MĀORI COMMUNITY ADAPTATION TO CLIMATE VARIABILITY AND CHANGE

Examining risk, vulnerability and adaptive strategies with Ngāti Huirapa at Arowhenua Pā, Te Umu Kaha (Temuka), New Zealand

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Executive summary

Climate impacts, vulnerability and the capacity to respond and adapt are known to be the result of complex relationships between human and biophysical systems. Yet, in spite of this understanding and the inevitability that all social-ecological systems are affected by direct and indirect changes in climate conditions, few studies with specific populations and communities in Aotearoa/New Zealand have been carried out to ground-truth the nature of these factors and the various determinants of change. The work undertaken in this study explores some of these complexities through a grounded analysis of Māori community vulnerability, resilience and adaptation to climate variability and change with Ngāti Huirapa community members from Arowhenua Pā – Te Umu Kaha (Temuka), the *hapū* [sub-tribal kin group] representative body Te Rūnanga o Arowhenua Society Incorporated, and NIWA's Māori Environmental Research and National Climate Centres.

Cross-disciplinary research approaches and methods in the physical and human systems sciences were integrated in the study to help explore the <u>current</u> (and <u>past</u>) climate conditions and risks that the 'community' at Arowhenua Pā contend with. This necessarily involved consideration of how the community responds to such challenges as well as the factors and processes that enable and constrain choices and actions. Downscaled projections of future climate change scenarios enabled examination of <u>future</u> impacts and risks – with attention (based on community knowledge of local environmental risks) given to flooding of the Temuka River and inundation of the coastal zone surrounding the Opihi River mouth due to sea-level rise. This mixed approach (embedded within a complex systems framework and conducted using grounded theory) provided an effective methodology to examine the complexity of existing local climate risks, sensitivities and adaptive capacities held by the 'community' at Arowhenua Pā.

Through semi-directive group-based, paired and individual interviews (including many informal discussions and land-walks), 42 'home-people' who reside within, or in close proximity to, the Arowhenua Pā, shared their experiences, values and concerns surrounding present and future climate induced hazards and stresses. Early dialogue was dominated by references to local flooding and impacts on *whānau* [extended family]; historical changes in river courses, flows and *mahinga kai* [food gathering areas]; causes and amplification of flood risks due to human modification of the environment; as well as the important role of local planning in setting regulations and managing natural hazards and risks. Community insights were offered also on the 'things' that specifically contribute or influence the way people are affected by, and deal with, climate hazards and stresses. Not surprisingly, the matters discussed often intersected environmental, economic, social, political and cultural aspects of community life. However, what was not expected was that our attempts to distinguish community sensitivities from adaptive capacities led to the recognition that one could not be discussed without the other. Four principal determinants of community sensitivity and adaptive capacity were subsequently identified: (i) social networks, conventions and transformation; (ii) knowledge, skills and expertise; (iii) resourcing and finance; and (iv) institutions, governance and policy. While this analytical outcome is contrary on the one hand with a number of vulnerability-based studies conducted with other indigenous communities that commonly consider exposure-sensitivity jointly (rather than sensitivity-adaptive capacity) the interconnected nature of human-biophysical (social-ecological) interactions is not dissimilar.

The analysis of interviews and on-land interactions demonstrated that the community at Arowhenua Pā possess considerable capacity to deal (i.e. cope) with climate hazards and related stresses. Much of this capacity is rooted in elemental cultural values and approaches such as *tikanga* [Māori conventions, culture, custom] and *kawa* [ceremonial rituals, protocol, etiquette, correct procedure] and actioned through *whanaungatanga* [relationships, interconnection, mutual support], *manākitanga* [hospitality, kindness, care] and *kotahitanga* [solidarity, unity, collective action]. In addition to the importance of internal (as well as external) social networks and conventions, knowledge of place and closer human-environment relationships through *mahinga kai* were often expressed as central to community strengths and well-being (resilience/endurance) and thereafter being able to deal with environmental risks. However, such capacities are not uniform across the community and some individuals are better equipped to cope and adapt than others. Rapid transformations in local community structure, decreases in Māori-owned land holdings, lack of financing for infrastructural maintenance and insurance, a growing reliance on modern services, land-use change, resource management regimes, and *whānau* spending more time away from traditional areas for employment and education (among other social and institutional changes) were readily identified as increasing the sensitivity of the community to climatic risks and inversely undermining certain aspects of adaptive capacity. Notwithstanding these insights, new interactions and the development of new skills and expertise were identified as opportunities for helping to meet the emerging demands of increasingly complex social, economic, political and bio-physical system issues facing the community.

The results produced from our modelling of future extreme peak flood levels for the Temuka River in 2040 AD and 2090 AD showed that in a high emissions world (i.e. the A2 Emissions Scenario) local inundation extents for the equivalent of an extreme flood event with a current average recurrence interval >500 years are unlikely to differ markedly from the inundation extents measured from a ~100-150 year extreme flood event that occurred on the Temuka River in 1986. That is, the most extreme modelled estimate of future peak flood levels in this study was more than 30% greater than those recorded for the 1986 flood event - but the relatively steep elevation of local terrain resulted in little additional surface area being flooded. While these results are favourable in terms of the higher ground occupied by the Marae, school buildings and many *whānau* homes, they also demonstrate that lower lying properties and infrastructure (includes some occupied and unoccupied *whānau* homes, storage buildings, fencing and sections of local roads) are likely to be at greater risk of flood damage under a A2 Emissions Scenario in 2040 and 2090. Heightened flood peak levels also raise the liklelihood of harm for farm-stock (sheep and cattle) that sometimes graze the lower plains of the Arowhenua Pā. Less is known is about the direct and indirect impacts of such physical changes on local ecosystem services and related wild-food availability; however, concerns about potential adverse impacts from pollution and destruction of septic tanks and sewer lines are common. Important note: the occurrence of higher flood levels on the Temuka River, flooding from other tributaries, or even failure of existing flood protection measures on the Opihi River, could result in quite different outcomes.

Coastal inundation extents surrounding the Opihi River mouth under current high tide levels, extreme storm tide levels and sea-levels for 2040 AD and 2090 AD with an assumed 40 cm and 80 cm sea-level rises respectively were also investigated. The most notable change for the area under projected high-tide levels was increasing flood extents over time on the northern side of the Opihi River. Currently, this area is occupied by a mix of leasehold bach's and a small number of permanent residents (commonly referred to as the Milford Huts) as well as extensive dairying operations that stretch along the coast. Blocks of this coastal land remain in communal and private Māori ownership and are for the most part managed through long-term leases. Such land-uses are likely to be impacted and disrupted more frequently under such scenarios, and therein the on-going value of such leases (and investment returns) are likely to decline, particularly as permanent inundation occurs. Analysis of an extreme storm-tide level, which incorporates the combined effect of storm surge coinciding with a high astronomical tide, along with climate change-adjusted sea-levels for 2040 AD and 2090 AD showed even greater flooding extents on the northern side of the Opihi River – especially under 2090 AD conditions when much of the Milford Huts coastal settlement is projected to be under water. A further risk (and adaptation option) identified by interviewees was the sale of coastal lands and the relocation of infrastructure. Previous migrations of *tūpuna* [ancestors, forbears] were cited as examples of such actions having occurred in the past; however, others were more motivated to see these traditional assets held in Māori ownership, regardless of the possibility of such lands being eventually 'gifted' to the sea. Important note: the inundation maps produced through this analysis only include sea-level effects; they do not include the combined effects of river flooding plus a storm-tide which are likely to produce more extreme inundation results.

Integrating these results, it is clear that considerations of vulnerability and adaptation to climate change are inseparable from issues linked to natural hazards management and sustainable development. Even without climate change and on-going climate variability and extremes, Māori from Arowhenua Pā remain affected by social-economic and political processes that influence their capacity to cope with challenges in the short-term and adapt in the longer-term. This point is critically important for leaders and decision makers across a range of scales and institutions, as well as *te hau kāinga* [home-people] on the ground who often indicated either how overwhelming and contentious the climate change issue can be or how much lesser of a priority it was when compared with other challenges currently confronting the community. In spite of these views, many of those community members also acknowledged the need to strengthen their social, cultural and institutional capacities to assess, plan, and respond to the direct and indirect challenges brought on by changing climate regimes and conditions.

It is further evident (as in other studies of vulnerability to climate stress) that the constraints and strengths identified represent points of entry for strategic community, iwi [tribal kin group] and government level planning and policy development that can minimise (or eliminate) existing sensitivities and enhance (as well as introduce new) coping and adaptive capacities. As expressed above, such points of entry are deeply connected with existing social-economic-political and environmental conditions; and therein the capacity of the community to deal with future climate risks, which are not limited to heightened river flood peaks and inundation of coastal lands due to sea-level rise, rests in large part upon responding to existing issues linked to resourcing, political participation, community governance, *whānau* health and education, cultural capital and management of risk associated with natural hazards. There are of course numerous complexities and uncertainties that will affect the management of future climate risks facing the community – including, among others, the capacity (and willingness) to create management practices that can accommodate changing risk and social-ecological conditions over time.

For other Māori communities interested in examining in their own climate change challenges it is important to emphasise that consideration of community vulnerability and resilience does not require the science of climate "prediction" to be more developed and nor does it require location-specific climate information of the kind produced in this report. Rather, first-order climate change projections are readily available and these can be used to enhance awareness about potential impacts and associated risks. Perhaps more importantly, strategies and policies to tackle vulnerability and enhance adaptability to future climate risks can be developed in spite of the uncertainties, because most of the factors and processes that constrain choices and actions intersect existing issues of *whānau*/*hapū* development and social-ecological well-being.

Whakarāpopotonga

Ko ngā pānga āhuarangi, ngā whakaraeraetanga, me ngā āheinga kia aro atu, kia takatū anō, he mea hua i ngā whanaungatanga matatini i waenga i te tangata me ngā momo taiao. Heoi, hāunga rā tēnei māramatanga, me te mōhio anō ka pākia tonutia ngā pūnaha pāpori-kaiao e ngā panonitanga āhuarangi, he iti noa ngā kaupapa rangahau e aro pū ana ki ngā taupori me ngā hapori motuhake o Aotearoa, e whai ana kia kimihia te tika me te pono o ia hapori tonu, mō ngā āhua o ēnei take, me ngā momo mea e hua ake ai ngā panonitanga. Ko tā tēnei kaupapa rangahau he whakatewhatewha i ētahi o ēnei āhuatanga matatini, mā te āta tātari i ō ngā hapori Māori whakaraeraetanga, tō rātou aumangea, me tō rātou āhei kia noho takatū i ngā panonitanga āhuarangi, mā te mahi ngātahi ki ētahi o Ngāti Huirapa o Arowhenua Pā – Te Umu Kaha (Temuka), te poari māngai o te hapū, arā, Te Rūnanga o Arowhenua Society Incorporated, me ngā ohu Rangahau Taiao Māori, Āhuarangi ā-Motu hoki, o NIWA.

Whakakotahingia ai ngā momo ara rangahau, me ētahi tikanga nō ngā momo pūtaiao ōkiko, ā-tangata anō, e taea ai te whakatewhatewha i ngā āhuatanga āhuarangi me ngā mōreareatanga o nāianei (o mua anō) e pākia ai te 'hapori' o Arowhenua Pā. Nā whai anō te whai whakaaro ki tā te hapori aro atu ki ēnā momo uauatanga, ngā āhuatanga, me ngā momo ara e taea ai, e tāmia ai rānei, ngā kōwhiringa me ngā mahi ka hua ake. Nā te whakawhāiti i ngā matapae mō ngā panonitanga āhuarangi o raurangi, i taea ai te tātari i ngā pānga me ngā mōreareatanga o raurangi – ka aronuitia (e ai ki ō te hapori mōhioranga mō ngā mōreareatanga ā-taiao o te takiwā) te waipuketanga o Temuka Awa, me te parawhenuatanga o te rohe tahamoana e karapoti nei i te wahapū o Opihi Awa, nā te piki haere o te taumata moana. Nā tēnei ahunga whai aronga nui (kua titia ki te tūāpapa pūnaha matatini, ā, i whakamahia mā te aro ki te tika me te pono o te hapori) i puea ake he huarahi whai hua, hei āta tātari i te matatinitanga o ngā mōreareatanga āhuarangi o te takiwā, ngā whakaraeraetanga, me ngā āheinga takatū o te 'hapori' o Arowhenua Pā.

