is deposited. Wear (1996) recommended that the course material be dumped frequently, in small quantities, and spread as widely and evenly as possible to provide the greatest benefit for biota.

The hydrographic surveys show that the bulk of this coarse material has indeed remained where it was initially deposited. The results of the beach profiles and sediment size analysis indicate that this sediment is not returning to the shore. The proposed new marine disposal site, since it has the same characteristics, is also considered to be at a suitable location for this activity.

5.3 Potential geomorphic and environmental effects

The results presented have illustrated the effects, or lack of effects, of the river extraction and by-product disposal activities. This is especially the case since 1999 when the coarse waste material has been dumped offshore. These results show a high degree of variability. This is typical of what would occur on a natural high energy coastline. The identified differences generally reflect the relationships between the river and coastal processes, and the conditions immediately prior to sampling, surveying, or photography.

Gravel beaches generally respond to storm conditions by steepening their profile. The profile tends to become more gravelly as a result of wave energy moving sand offshore. Sandy beaches flatten and dissipate the wave energy further offshore; mixed sand and gravel beaches respond with a mixture of these processes.

During the more normal northerly conditions, waves at Petone Beach flatten the profile and sand is deposited onshore. To compare profiles without any knowledge of prior wave conditions is difficult, and can be misleading. However, comparing such data over longer periods can indicate net movement of a particular area in a certain direction.

The above results show that the Hutt River has become shallower, and in parts wider, above the river mouth. It has also become slightly deeper where it enters the harbour. Little change has occurred to the harbour bed apart from some aggradation in the vicinity of the offshore disposal area.

The beach displays a high degree of variability in the sediment size. It tends to be more gravelly at the east, and becomes sandier further west. The beach profile initially eroded near the by-product disposal bund, although this now appears to have slowed or stopped. The beach continues to accrete at distances greater than 500m from the bund, with the rate of accretion decreasing in a westward direction.

If sediment extraction and waste disposal activities continue in the same manner as since 1999 the current patterns, including the high degree of variability, are likely to persist. The offshore disposal site will continue to aggrade, although if by-product was placed as suggested by Wear (1996) the amount of aggradation should be mitigated.

The flood risk is mitigated by dredging to reduce river bed levels. The volume of material extracted since 2005 has been decreasing. The percentage of waste material, both coarse and fine, has also increased significantly. This is likely reflecting a lack of sand-sized sediment in the system caused by a recent reduction in the frequency of coarser sediment-transporting flood events.

Notwithstanding the above, it would appear that the extraction of sediment from the river mouth, and dumping of coarse waste offshore, has had only a minor effect on the environment. Despite the extraction of over 30,000m^3 of material each year there still appears to be a net surplus of material arriving at the river mouth. This is shown by the continued net aggradation.

6. References

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