Nā ngā uiuinga ā-rōpū, takirua, takitahi anō i āta ārahirahitia (āpiti atu anō he whakawhitinga kōrero ōpaki me ētahi takahitanga whenua), e 42 te hunga 'ahi kā' kei Arowhenua Pā tonu, kei kōtata atu rānei e noho ana, i whakapuaki i ō rātou wheako, mātāpono, māharahara hoki mō ngā mōreareatanga āhuarangi me ngā taumahatanga ka hua ake, o nāianei, o raurangi anō. He nui tonu ngā kōrero i puta mō ngā waipuke i te takiwā me ngā pānga ki ngā whānau; ngā panonitanga i roto i ngā tau ki ngā ara o ngā awa, te rere o ngā wai, me ngā mahinga kai; ngā take i hua ake ai, i kino ake ai anō ngā mōreareatanga waipuke nā ngā panonitanga ā-taiao, ko te tangata te take; me te tino whai take o ngā whakaritenga ā-takiwā hei whakatau ture, hei āta aro anō ki ngā mōreareatanga ā-taiao kei tūpono noa ake. I tukuna anō ko ō te hapori whakaaro mō ngā 'mea' ka whai wāhi atu, ka whai pānga rānei, ki te pākia o te tangata e ngā mōreareatanga āhurangi me ngā taumahatanga ka hua ake, me tō rātou aronga atu anō. Nā whai anō, ko ngā kōrero i puta i pā ki ngā torotoronga ā-taiao, ā-ōhanga, ā-pāpori, ā-tōrangapū, ā-ahurea hoki o tō te hapori noho. Heoi, he hua kāore i matapaetia, ko te whakatau i puta i tā mātou ngana ki te whakawehe i ngā whakaraeraetanga ā-hapori me ngā āheinga takatū, arā, tē taea te kōrero i tētahi, ki te kore tērā atu e kōrerotia ngātahitia. Kāti, e whā ngā mea ka mātua tohu i ngā mōreareatanga me ngā āheinga takatū o te hapori, i kitea: (i) ngā whanaungatanga, tikanga, panonitanga ā-pāpori; (ii) ngā mōhioranga, pūmanawa, pūkenga hoki; (iii) ngā rauemi me te pūtea; ā, (iv) ngā momo ohu whakahaere, whakataunga, kaupapa here hoki. Hāunga rā te rerekē o tēnei hua ki ētahi atu kaupapa rangahau whai tūāpapa whakaraeraetanga mō hapori taketake kē atu, i aro ngātahi ki ngā pānga-whakaraeraetanga (kaua ngā whakaraeraetanga-āheinga takatū) ko te tini o ngā hononga whanaungatanga i waenga i te tangata me ngā momo taiao (pāpori-kaiao) he ōrite tonu.

Nā te tātari i ngā uiuinga me ngā nohotahitanga ki runga whenua, kua kitea he āheinga nui tō te hapori o Arowhenua Pā kia noho haumaru tonu, hāunga rā ngā mōreareatanga āhuarangi me ngā toimahatanga whai pānga, ka hua ake. Hei tūāpapa mō tēnei āheinga ko ngā momo mātāpono ahurea o te Māori pēnei i ngā tikanga me ngā kawa, ka whakatutukitia mā te aro ki te whanaungatanga, te manaakitanga, me te kotahitanga. Hei āpiti ki te whai take nui o ngā ara me ngā tikanga whanaungatanga i waenga i te whānau, i te hapū (ki ohu kē atu anō), he pānga nui hoki tō ngā mōhioranga mō te takiwā me ngā hononga o te tangata ki te taiao i hua ake i ngā mahinga kai, ki te pakari me te ora o te hapori, me tā rātou āhei ki te noho haumaru tonu, hāunga rā ngā mōreareatanga ā-taiao. Heoi, ehara i te mea he ōrite tonu ngā āheinga o te katoa i te hapori ki te noho haumaru, kia takatū anō, engari kē, he āheinga nui ake ō ētahi, i ētahi atu. Ko te hohoro o ngā panonitanga ki te āhua o te hapori, te mimiti haere o ngā whenua o te Māori, te iti o te pūtea hei utu i ngā mahi whakatika hanganga me te inihua, te kaha whakawhirinaki atu ki ngā ratonga hou, te rerekē haere o ngā momo whakamahinga whenua, ngā ture whakahaere rauemi, me te nui o te wā e noho tawhiti atu ai ngā whānau i te wā kāinga kia whai mahi ai, kia whai mātauranga ai (me ētahi atu panonitanga ā-pāpori, ā-ohu whakahaere anō) i tohua hei take i kino kē ai te noho whakaraerae o te hapori ki ngā mōreareatanga āhuarangi, i ngoikore anō ai ngā āheinga kia takatū atu. Hāunga rā ēnei kitenga, ko te whai whanaungatanga hou, me te whakawhanake pūmanawa, pūkenga hou anō, he ara hei whakaea i ngā taumahatanga matatini ka hua ake i te pāpori, te ōhanga, te ao tōrangapū, me ngā momo taiao, e pā ana ki te hapori.

Mea rawa ake, ko ngā kitenga o ā mātou matapae mō ngā waipuketanga kino rawa atu kei tūpono noa ake ki Temuka Awa hei ngā tau 2040 AD me 2090 AD i tohu ake, i tētahi ao, he nui tonu ngā tukunga waro (hei tauira, Te Whakapae Tukunga Waro A2) ka kore e tino rerekē te kino o ngā parawhenuatanga i te takiwā nā te waipuke ~500 tau kino rawa, i te parawhenuatanga i hua ake i te waipuke ~100-150 tau kino rawa i puea ake i Temuka Awa i te tau 1986. Inā hoki, ko te whakapae o tēnei kaupapa rangahau mō ngā taumata waipuke kino rawa o raurangi, he 30% nui ake i ērā i hua ake i te waipuke o te tau 1986 – heoi, nā te hanga hūkere o ngā whenua o te takiwā, ka kore e tino nui ake te mata o te whenua ka waipuketia. Ahakoa te hanga pai o ēnei hua nā te tū o te marae, ngā whare kura, me te maha o ngā kāinga o te whānau ki whenua teitei, he mea tohu anō i te noho whakaraerae rawa atu o ngā wāhi me ngā hanganga kei ngā whenua tāpotupotu (ko ētahi he whare whai kainoho, noho kainoho-kore anō o ngā whānau, he whare whakaputu, he taiapa, he wāhi huarahi hoki o te takiwā) kei pākia kinotia e te waipuke i raro i Te Whakapae Tukunga Waro A2 hei te tau 2040 me te tau 2090. Nā te piki haere o ngā taumata waipuke kino rawa, ka noho whakaraerae ake ngā kararehe ahuwhenua (ngā hipi, ngā kau) ka kai otaota i ngā raorao tāpotupotu o Arowhenua Pā. Kāore e mōhio whānuitia ana ngā pānga ka hua ake ki ngā ratonga kaiao me ngā kai tupu poka noa o te takiwā, i ngā panonitanga ki te taiao; heoi, he nui ngā āwangawanga i puta mō ngā pākinotanga kei tūpono hua ake i te parahanga, me te tanukutanga o ngā kura hamuti me ngā pininga parakaingaki. He karere mātuatua: ki te kino ake ngā taumata waipuke ki Temuka Awa, ki ngā kautawa rānei, ki te raru rānei ngā āraihanga waipuke ki Opihi Awa, kei rerekē mārika te otinga ake.

I whakatewhatewhangia hoki te whānui o ngā parawhenuatanga o te rohe tahamoana e karapoti nei i te wahapū o Opihi Awa, i raro i ngā taumata moana tai pari o nāianei, ngā taumata moana āwhā kino rawa, me ngā taumata moana mō te tau 2040 AD me te tau 2090 AD, kua āpitihia atu ngā pikinga e 40 cm, e 80 cm hoki, e matapaetia ana. Ko te panonitanga nui rawa atu ki te takiwā e ai ki ngā matapae taumata moana tai pari, ko te āta whānui haere o ngā waipuke ki te taha raki o Opihi Awa. I tēnei wā he kōpuha rīhi, he kainoho pūmau ruarua (e karangatia whānuitia ana ko Ngā Whare Milford), me ētahi pāmu miraka kau nui hoki, kei taua rohe tahamoana. He wāhi whenua tonu o tēnei rohe tahamoana nō te Māori noho takitini, takitahi hoki, ā, ko te nuinga ka whakahaerehia mā ngā rīhi ahungaroa. Ka kaha ake te whakararua o aua whakamahinga whenua i raro i ēnā momo matapae, ka heke hoki te wāriu o aua rīhi (me ngā hua ka puta i ngā mahi whakangao) ā hāere ake nei, ka whakaparawhenuatia rawatia ana ēnā pito whenua. Nā te āta tātari i tētahi taumata moana āwhā kino rawa, e whai wāhi atu ana ngā hua ka puta i te taumata moana āwhā kua hono ki te taumata moana teitei ā-arorangi, me ngā taumata moana teitei ake e matapaetia ana mō ngā tau 2040 AD me 2090 AD, i kitea ake ka whānui mārika ake te toro o ngā waipuke ki te taha raki o Opihi Awa – i pērā pū te otinga i raro iho i ngā matapae mō te tau 2090 AD, inā hoki ko te whakapae, hei reira kapia ai te papakainga tahamoana o Ngā Whare Milford ki te wai. Ko tētahi anō mōreareatanga (ara takatū atu anō) i puta i te hunga i uiuitia, ko te hoko i ngā whenua tahamoana me te whakaneke i ngā hanganga o te rohe. I kōrerotia ngā hūnukutanga o ētahi tūpuna hei tohu ake, kua hua kē ake ēnei momo tūāhua i ngā rā o nehe; heoi, arā tonu ētahi e ū ana ki te hiahia kia pupuritia tonutia ēnei rawa tuku iho e te Māori, hāunga rā te mōhio, kei eke pea te wā e ‘takohangia’ atu ai ēnei whenua ki a Tangaroa. He karere mātuatua: ko ngā mahere parawhenuatanga i hua ake i tēnei mahi tātari ka tohu noa i ngā panonitanga ki ngā taumata moana; kāore i whai wāhi atu ngā hua ka puta i te waipuketanga awa me te taumata moana āwhā ka whakakotahingia, otirā, kāore e kore ka kino kē atu ngā hua parawhenuatanga ka puta, ki te pērā.

Nā te whakakotahi i ēnei hua, i mārama te kite atu, ko ngā whakaraeraetanga me ngā āheinga kia takatū ake i ngā panonitanga āhuarangi, e herea ana ki ngā take tiaki i ngā mōreareatanga o te taiao me ngā whanaketanga tupu noa. I te korenga o ngā panonitanga āhuarangi, me ngā aupiki, auheke hoki ā-āhuarangi, ka pākia tonutia ngā Māori o Arowhenua Pā e ngā take pāpori-ōhanga, tōrāngapū anō, otirā ka pākia ō rātou āheinga kia noho haumaru tonu, hāunga rā ngā uauatanga o te wā, i te ahungapoto, ki te takatū atu hoki, i te ahungaroa. He take mātuatua rawa atu tēnei ki ngā kaiārahi me te hunga whakatau i ngā momo ohu whakahaere katoa, me te hunga hau kāinga tonu i kaha te tuku kōrero mai mō te taumaha, hanga whakatutū puehu hoki o te kaupapa panonitanga āhuarangi, mō tā rātou aro kore atu ki te take rānei, nā te kino kē ake o ngā tini uauatanga atu e pēhi nei i te hapori. Hāunga rā ēnei whakaaro, he nui tonu ngā mema o te hapori i whakaae, me whakapakari ake ō rātou āheinga ā-pāpori, ā-ahurea, ā-ohu whakahaere anō, e taea ai te āta arotake, te whakarite rautaki, te aro pū atu hoki ki ngā momo wero ka hua ake i ngā panonitanga āhuarangi.

I kitea anō hoki (pērā i ētahi atu rangahau mō te noho whakaraerae ki ngā taumahatanga āhuarangi) ka riro mā ngā here me ngā pakaritanga e tohu i ngā ara rautaki ā-hapori, ā-iwi, ā-kāwanatanga hoki mō te whakarite mahere, kaupapa here anō, hei whakangāwari (whakakore rānei) i ngā whakaraeraetanga, hei whakapakari hoki (whakahou anō) i ngā āheinga ki te takatū atu, ki te noho haumaru tonu. Hei toai i tērā i kōrerohia i runga nei, ko aua momo ara e whai pānga nui ana ki ngā āhuatanga pāpori-ōhanga-tōrangapū me ērā o te taiao; nā reira ko ngā āheinga o te hapori kia noho haumaru tonu, hāunga rā ngā mōreareatanga taiao o raurangi, ehara anake ko te piki o ngā taumata waipuke awa me te parawhenuatanga o ngā whenua tahamoana nā te piki o te taumata moana, ka whai tūāpapa i te aro pū atu ki ngā take o nāianei mō te whai rauemi, te whai reo tōrangapū, ngā whakahaeretanga hapori, te hauora me te mātauranga o te whānau, te ora o te ahurea, me te aro atu ki ngā mōreareatanga i te taiao. E hia kē ngā matatinitanga me ngā āhuatanga tē taea te mōhiotia i tēnei wā tonu, ka pā ki ngā aronga atu ki ngā mōreareatanga āhuarangi o raurangi ka pā ki te hapori – ko ētahi ko ngā āheinga (me te hiahia) ki te whakarite rautaki whakahaere, e whai wāhi atu ana ngā panonitanga ki ngā mōreareatanga me ngā āhuatanga pāpori-kaiao, i roto i ngā tau.

Mō hapori Māori kē atu e hiahia ana ki te arotake i ō rātou ake uauatanga ka hua i ngā panonitanga āhuarangi, me whakataukī ake, ehara i te mea me whai mōhioranga āhuarangi mō te takiwā tonu, pēnei i te momo i kōrerohia i tēnei ripoata, ehara hoki i te mea me whakawhanake te pūtaiao “matapae” āhuarangi, e taea ai te whai whakaaro ki ngā whakaraeraetanga me ngā pakaritanga o te hapori. Ko te mea kē, he māmā noa te toro ki ngā matapae panonitanga āhuarangi ahunga whānui, hei whai māramatanga mō ngā pānga me ngā mōreareatanga kei tūpono hua ake. Me mātua mōhio, ka taea tonu te whakarite rautaki hei kaupare i ngā whakaraeraetanga, hei whakapakari hoki i ngā āheinga kia aro atu ki ngā mōreareatanga āhuarangi o raurangi, hāunga rā ngā āhuatanga tē taea te mōhiotia i tēnei wā, inā hoki, ko te nuinga o ngā āhuatanga e here ana i ngā kōwhiringa me ngā mahi, ka whai pānga ki ngā take whakawhanake whānau/hapū me te oranga pāpori-kaiao.

1 Introduction and background

This report documents a community-based project led by NIWA's Māori Environmental Research and National Climate Centres in close collaboration with Ngāti Huirapa community members from Arowhenua Pā – Te Umu Kaha (Temuka) and the *hapū* [sub-tribal] representative body Te Rūnanga o Arowhenua Society Incorporated – Arowhenua, New Zealand. It is the first report in a series of place-based studies with Māori communities investigating 'community' vulnerability, adaptation and resilience to climate variability and change. The information and learning derived from this work is expected to assist not only the participating communities but also provide necessary information to assist adaptation planning by other Māori communities as well as central and local government to the direct and indirect impacts of climate change (and on-going climate variability).

The following sub-sections set the context for this study and provide background information relevant to this research programme. A brief overview of the latest science on climate change – including consideration of the differentiated nature of climate change impacts and risk for Māori communities is first provided, and thereafter key global change terms and concepts used within this programme are defined. Finally, before articulating the key objectives of this study, a summary of published climate adaptation research conducted to date with indigenous peoples who have similar historical and socio-political landscapes to Māori is presented.

1.1 Climate change science

Scientific evidence about global climate change continues to accumulate and therein affirm the links between human activities, increasing greenhouse gas (GHG) emissions, and rising global surface temperatures (among other climate-environment related changes). In spite of evidence for human-induced climate change, determining how different groups across society are likely to be impacted, including the contextual factors that drive their relative vulnerabilities and resilience, is an extremely difficult task. Yet it is one that is vitally important for identifying risks and making actual decisions about appropriate response and adaptation strategies.

Before recapping the limited work conducted to date on Māori climate change issues, a brief summary of the physical science is provided below as a basis for understanding the 'projected' and 'downscaled' assessments of change given later in this report. Note that more detailed information on climate change projections is available through the latest Inter-governmental Panel on Climate Change (IPCC) series of reports (more commonly referred to as fourth assessment reports – AR4) and for the New Zealand context from the Ministry for the Environment (MfE) funded 'Climate change effects and impacts assessment: A guidance manual for local government in New Zealand' (MfE, 2008a).

The most recent summary reports produced by the IPCC in 2007, concluded that warming of the climate system is now "unequivocal" and that most of the observed increase in global average temperatures since the mid-20th century is "very likely" due to the observed increase in anthropogenic [human] GHG concentrations (IPCC, 2007). At the crux of this issue (from an atmospheric science perspective), human activities such as fossil fuel burning and land use change have been increasing the natural levels of greenhouse gases (e.g. carbon dioxide - CO_2, methane - CH_4 and nitrogen dioxide - N_2O, among others) in the atmosphere, causing heat from the sun to be trapped in the atmosphere instead of being radiated back into space and therein the Earth to warm and the climate, by consequence, to change. Over the last century alone, atmospheric concentrations of carbon dioxide increased from a pre-industrial[1] value of 278 parts per million to 379 parts per million in 2005, and the average global temperature rose by 0.74° C (UNFCCC, 2007). These changing concentrations are consistent with an increasing rate of warming that has taken place over the last 25 years, with 11 of the 12 warmest years on record (over the past 150 years) having occurred between 1995 and 2006.

Scientists have designed climate models (based on the physical laws of how the atmosphere behaves) that evaluate the role of increasing GHG's on our climate. Using mathematical representations of the atmosphere, land and oceans, scientists have shown that natural effects such as solar variability and volcanoes do not fully explain the increases in temperatures that are observed in the instrumental record – particularly the latter part of the twentieth century. In contrast, when GHG's are included into these simulations, the observed warming is more closely followed – indicating that the warming observed over the past 100 years is unlikely to have been caused by natural variations alone. Figure 1 shows the influence in modelled output when GHG's are excluded and included in globally modelled temperature (IPCC, 2007).

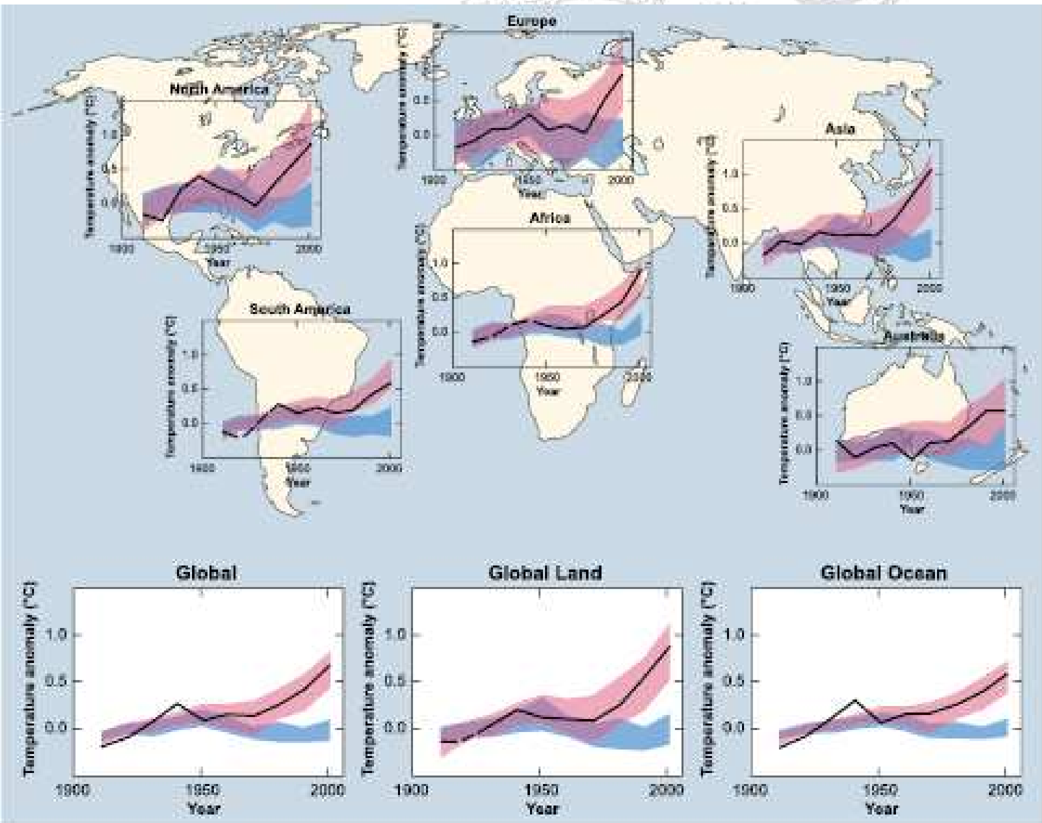

Figure 1: The figure shows the influence in modelled output when GHG's are excluded and included in globally and regionally modelled temperature. The black line indicates the observed increases in temperature over the years. In the blue band modeled average temperature takes into account solar, volcanic effects, and observations. In the red band GHG's and aerosols are included (IPCC, 2007).

[1] Typically refers to the period prior to 1750 AD.

In conjunction with these assessments, detailed climate projections for the 21st century (which simulate the effect on the atmosphere and oceans of different possible future scenarios of GHG emissions) show that climate change will most likely continue and may even accelerate with "unexpected surprises" (IPCC, 2007). While there are still many uncertainties associated with predicting future climatic changes, the latest climate projections summarised by the IPCC AR4[2] include:

- An increase in globally averaged surface temperatures of between 1.1ºC and 6.4ºC by 2100 AD, and a very likely increase in the frequency of hot extremes and heat waves.
- Both increased and decreased average annual rainfall - depending on location - of between 5-20% at regional scales during the 21st century.
- A likely increase in the frequency of heavy precipitation (rainfall) events.
- Continued widespread retreat of glaciers throughout the 21st century.
- A basic rise in global mean sea-level of between 0.18 to 0.59 m by the 2090's relative to the 1980-1999 average[3].

Importantly, these global averages do not necessarily reflect the complex range of outcomes that will occur across national and regional scales. Recent studies already have shown larger biological impacts in equatorial regions and these are understood to be related to the change in temperature relative to what the biological systems have become adapted to, rather than the absolute magnitude of temperature change (Dillon *et al*., 2010). Notwithstanding the importance therefore of remaining cautious when interpreting these global projections, the information needs to be 'down-scaled' to be meaningful at the national or regional level. Full details of available national and regional 'down-scaled' predictions for New Zealand, in the context of Local Government, is summarised in the guidance manual referred to above. Broad patterns of change over New Zealand for the next 50-100 years are expected to consist of:

- Rising temperature of ~1ºC by 2050 and 2℃ by 2100 - with greater increases in the winter season, and in the north of New Zealand
- Decreased frost risk but increased risk of very high temperatures
- Enhancement of westerly winds
- Stronger west-east rainfall gradient (wetter in the west and drier in the east)
- Increased frequency of extreme (heavy) daily rainfalls resulting in floods

[2] These projections are for the so-called SRES (Special Report on Emission Scenarios) scenarios, which were developed for a range of possible future economic, development and social scenarios. The scenarios do not include climate-policy initiatives to reduce greenhouse gas emissions (IPCC, 2007).

[3] These projections do not include contributions due to changes in the dynamics of ice-sheet discharge, which is less well understood and likely to be an increasing factor, particularly if greenhouse gas emissions are not reduced. Instead IPCC provided an estimated rise in the upper ranges of the emission scenario projections that would be expected with "scaled-up ice sheet discharge" if contributions to sea-level rise were to grow linearly with global temperature change for each emission scenario. This was estimated within the IPCC AR4 as varying between an additional 0.09 m to 0.17 m (depending on emission scenario) but was rounded up in the IPCC (2007) Synthesis Report to an additional 0.1 to 0.2 m rise. It was also clearly stated that larger contributions from the Greenland and West Antarctic ice sheets over this century could not be ruled out (IPCC, 2007).

- Large areas of the east are likely to have less soil moisture
- Snow line rise and glacier shrinkage
- Continued sea-level rise, possibly of the order of 1m or more by 2100[4].

Note that a range of emissions scenarios is typically used in projecting future climate conditions as we do not know exactly how human-induced greenhouse GHG's will vary over the century, and therefore cannot define exactly how the emissions will translate into climate changes and sea-level rise. Consequently, future changes in climate are typically presented as ranges, rather than a single value. In spite of the uncertainties, confidence in estimates of future changes in climate-related risks is increasing. This is due to the consistency in model-based projections of changes in the likelihood of extreme events and climate variability, as well as increased consistency between these projections and the observed changes in these likelihoods over recent decades. More specific information on climate change scenarios is presented in Section 5 of this report.

A final point to emphasise here is that there is considerable natural variability in climate which can deviate from long-term averages. Subsequently, human-induced long-term trends will be superimposed on these natural variations, and it is this combination that will provide the future climate extremes to which societies and the varied groups within them will be exposed (Smit and Pilifosova, 2003).

1.2 Māori communities and climate change

To date, only a handful of studies have considered how Māori society is likely to be affected by climate change – and these studies have tended to be either very sector specific in their analyses (e.g. Harmsworth, 2003; Funk and Kerr, 2007; Insley and Meade, 2008; Insley, 2010) or more general in scope inferring risk and vulnerability based on exploratory engagements with varied stakeholders and existing social-economic-political and ecological conditions (e.g. Packman *et al*., 2001; Cottrell *et al*. 2004; King and Penny, 2006; Hennessy *et al*., 2007; MfE, 2007; King *et al*., 2010). Aside from the need for more detailed information across all the different sectors, systems and groups that make up Māori society – it is generally recognised that Māori society is climate sensitive due to the strong links that exist between Māori economic, social and cultural systems and the natural environment (NZIER, 2003). Added to this, it is also recognised that the projected impacts of a changing climate on Māori will be differentiated depending on social, political, economic and environmental circumstances (Figure 2).

The vulnerability and resilience of Māori will also vary between Māori living in small rural settlements to Māori in regional centres and larger municipal areas. But, in what ways? How might specific groups reduce their vulnerability and manage risk? Do Māori governance structures (including policy makers and local authorities) have adequate information and tools to respond to the pressures that Māori face? And, how should priorities for adaptation action and planning in communities and settlements be decided? All of these questions are important when considering the distinctive character of, and challenges already facing, Māori society. Although it is well known that Māori are experienced in dealing with climate

[4] Sea-level rise projections for New Zealand are currently based on global model output. There remains considerable uncertainty over how much sea-level rise will occur globally and therefore little guidance about a possible upper limit for New Zealand (MfE, 2008b).

variability, new and untried strategies may be needed to ensure the long-term sustainability of climate sensitive communities and activities in the context of a changing climate (King *et al*., 2010). However, it is also important to recognise, that for some Māori communities, businesses and group, climate change will create opportunities via an untold number of interacting drivers of change including new technologies, advanced business networks, diversification of industrial practices, settled Treaty of Waitangi[5] claims, cultural capital and creativity.

Making decisions about what to do about climate change is complicated due to the existence of uncertainty about the magnitude and distribution of possible impacts, and the risks attached to making poor decisions or no decisions at all. Important questions are therefore being asked about whether all groups are likely to face the same challenges and/or a combination of pressures that put some groups more at risk than others. In particular, Māori coastal communities and associated infrastructure have been identified as being highly vulnerable to sea-level rise and extreme events such as storms and high waves (Hennessy *et al*., 2007). Currently many of these coastal areas and values are being compromised by environmental changes (including coastal erosion, floods and catchment runoff, among others), increased pressure on resources and widespread coastal development – in both urban and rural areas (Penny *et al*. 2007a, 2007b).

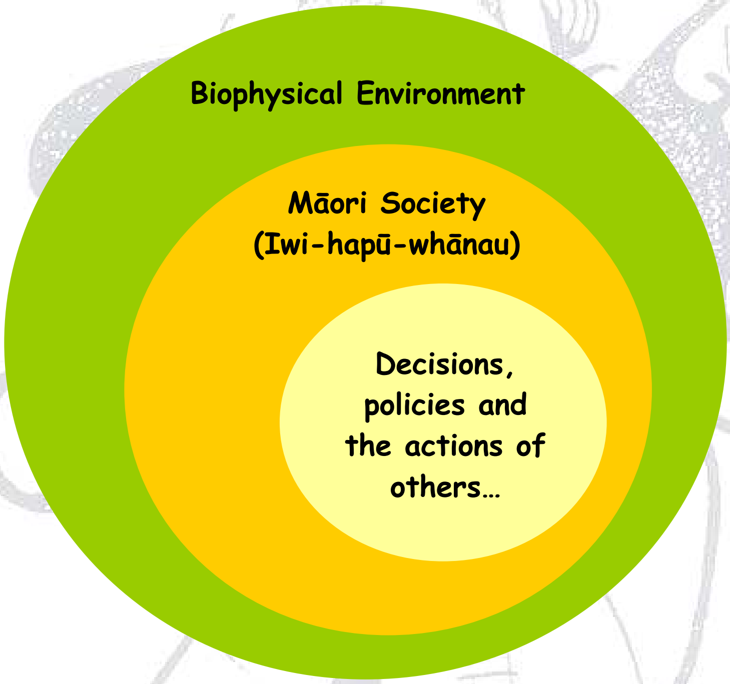

Figure 2: The key spheres of influence that complicate the climate change issue for Māori society (Source: King *et al*., 2010).

A further challenge in understanding the dynamics of these drivers across Māori communities relates to the diversity of community types themselves and the various realities that underlie all social-cultural groups. From a planning perspective, one of the tasks policy-makers face in responding to the vulnerability of different groups in society is designing

[5] The Treaty of Waitangi is an agreement drawn up between representatives of the British Crown and representatives of Māori *iwi* and *hapū*. It was first signed on 6 February 1840 at Waitangi, Northland – New Zealand. See: Orange (1989); Durie (1998); Walker (2004).

policies that target the causal factors responsible for vulnerability. Given the complexity of factors involved, and because policy initiatives to address the issue are likely to be incremental and constrained by resources and budgets, policy makers have the difficulty of deciding on where, and at what scale(s), to direct their efforts. Reliable and evidence-based information is therefore required to better understand the vulnerability and adaptive capacity of *whānau/hapū/iwi* and Māori businesses. This needs to include the inter-linkages and dependencies between people and the physical environment (across space and over time). Such information will help to understand what makes some stakeholders more resilient than others, while at the same time assist in to identifying vulnerable systems and groups where failure is likely to carry the most significant consequences.

1.3 Concepts of community, risk, vulnerability, adaptation and resilience

Due to the contestable (and sometimes confusing) use of key concepts and terminology in global environmental change studies, we provide below a brief overview of our assumptions and interpretations. It is hoped the following material will highlight some of the nuances of these terms including our own interpretations and applications. Note that opportunities to reflect on the role of these concepts in research, policy and practice will be offered during the forthcoming stages of this programme.

Community

The concept of 'community' is often central to any research which calls for an examination of social, political, economic, or environmental realities. While some researchers and research funding agencies recognise (and sometimes acknowledge) the reality and challenge of oversimplified conceptions of community, it is also apparent that how this influences and shapes research and policy is often overlooked – whether conveniently or simply unknowingly (Agrawal and Gibson, 1999). Added to this dilemma, research objectives and strategies surrounding 'communities' often demand results and/or outcomes that can be treated as universal and implemented locally, regionally and nationally (i.e. 'transferable' across different groups in society). In our case, the ability of the research team to consider and appreciate the "context-specific vulnerability and adaptation options facing rural and urban Māori communities" heavily relies on how the term 'community' is identified, explored and eventually defined.

Our consideration of social theory on this topic (Cohen, 1985; Walmsley and Lewis, 1993; Jewkes and Murcott, 1996; Agrawal and Gibson, 1999; Anderson *et al*., 1999; Jorgensen and Stedman, 2001; Panelli and Welch, 2005) confirms that 'communities' more than ever before involve complex social realities and diverse configurations – that evolve and transform through time. It is no longer viable or realistic therefore to assume that a social group or 'community' (including the people within it) will fit 'neatly' or exclusively into a single category. Subsequently we agree with arguments that advise against using universalist notions of community that ignore the complex internal and external realities (i.e. critical interests and processes within communities as well as between communities and other social actors) that underlie contemporary living arrangements – be it urban, rural or otherwise. Note this acknowledgement is crucial for not only avoiding the oversimplification of dynamic social and physical realities, landscapes and structures at the beginning of the twenty-first century for Māori, but also because oversimplified notions can contribute to misaligned social plans and policy that lead onto unsuccessful social and environmental outcomes (Agrawal and Gibson, 1999).

In the work ahead, we presuppose that Māori 'communities' are a social group defined first and foremost by *whakapapa* [ancestral and kinship linkages to people and place, genealogy, literally means 'to place in layers'] and thereafter characterised by complex internal and external relationships which are underpinned by a high degree of personal intimacy, emotional depth, moral commitment, social cohesion and continuity through time linked to place (Wellman and Leighton, 1979). And, although Māori society remains essentially a 'tribal' (putting debates about the historical basis and cultural specificity of the term aside) it is obviously not exclusively tribal. That is, in addition to the historical formations of *whānau*, *hapū* and *iwi*, Māori society also needs to be understood as consisting of individuals, groups, pan-Māori collectives, business enterprises and sectors – all of which include an assortment of perceptions, values, beliefs, professions and expectations that can result in equally diverse social, political and economic realities (Maaka, 2003). Furthermore, it is the inter-relationships between groups and individuals that make the varied dimensions of communities operate – to consider anything otherwise is a precariously narrow and limiting view of Māori social organisation today.

Risk

One of the problems with defining risk is that it has been developed and applied across a range of disciplines and activities leading to varied conceptual definitions and meanings. In spite of this, most definitions of risk involve probabilities, relating mostly to (i) the probability of occurrence of a hazard that acts to trigger a disaster or series of events with an undesirable outcome, or (ii) the probability of a disaster or outcome, combining the probability of the hazard event with a consideration of the likely consequences of the hazard (Brooks, 2003). In this report, 'risk' is understood to mean the probability of loss, injury or harm caused by a given hazard[6], and is influenced by the vulnerability of a specific sector, system or group (Crichton, 1999). Importantly, it is understood that risks can be avoided or mitigated by modifying any of the elements of vulnerability.

In the context of climate change, managing risk is about drawing upon the best available information to determine the likelihood of climate impacts, and the secondary or flow-on effects of their consequences. This information is then used to select and implement response options that will minimise risk and therein reduce potential harm or loss. In this way, climate adaptation is basically a risk-management strategy (NRC, 2010). However, given the dynamic nature of climate and our existing knowledge of projected impacts and possible response options which will inevitably change through time, the actual management of risk can also be significantly improved if it allows space for "adaptive management". That is, there are numerous complexities and uncertainties that affect the management of risk and therefore management practices must be based on iterative processes that recognise changing environmental conditions and the need to monitor progress in real time and to learn through such processes. In short, learning by experience and from mistakes can help to improve decisions about risk over time (Brooks, 2010).

There are many ways used to assess or to measure risk (Brooks, 2003). In the context of climate change, risk assessment typically involves the identification of specific climate

[6] Note that the term 'hazard' is commonly used to mean something that could cause harm.

hazards and appraisal of the adverse effects (in some cases these will be beneficial and/or create opportunities) in terms of magnitude, spatial scale, time-frame, duration and intensity for different systems, sectors or groups across society (NRC, 2010). Once these characteristics of the physical hazard have been identified, the potential severity of loss and the probability of occurrence are thereafter typically assessed. This can be relatively simple to establish, such as the likelihood of a flood event, or impossible to know in the case of the probability of an extreme or unlikely event occurring. This will sometimes require groups or individuals to make the best educated guesses possible in order to properly prioritize the implementation of risk management decisions. Importantly, when insufficient advice cannot assess the risks with sufficient confidence to inform decision-making but there nonetheless is good reason to believe that harmful effects may occur to human or bio-physical systems, regulatory bodies or other decision-making organisations may either ignore the unknown risk or invoke the 'precautionary principle' (Brooks, 2010).

Risk management is about making decisions that minimize, monitor, and/or control the risks of adverse events by considering different adaptation options against costs and benefits. These might involve any number of independent and/or inter-connected strategies such as policy regulation, economic incentives, and public education, among many others. Techniques to manage risk typically fall into four major categories: avoid the risk, reduce the negative effect of the risk, transfer the risk to another party, and/or accept some or all of the consequences of a particular risk (Dorfman, 2007). One of the central components of risk management lies in allocating resources. In an ideal world, risk management minimizes spending while simultaneously minimizing the negative effects of risks. Importantly however, all risks can never be fully avoided or mitigated simply because of financial and practical limitations. Therefore all organizations or groups have to accept some level of residual (remaining) risks (Brooks, 2010).

Vulnerability

Definitions of vulnerability to environmental stress and susceptibility vary widely across the different domains of social research (e.g. natural hazards, engineering, development, food security, climate and global change sciences, among others). And subsequently, numerous frameworks, conceptual models, and vulnerability assessment techniques have been developed to advance the theoretical underpinnings and practical applications of vulnerability (Kelly and Adger, 2000; Adger, 2006; Smit and Wandell, 2006). Notwithstanding this scholarship, there are two dominant ways used to explore or 'frame' climate change vulnerability (Kelly and Adger, 2000; O'Brien *et al*., 2007). The first is the 'end-point' approach (also referred to as 'outcome vulnerability'), which considers the projected impacts of climate change on a particular exposure unit (can be either biophysical or social) and the modifying role of adaptation measures to determine the vulnerability. The second is the 'starting-point' approach (sometimes referred to as 'contextual vulnerability') whereby a multidimensional view of climate–society interactions is taken. Typically, attention is given in starting-point studies to the socio-economic and political context within which climate impacts and linked processes take place; and therein a broader scope of possible policy interventions is identified. Noteworthy, O'Brien *et al*., (2007) argue that because each 'framing' or 'discourse' prioritises the production of different types of knowledge, as well as emphasises different types of policy responses to climate change, it is crucial that vulnerability studies be explicit about the kind of vulnerability actually being explored. In recognition of these differences, our research team combined these approaches to explore present and future community vulnerability at Arowhenua.

Overall, the analysis of vulnerability to climate variability and change helps provide a place to begin to inform decision-making about actions that will limit and/or avoid impacts by supporting coping and adaptive strategies (Kelly and Adger, 2000; Smit and Wandell, 2006). Importantly, this also involves identifying the constraints and barriers that stand in the way of developing and implementing practical and achievable coping and adaptive strategies. In the research documented here, we adopt a definition of vulnerability that is closely aligned with the work of the IPCC, which defines vulnerability as "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. It is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2007: 883)". A key premise for this work is that ***vulnerability*** in the context of climate change is a function of the ***exposure*** and ***sensitivity*** of a system to climatic risks and the ***adaptive capacity*** of the system to deal with those risks (Figure 3). Furthermore, these "determinants are dynamic (they vary over time), they vary by type, they vary from stimulus to stimulus, and they are place- and system-specific" (Smit and Wandell, 2006: 286).

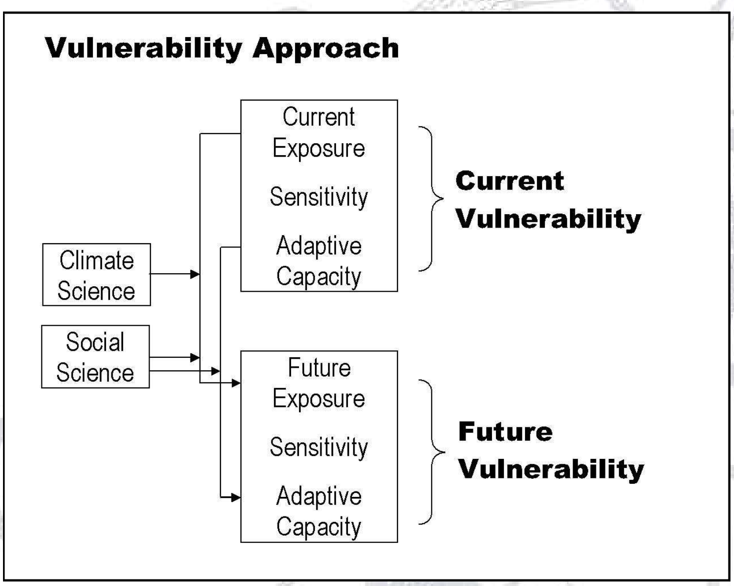

Figure 3: Analytical framework for vulnerability. (Source: Adapted from Smit, 2003).

Exposure generally refers to the state and change in external stresses that a system is exposed to. In the context of climate change, these are normally specific climate and other biophysical variables (including their variability and frequency of extremes) (IPCC, 2007). The main characteristics of these stresses include their magnitude, frequency, duration and areal extent of the hazard (Burton *et al.*, 1993). For the purposes of this study, we classify physical determinants as exposure.

Sensitivity refers to the factors that contribute or influence the degree to which people (or a system) are directly and/or indirectly affected, either adversely or beneficially, by climate variability or climate change (IPCC, 2007). Typically, sensitivity (as well as adaptive capacity) in community-based vulnerability studies emphasizes the importance of non-climatic factors such as age, income levels, economic resources, housing type and construction, living arrangements, infrastructure, technology, information and skills, institutions, and equity in amplifying or attenuating vulnerability alongside the nature of the climatic stress (i.e. exposure) (Kelly and Adger, 2000; Smit and Wandell, 2006; Ford *et al*., 2010). In line with these previous studies, this work also interprets sensitivity within the socio-political and economic context that particular climate stresses and/or impacts take place. Acknowledgement of antecedent conditions is also crucial which highlights place-specific and multi-scale processes that occur within and between social-ecological systems (Cutter *et al*., 2008). As Kelly and Adger (2000: 329) point out, this "…may well determine vulnerability not only to climate stress but also to other forms of environmental and societal pressures".

Adaptive capacity describes the ability of a system to adapt to climate change to moderate potential damages, make use of opportunities, or cope with adverse impacts (IPCC, 2007). This definition covers two distinct aspects: one is coping or tactical capacity (i.e. the actions performed in response to immediate climate stresses), and the other may be regarded as the capacity to strategically adapt (i.e. to plan and change system exposure or sensitivity to reduce future impacts) (Eriksen and Kelly, 2007). Some communities may have high coping capacity but possess low adaptive capacity due to resourcing. Both coping capacity and the ability to adapt can change over time because of social and economic changes. However, coping capacity usually implies a return to a previous state, while the ability to adapt does not assume that an original state should or can be maintained, but rather it is a more future oriented and long-term process. Determinants of adaptive capacity typically include financial, human and technological resources, knowledge, education and health status, social networks, governance structures, and existence of natural and man-made assets (Adger *et al*., 2007). Importantly, high adaptive capacity does not guarantee that adaptation will in fact occur because numerous barriers can limit its practical implementation, and further there are some fundamental questions about absolute limits to adaptation (depending on the magnitude and rate of change) (Adger *et al*., 2006). Hurricane Katrina and its impacts on New Orleans in the USA are a well-known example of a region with high adaptive capacity (as measured by most criteria) but failure to implement effective and long term adaptation measures (Bell and Morse, 1999).

Resilience

The emergence of the concept of resilience has its roots in interpreting ecosystems. Holling (1973: 14) first used the term resilience to describe a ‘‘measure of the persistence of ecosystems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables". However, more recently the global environmental change community has been active in conceptualising resilience in terms of socio-ecological systems (or human-environment interactions) (Janssen *et al*., 2006). And consequently, resilience has now come to be most frequently defined as "the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change" (IPCC, 2007: 880). Note this definition includes not only a system's capacity to return to the state (or multiple states) that existed before the disturbance, but also to advance the state through learning and adaptation (Adger *et al*., 2004; Klein *et al*., 2003; Folke, 2006). In other words, one might say that a socially resilient system is a system that has minimised its vulnerability through successful application of adaptive capacity. Note that a major criticism of resilience as a concept to explore indigenous well-being is that it tends to downplay or ignore higher-level systemic and structural issues that may be the root causes of vulnerability and hold potential for more effective interventions (Kirmayer *et al*., 2009: 70). More recent approaches therefore emphasise the global, cultural and other contextual factors that impact on resilience (Ungar, 2008), and the importance of multiple elements, ranging from governance to risk prevention and access to resources (Te Puni Kōkiri, 2009). However, class, power, gender and ethnicity are often ignored in resilience framings that assume people are able to be reflexive and make rational choices around risk (Lupton, 1999). In spite of these arguments, given that we are concerned with matters such as the ability of communities and associated institutions to go on flexibly adapting behaviours and rules over time, then the concept of resilience nested within an overall vulnerability systems structure still seems potentially valuable[7].

Adaptation

In the research here, we again adopt a definition of adaptation that is closely aligned with the work of the IPCC (2007: 881): that is, adaptation to climate change is defined as "an adjustment in ecological, social or economic systems in response to observed or expected changes in climatic stimuli and their effects and impacts in order to alleviate adverse impacts of change or take advantage of new opportunities". This definition includes the notion that adaptation can be indirect and not necessarily a conscious response to observed climate changes and/or their effects, as well as anticipatory, planned or proactive (i.e. as a result of deliberate policy decisions in anticipation of future changes and effects). A common analytical approach towards facilitating climate change adaptation typically focusses on: (i) reducing the sensitivity of the system, (ii) altering the exposure of the system, and (iii) increasing the resilience of the system (social and ecological) to cope with changes (Adger *et al*., 2004).

Importantly, adaptation varies "not only with respect to climatic stimuli but also with respect to other, non-climatic conditions, sometimes called intervening conditions which serve to influence the sensitivity of systems and the nature of their adjustments" (Smit *et al*., 2000: 235). Smit *et al*., (2000) provide a useful example of a drought that produced similar crop yields in two different regions, but quite distinct impacts on people within these two areas because of differing economic and institutional arrangements as well as different adaptive responses over different time frames. Adger *et al*., (2004: 78) similarly argue that "adaptations are not isolated from other decisions, but occur in the context of demographic, cultural and economic change as well as transformations in information technologies, global governance, social conventions and the globalising flows of capital and labour - it can therefore be difficult to separate climate change adaptation decisions or actions from actions triggered by other social or economic events". In short, it is unlikely that adaptation decisions and actions by communities will be taken in light of climate change alone. Rather, there is mounting evidence that climate change adaptation initiatives and opportunities will be integrated with other programs and strategies (e.g. natural hazards management, land-use planning and infrastructure replacement, among many others) (Smit and Wandel, 2006; Moser and Ekstrom, 2010).

[7] Note the concept of sustainability is also central to studies of resilience because the resilience of communities is inextricably linked to the condition of the environment and the treatment of its resources.

1.4 Previous climate adaptation research with Indigenous peoples

A sweep of published studies on indigenous adaptation to climate change reveals that the experience of the Inuit in northern Canada has attracted more climate change related research than any other indigenous group (possibly even more than for all other indigenous groups put together). Some of the earliest research to focus on indigenous communities and climate in the Canadian Arctic recognised from the start that indigenous groups have throughout time demonstrated adaptability and resilience in the face of changing conditions (Sabo, 1991; Cruikshank, 2001; Berkes and Jolly, 2001), as well as faced limits to coping and adapting to climate changes, variations and extremes (Brody, 1987; Krupnik, 2000; Berkes and Jolly, 2001). These research contributions have more recently been added to by a rapidly expanding library of local studies on climate change vulnerability, adaptation, and resilience with 'northern' indigenous peoples. A few place-based studies relevant to this project include the work of Ford *et al*., (2006a), Wenzel (2009), Pearce *et al*., (2010), and Ford *et al*., (2010).

Ford *et al*., (2006a) developed a vulnerability-based approach to characterize the human implications of climate change in Arctic Bay, Canada. These authors concluded that Inuit in Arctic Bay possess significant adaptability in the face of changing climate-related exposures. This adaptability includes mechanisms such as traditional Inuit knowledge, strong social networks, flexibility in seasonal hunting cycles, some modern technologies, and economic support. However, changing Inuit livelihoods have also undermined certain aspects of adaptive capacity, and have resulted in emerging vulnerabilities in certain sections of the community. Meanwhile, in the paper: "If the climate changes, must the Inuit?" Wenzel (2009) attempted to get to the heart of the cultural question of climate change in the Arctic. While the author largely skirted around this core question, it nonetheless raised some valid issues – namely that biophysical change alone is not an insurmountable threat; rather the greatest threat comes from the politics of climate change. In particular, the paper argues that resource substitution and mobility, used by Inuit ancestors during periods of climate extremes in the past, are now severely constrained by outside actors and the move to permanent settlements. While the paper largely fails to answer the question it poses itself in its title, it does stress that in order for Inuit subsistence culture to survive it needs to be defended in light of outside environmental pressures that may seek to constrain its potential for adaptation.

More recently still, Pearce *et al*. (2010) presented an easy to follow assessment of climate related vulnerability facing the community of Ulukhaktok in the Northwest Territories of Canada. This study was predicated upon the rationale that limited work had been undertaken regarding the implications of climate change for indigenous people and their livelihoods, and their capacity to deal with and adapt to changing conditions. These authors concluded that "Inuit in Ulukhaktok are coping with climate change related changes by taking extra precautions when travelling, shifting modes of transportation, travel routes and hunting areas to deal with changing trail conditions, switching species harvested, and supplementing their diet with store-bought foods" (Pearce *et al*., 2010: 157). However, limited access to capital resources, changing levels of traditional knowledge and land skills, and substance abuse were identified as key constraints to adaptation. And further, Ford *et al*. (2010) examined how policy intervention can assist Inuit communities to adapt to climate change. The authors make clear that opportunities for adaptation are available through the considerable adaptive capacity that Inuit possess on the one hand and via policy interventions on the other, including (i) the support of teaching and transmission of environmental knowledge and land skills, (ii) enhance and review emergency management capability, (iii) ensure/support flexible resource management regimes, (iv) provide economic support to assist adaptation among households with limited income, (v) increase research efforts to help improve understanding of short-term and long-term risk factors and the diverse options for different places, (vi) protection of key infrastructure, and (vii) promotion of awareness about climate change impacts and adaption among policy makers.

A selection of other notable publications related to indigenous vulnerability and adaptation to climate change from the Canadian Arctic include: Berkes *et al*., (2003); Ford and Smit (2004); Smit and Wandel (2006); Furgal and Seguin (2006); Ford *et al*., (2006b), Ford *et al*., (2007); Ford *et al*., (2008); Ford (2009); Ford and Furgal (2009); Laidler *et al*., (2009). Further, in spite of an increasing indigenous voice concerned about climate change impacts in the neighbouring U.S.A., there has been very limited climate change adaptation research produced for, or by, Native American peoples to date[8]. Some of the exceptions include the work of Houser *et al*., (2001), which is part of the foundation report completed by the National Assessment Synthesis Team (NAST) for the U.S Global Change Research Program. These authors provide a broad overview of the potential environmental, social and ecological impacts of climate change on Native American peoples and their homelands throughout the U.S.A. In turn, they discuss impediments to climate resilience, many of which exist for reasons other than climate exposure. For example, some native communities are restricted by reservation boundaries, and thus, have limited relocation options available to them if their homeland is compromised by climate related impacts. Subsequently, the authors identify three principal strategies for coping and adapting to future climate change impacts, including; (i) enhance education and access to information and technology, (ii) promote local land-use and natural resource planning, and (iii) participate in regional and national discussions and decision-making. In a follow-up report, the NAST (2009) produced an updated account of climate related vulnerabilities facing the U.S.A., including some reference to the unique vulnerabilities which affect Native American communities. The U.S. Army Corps of Engineers most recently directed vulnerability assessments for coastal flooding and erosion for six native Alaskan communities – leading to a proposal to relocate these communities inland at an estimated cost $30-50 million per community (NRC, 2010). Note the reasons for the limited research conducted to date in this space have been attributed to other priorities dominating the focus of both governmental agencies and local peoples themselves – most importantly poverty, unemployment and dislocation, among other ‘everyday’ social-ecological challenges (Finan *et al*., 2002).

With respect to Scandinavia, investigations into the impacts of climate change on the indigenous Saami people, and their adaptive capacity, are negligible (at least those in published in English), and appear to be largely through the lens of its affects on reindeer husbandry (Weladji and Holand 2003; Weladji and Holand 2006; Tyler *et al*., 2007; Rees *et al*., 2008). More recently, Keskitalo and Kulyasova (2009a) investigated the adaptive capacity of two small-scale coastal fishing communities in Finnmark, northern Norway. Saami peoples of the area were identified as “Sea Saami”. The study found that adaptation for indigenous and non-indigenous coastal fishing groups is highly dependent on regulation, legislation and market mechanisms including; increased competition, changes in the

[8] Considerable grey literature exists on this rapidly emerging topic; however, the boundaries of this review prevent this material being included.

economic and employment structure of the region, and access to quota - circumstances which sit beyond the control of the local community. Keskitalo (2009) also examined the complexity of climate change vulnerability for renewable-resource sectors such as forestry, fishing and (mainly indigenous) reindeer herding in northern Norway, Sweden and Finland. These authors concluded that there are a number of international and regional levels of influence which shape the adaptive capacity of communities as they struggle to comprehend (and respond to) globalising factors, such as internationalisation of economies and the changing role of the state. In addition, this study found that stakeholders with limited economies and political capabilities were most vulnerable to climate change, as successful adaptation, even at the local level, often required access to considerable resources and ability to influence international decision-making processes and complex governance networks.

What little published research on Pacific Island communities exists tends to either view their experience as a microcosm of the wider changes and adaptive responses required for all people to cope with the predicted impacts of climate change (Mimura *et al*., 2007) or enter into discussions and debates about migration as a coping and adaptation strategy (Barnett and Adger, 2003; Barnett, 2005; Mortreux and Barnett, 2009; Boncour and Burson, 2009). Barnett and Adger (2003) contend that overstating the dangers of climate change may lead investors and aid donors to reconsider the worth of financial support. And, if internalised by local people, may even lead to practices of unsustainable development, such that the impacts of climate change materialise more through the idea of climate change rather than through actual changes driven by climatic processes. Similarly, Barnett (2005: 328) suggests that encouraging migration as a solution to climate change detracts from the need for adaptation policies to allow people to ‘‘lead the kind of lives they value in the places where they belong’’. Further still, Mortreux and Barnett (2009) presented evidence collected from Funafuti – the main island of Tuvalu – to challenge the widely held assumption that climate change will, or should result in large-scale migration from Tuvalu. Their work shows that for most people climate change is not a reason for concern, let alone a reason to migrate, and that would-be migrants do not cite climate change as a reason to leave. People in Funafuti wish to remain living in Funafuti for reasons of lifestyle, culture and identity. Somewhat differently, Boncour and Burson (2009) examined (from a distance) climate change and migration in the Pacific, and pointed out that while migration may be a climate change adaptation strategy, it could well run into conflict with border security. A lack of data and understanding on how people will respond to the impacts of climate change, however, makes any predictions about migratory behaviour difficult to assess. The paper nonetheless stresses that migration should be given weight as a useful adaptive response.

In spite of these analyses there remains a dearth of studies that have considered the capacity of social (and ecological) systems to adapt, and the constraints and limits to adaptation for Pacific Island peoples (Barnett and Adger, 2003). Some exceptions include Barnett (2001); Sutherland *et al*., (2005); Hay and Mimura (2006); Bridges and McClatchey (2009); and Rasmussen et al., (2009), among others. Although theoretical, Barnett (2001) investigated the problem of scientific uncertainty and the way it impedes planning for climate change and accelerated sea-level rise in Pacific Island Countries. Shortly thereafter, Sutherland *et al*. (2005) reviewed a community based vulnerability assessment to climate change in Samoa. This involved exploring future changes in climate-related community exposure and associated challenges in terms of future adaptive capacity. These authors concluded that enhancing adaptive capacity will only be successful when it is integrated with other policies such as disaster preparedness, land-use planning, environmental conservation, coastal planning, and national plans for sustainable development. Meanwhile, Hay and Mimura (2006) examined the linkages between climate and sustainability in the context of local level climate risks and adaptation responses for the wider Asia-Pacific region. In their analysis of a series of regional and local case studies, climate change is viewed as both an impediment to increasing sustainability and as an opportunity, though in most cases the former far outweighs the latter. Assessments of climate change vulnerability and risk are shown to be of critical importance because they inform decisions as to where resources for adaptation are best invested. Thereafter, Bridges and McClatchey (2009) attempted to understand general resilience and vulnerability to climate change through the experience of villagers living on low-lying atolls in the Marshall Islands. These authors concluded that atoll life forces recognition of the 'boundedness' of small ecosystems, and as such has resulted in social systems that utilize a parallel sort of logic in order to further support continued existence in marginal environments. However, successful adaptation by island dwellers in the past is no guarantee of success in the future. Rather, greater flexibility in resource management may be required to cope with predicted changes resulting from climate change. Further still, Rasmussen *et al*., (2009) examined, among other questions, to what extent the traditional Polynesian social structure reduces vulnerability and enhances adaptive capacity. These authors concluded that the Polynesian value system helps to reduce vulnerability because people feel a responsibility to look after their wider family, clan members and neighbours. Similarly the traditional system of redistributing food resources is also considered critical tool for increasing resilience.

Finally, there is a growing, yet comparatively smaller quantity of research available on indigenous adaptation to climate change in Australia (Hennessey *et al*., 2007). Initial research contributions were largely concerned with the potential impacts of climate change on the health and culture of Indigenous Australians (Braaf, 1998; Green, 2006; Altman and Jordan, 2008; Green, 2009; Green *et al*., 2009). For example, Green *et al*. (2009) examined the potential impacts of climate change on indigenous people across tropical Northern Australia. Focussing on biodiversity, health, infrastructure, education and livelihood opportunities the scoping study concluded that there can be no one-size-fits-all approach to producing adaptation strategies, and that collaboration and partnerships will be key to the development of future adaptation strategies. Most recently these efforts have been added to by the place-based adaptation-focussed research of Petheram *et al*. (2010) and Green *et al.* (2010). Interestingly, Petheram *et al*. (2010) conducted workshops and in-depth interviews in two 'communities' to develop insight into Yolngu peoples' observations and perspectives on climate change in North East Arnhem Land (Australia), and their ideas and preferences for adaptation. Among other valuable insights, the participants concluding strongly that climate change adaptation policies would need to address current non-climate issues too – because they were so interconnected and overwhelming in comparison to climate change. Participants' preferences included greater self-sufficiency, independence, empowerment, resilience and close contact with the natural environment. The results suggest that strategies and policies are needed to strengthen adaptive capacity of communities to mitigate existing poverty and well-being issues, which will in turn assist with responding to changes in climate.

1.5 Research objectives

This project seeks to better understand the conditions or drivers of vulnerability (as well as the actual processes that lead to adaptation) of different Māori communities to the various aspects of climate change and its impacts. A step guide to conduct such work involves assessing the present exposure, sensitivity and adaptive capacity of a given community to help understand the contemporary risks, and the factors and processes that constrain community choices and actions. Importantly, we do not seek to presume any of these community variables, but rather to identify these empirically through conversations with Ngāti Huirapa people from around the area. Our focus was directed by the experience, knowledge, values and priorities that are important to the well-being and identity of the community at Arowhenua Pā. The resulting information is then considered alongside the latest information about likely future climate conditions – the scenario settings of which were importantly directed based on community knowledge of local environmental risks. Determining some of the future risks and vulnerabilities of the community to the impacts of climate change will therein contribute to the identification of targeted response strategies for adaptation action and planning. It is also expected that this work will contribute information and tools to assist adaptation planning by central and local governments as well as other communities to the direct and indirect impacts of climate change.

Specifically the objectives of this project are:

- To examine the processes that contribute to vulnerability (includes adaptive capacity) as well as those processes that lead to adaptation – paying close attention to the impediments and strengths that facilitate or constrain adaptations.
- To explore selected future climate change scenarios and consider how the risks and vulnerabilities of the 'community' at Arowhenua Pā might change under altered environmental conditions.
- To identify coping and adaptation measures/practices/strategies/policies that assist in reducing vulnerability (includes enhancing adaptive capacity) appropriate to the Arowhenua Pā community.

In order to realise these objectives the project comprises five key phases:

Phase I. Project design - Planning and relationship-building
Phase II. Fieldwork - Examining present vulnerability and resilience
Phase III. Fieldwork - Examining future vulnerability and resilience
Phase IV. Synthesis - Analysis of risk, vulnerability and adaptation options
Phase V. Project finalisation - Community review and dissemination of results

Note that although the lessons from this project will ultimately reflect the issues being faced at the local level – and hence lead to the identification of specific challenges and adaptive measures or practises, there are also likely to be some common-ground issues and opportunities that will help to provide broad lessons on the vulnerability and adaptation options facing Māori individuals, *whānau*, *hapū* and *iwi* at other locations.

2 Ngāti Huirapa – Arowhenua / Te-Umu-Kaha

This section provides background information on the people and physical landscapes that comprise the Arowhenua / Te-Umu-Kaha (Temuka) area. It also provides a brief overview of previous studies of flood process and risk conducted in and around the area.

2.1 Ngāti Huirapa

Arowhenua Pā is a settlement of approximately 120 full-time residents (90% Māori) situated between Te-umu-kaha-awa (Temuka River) and the Opihi River on the coastal plains of southern Canterbury (Figure 4). This settlement is one of a number of traditional *kāinga* [home, village, settlement, habitation] and has been occupied by generations of *whānau* who link to Ngāti Huirapa (Anderson, 1998). The *hapū* of Ngāti Huirapa traces its descent through the five main *iwi* of Te Waipounamu (South Island of Aotearoa/New Zealand): Hawea, Rapuwai, Waitaha, Ngāti Mamoe and Ngāi Tahu; and is closely connected with the *hapū* of Taoka and Te Rakai. Ngāti Huirapa is one of eighteen *Papa-tipu rūnanga* that make-up the *iwi* confederation of Ngāi Tahu, and it is through the legal identity of Te Rūnanga o Ngāi Tahu that the people of Arowhenua[9] hold *mana-whenua* [territorial rights, power and authority associated with possession and occupation of the tribal land] over specific lands and waters within the *rohe* [area, boundary, region, district] of Ngāi Tahu (Tipa *et al*., 2010). Specifically the *mana-whenua* of the *hapū* extends from the Rakaia River to the Waitaki River, and thence inland to Aoraki and the main divide to the sea. Note it is important to acknowledge that Ngāti Huirapa refers to a wider community than simply those living at the Pā. That is, the *hapū* includes all those living in, having a cultural relationship with, or significant interest in, the Arowhenua Pā and surrounding land and water-scapes.

At the time of the earliest colonial contact in the late 1700's, Arowhenua is understood to have been a *māra* [garden, cultivation] supporting the main Pā at Waia-te-ruaiti - sited on an elevated hill beside the Orakipaoa[10] Stream not far from the mouth of the Opihi River (Anderson, 1998). Waia-te-ruaiti was surrounded by an extensive wetland, and with many access waterways this locality was a major *mahinga-kai* area where *tuna* [eel], *kōura* [freshwater crayfish], *īnanga* [whitebait], *kōkopu* [galaxiids (fish)], *kanakana* [lamprey], water fowl and bush birds were hunted and collected. Waia-te-ruaiti was also famed for the *kāuru* or baked root of the Ti Tree (Shortland, 1851)[11]. Numerous other *kāinga* were also sited around the Opihi and Temuka rivers. The settlements of Hawea and Tahiku were on the south side of the Opihi mouth while other settlements included Ūpokopipi, Ohou and Wai-te-mati within the Waipopo area. There were also significant Pā sites in and around what is now called Caroline Bay and Māori Park Pool, Waimātaitai Park, Dashing Rocks as well as Waitarakao (Washdyke Lagoon). It is estimated that before 1840 there were more than 1000 inhabitants living across the aforementioned settlements (Shortland, 1851). Most of these

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[9] There is no direct translation for Arowhenua with the name understood to have been brought from Hawaiki. However, the ancestor Te Rakitauneke is known to have taken the name down to Murihiku (Stewart Island) and named a large track of land Arowhenua. There is also a Titi Island down in Murihiku called Huirapa (Anderson, 1998).

[10] Also spelt as Orakipawa (Personal communication: Carlysle Walker).

[11] The root is shaped like a carrot (some two to three feet long) and contains high quantities of saccharine before the tree flowers. This was typically cooked in large *umu* [earth oven], processed and stored. Huge lone *umu* were made to cook the Ti, and when cooled, the sugar was partially crystallized and easily separated by tearing the fibre apart and stored for later use, by dipping in water and chewing. January was the time for digging the root of the Ti or Whanake. The *aruhe* [fern-root] was processed the same way and traded up and down the coast with other *hapū/iwi* (Shortland, 1851).

sites are now gone however having been altered by land-use change and water-way conversions.

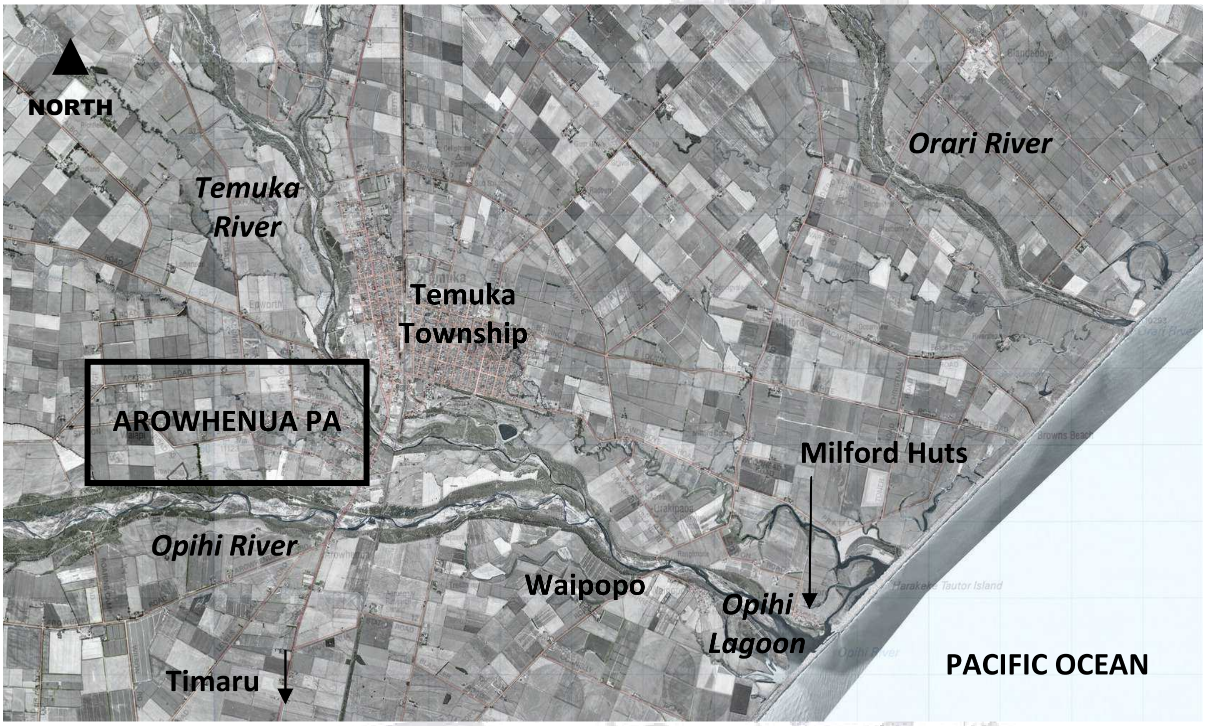

Figure 4: Key locations referred to across the Arowhenua Pā and Te-umu-kaha (Temuka) areas.

In the early years of twentieth century, small cattle blocks and family gardens were common-place in around Arowhenua, however, like other rural Māori communities during the 1940s, 50s and 60s, many of the *whānau* moved into towns and cities such as Timaru, Temuka and Christchurch (Evison, 1993). This migration increased further in the 1970s as the scale of farming in the area reduced – negatively impacting seasonal work opportunities such as shearing and the freezing works. Today, Ngāti Huirapa still have small holdings of collectively owned Māori reserve land on the coast but the historical legacy of loss of land and resources coupled with contentious land-use plans and the adverse effects from local floods and coastal erosion have severely checked economic opportunities[12]. Employment in the area consists mainly of seasonal work for a resurgent dairy industry and service-based businesses in and around Temuka and Timaru[13]. Many household food supplies are equally supported by hunting, fishing and gathering of traditional *kai* [food, to eat] species on public and private lands and waterways. However poor health (and depletion) of natural resources across the greater Arowhenua area is of deep concern (Tipa *et al*., 2010).

The present settlement of Arowhenua is supported by the *marae* [meeting house and surrounding area], a school, a health-clinic, and the Anglican and Ratana churches. Arowhenua Pā is the focal point of the community – where *whānau* attend *tangi* [funerals], *wānanga* [seminars, fora], *hura kōhatu* [unveiling of graveyard headstones], birthdays and weddings (Figure 5). Further the affairs of Ngāti Huirapa are managed from the *marae*

[12] The role of land-use planning in exacerbating loss and erosion of Māori owned land is a contentious issue for many *whānau* – particularly the construction of irregular stop-banks and selective river channel modification.
[13] In recent decades the high prices achieved for milk solids have resulted in large-scale conversions of many farms to dairying. These require water for pasture irrigation throughout the summer. The limited available water resources led to the construction of the Opuha Dam on a tributary of the Opihi River in 1995-1996.

through Te Rūnanga o Arowhenua Incorporated Society. Tarahaoa School (Bi-lingual) caters for students from ages 5 to 12 and reflects the Māori cultural values of the school and the nature of the community. Arowhenua *whānau* health services are also located on the Pā, which provides general health care as well as plunket and mental health support. The Anglican Church was established in the 1890's, and followed by the Ratana Church in the 1940's (Evison, 1993). Numbers at both churches have dropped considerably in the last few decades with plans ahead to bring the churches together under a non-denominational title. Finally, in spite of diverse living arrangements and clear socio-economic disparities across different whānau in the *hapū*, the people of Ngāti Huirapa remain independent in many respects and take strength through strong internal relationships.

Figure 5: Te Hapa o Niu Tireni Marae – Arowhenua Pā. Te-umu-kaha (Temuka).
Photo credit: Davina Ashford-Hosking

2.2 Environmental setting

The settlement of Arowhenua area lies adjacent to State Highway 1 (SH1), 2-3 km south of Temuka and some 6 km inland from the coast (Figure 4). The lower Opihi River runs through the area, and the Temuka River which joins the Opihi a short distance downstream from SH1, separates Arowhenua from the Temuka Township. Both these rivers originate in the South Canterbury foothills. The catchments are bounded in the west by the Hunters Hills, the Rollesby and Two Thumb ranges. The rivers emerge from the foothills and in the lower reaches flow across outwash gravels from the alpine regions. The Waihī, Haehae-te-Moana and the Kakahu rivers are the three main tributaries of the Temuka River. The Kakahu joins the Haehae-te-Moana which in turn meets the Waihī to form the Temuka River at the northern end of the Temuka Township. The Temuka catchment consists primarily of interbedded greywacke and argillite, though the Kakahu catchment has areas of limestone, siltstone and mudstone. The lower catchment area consists of outwash gravels and fluvial deposits (Lynne *et al*., 1997). The northern catchment boundary of the area is marked by the Orari catchment. However this boundary in the lower reaches is somewhat ill-defined.

Groundwater sourced from the Orari discharges into the Waihī tributary of the Temuka and before 1855 the Orari River itself joined the Waihī River at Winchester (Lynne *et al*., 1997).

The rainfall record for Timaru Airport, some 4 km south of Arowhenua, is broadly representative of the rainfall for the area. The annual total averages 560 mm, and shows a slight seasonal pattern toward lesser monthly totals in August and September (Figure 6). However, in any month there is considerable variation and rainfall totals exceeding 100 mm have occurred in all months. Temperatures show strong seasonal patterns. For Timaru, the average daily maximum ranges from 21.4 ºC in January to 9.8 ºC in July. The averages for January and July are 16.2 ºC and 5.3 ºC respectively, and the average daily range is typically 10.0 ºC. Frosts are common in winter.

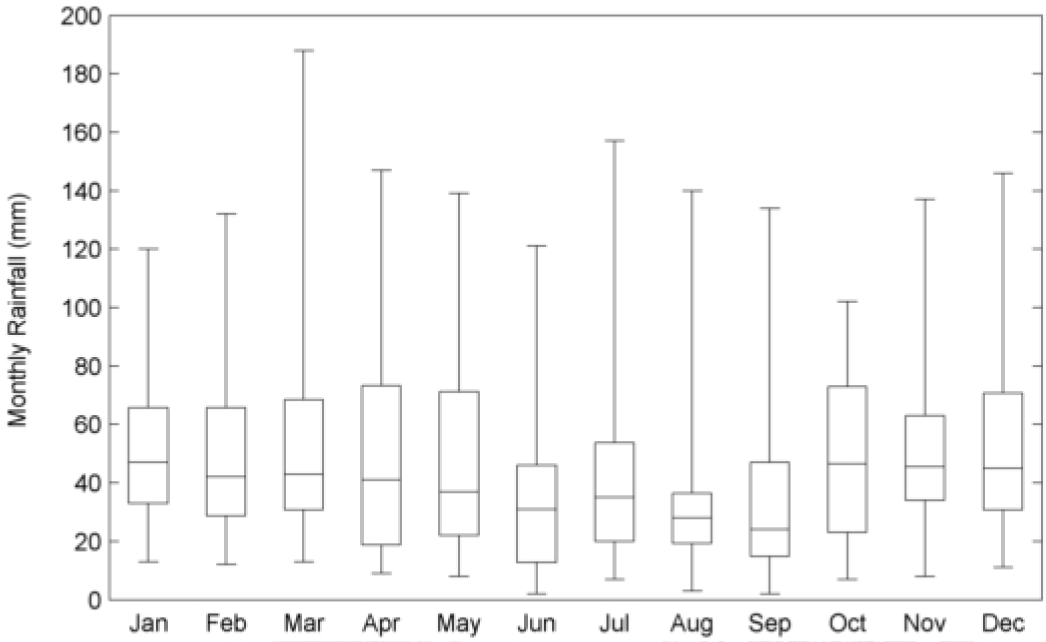

Figure 6: Monthly rainfall for Timaru Aero (1956-1989). The box-plots show the maximum and minimum for each month as well as the values exceeded in 75%, 50% and 25% of years.

As is typical for coastal Canterbury, the area is windy, albeit with notable seasonal and diurnal variations (Figure 7). Day and night wind statistics for summer and winter show that much more wind occurs during the day in summer than at other times. The summer wind typically is from the east or southeast whereas in winter the northwesterly wind is dominant. Annual potential evapotranspiration (not shown) reaches peak values in January and February and falls to low levels in midwinter. As a consequence, the area suffers a seasonal soil moisture deficit in summer and autumn which is usually replenished in winter.

Recording of river-flows for the Temuka River commenced in 1969, albeit with long periods of missing data. Inspection of these data shows that the flows are highly variable. They can drop to low values, typically in late summer and autumn, but in contrast to some other Canterbury foothills rivers, the Temuka is always flowing at the recorder. A summary of the monthly mean flow data is presented in Figure 8. Lower flows typically occur in late summer or autumn with higher flows in winter. However, in any month high flow flood events can occur. This is important for the survival of aquatic species such as tuna.

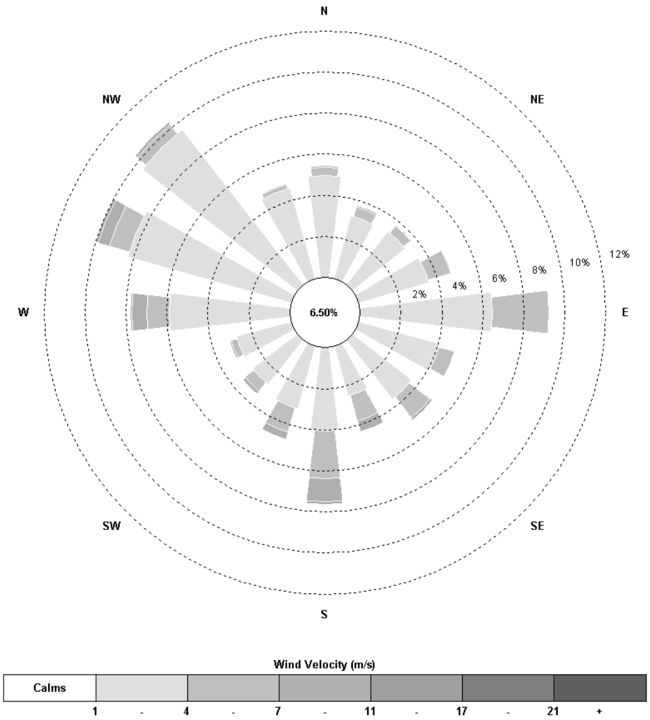

Figure 7: Summary of wind data for Timaru Aero AWS (2000 - 2010) – Station No. 413205.

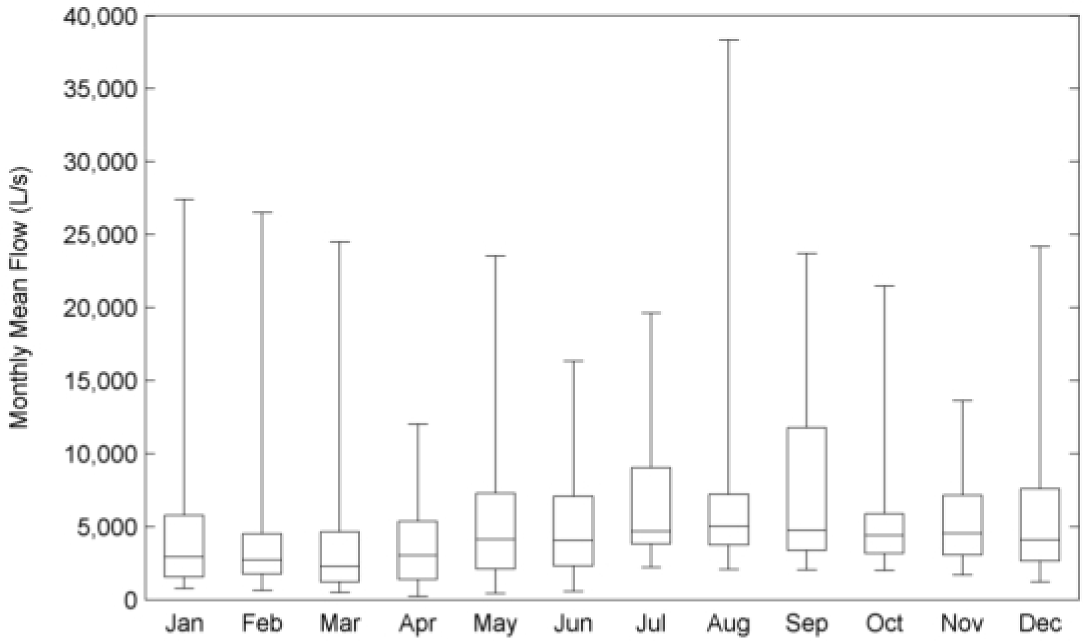

Figure 8: Monthly mean flows for the Temuka River for 1983-2010. The boxes enclose the central 50% of the values; the median of the monthly means is shown by the line dividing the rectangles; the whiskers show the full range of the values.

2.3 Previous studies of flood risk and environmental change

A number of river hydrology and flood inundation risk studies have been conducted across the Orari-Waihī-Temuka flood plains. As with other small and medium sized rivers across the Canterbury Plains, these river systems extend only a short distance into the Southern Alps[14]. During flood flows these shallow channels are more likely to breach river-banks and over-top (as well as out-flank) stop-banks causing flooding of adjacent flood plains (Connell, 1993; Hall, 1997; Lynne *et al*., 1997).

Several notable flood events have inundated the Orari-Waihī-Temuka flood plain, resulting in severe property and infrastructure damage. The earliest flood event available on record occurred on 4-5 February 1868[15] (SCRCC, 1957) when 8.08 inches (205 mm) of rainfall was recorded at Mt Peel over 24 hours. No quantitative data on flood flows are available for this event, but the depth of inundation has been inferred based on 'flood-lines' (Lynne *et al*., 1997). Another significant flood event in February 1945 washed away the main trunk railway track at the Temuka Bridge and flooded the town of Temuka. This event resulted in the implementation of the Orari-Waihī-Temuka Flood Control Scheme, to provide flood protection across this region (Connell, 1993). The largest flood to be recorded in South Canterbury occurred during the 13-14 March 1986 (Figure 9). Significant inundation of several settlements, flooding of farm lands and severe damages to several kilometres of roads and other infrastructure were reported following this event with financial losses in the order of $60 million estimated (not corrected for inflation) (Scarf *et al*., 1987).These authors estimated that this flood event had an average recurrence interval (ARI) of 100 years (i.e. it has a 1% chance of occurring in any one year).

In response to severe flood events the Canterbury Regional Council commissioned a review of the flood hazard across the Orari-Waihi-Temuka flood plain in 1993 (Connell, 1993). The core purpose of the review was to examine the possible alternatives for managing the natural flood hazard. This document covered a wide range of factors related to flooding in this region, such as land use, effective warning time, evacuation procedures, and potential flood damage and sediment movement during floods. Several possible alternatives were discussed with the wider community. These alternatives included (i) modifying the flooding through catchment treatment such as detention dams, stopbanks and channel improvement; (ii) modifying the susceptible areas through zoning and building permit restrictions; and (iii) modifying the flood loss burden through insurance promotion and disaster relief fund assistance (Connell, 1993).

Some limited hydrological and hydraulic field and modelling studies have been carried out on the rivers across the Orari-Waihī-Temuka flood plains. Based on measured and design flood hydrographs for the Temuka River, Connell (1993) and Oliver (2009) simulated the inundation of the lowland flood plains around the Temuka Township for a range of extreme events. This included recognition of the potential for the Arowhenua flood plain to inundate during large flood events[16]. More recently, Martin and Leftley (2011) developed and tested a

[14] The direct influence of late-Holocene glacial activity was largely minimal, preventing the evolution of well-incised river channels (Connell, 1989).
[15] For a complete listing of flood events that inundated this region, consult Connell (1993) and Lynne *et al*. (1997).
[16] Field measurement and modelling of floods across the lowland flood plains of the Orari, Waihī and Temuka rivers are also complicated by poorly defined topographical divides among the lowland catchments (Oliver, 2009). Consequently, during extremely large flood events (500-year return period or more), the Temuka River could receive a large influx of flows from the Orari river located to the north. Thus, for such extreme flood events, it is

flood forecasting hydrology model for the Temuka River to simulate the timing and magnitude of peak flows based on forecast rainfall data. However, it was concluded that the performance of the model was mixed, and additional testing recommended before its full deployment. Despite these modelling studies, none to date have combined the investigation of hydrological and hydraulic controls on flooding in this region. More recently, Griffiths *et al*. (2011) summarised the flood flow frequency for the Temuka River at Manse Bridge (See: Table 1). The table shows there is a 50% chance of a flood flow exceeding 140m^3/s in any one year, and a 10% chance of a flood flow exceeding 499m^3/s in any one year. The estimates of the larger flood flows of lower probabilities, while based on best available practice, nevertheless have significant errors of estimate. For example, for the 1% annual exceedance probability flood, a standard error of estimate is probably at least +/- 25%.

Figure 9: Aerial view of flooding looking north-east over Arowhenua Pā and the Temuka River at State Highway One - March 13th March 1986 (1430-1630 hours). Temuka Township is in the background. Source: RNZAF – K38 723 600.

The impact of flooding on Arowhenua flood plain and a summary on the state of flood plain structures and management within and around the Arowhenua flood plain region was conducted by Hall (1997). This indicated that the potential of Arowhenua Pā to be inundated by the Temuka River is far greater than the flood hazard risk associated with the Opihi River. Hall (1997) concluded that the stop-bank between the Opihi River and the Arowhenua flood plain offers protection against floods from that river, but the absence of such a structure on the southern side of the Temuka River, significantly increases the risk of flooding for the Arowhenua flood plain area. Interestingly, Hall (1997) noted also an absence of dialogue between the Arowhenua community and the regional authority responsible for funding and overseeing the flood control management practices in this region.

essential to include the hydrological and hydraulic responses of the neighbouring catchments to accurately assess the flood flows in the Temuka River.

Table 1: Estimates of flood peak frequency for the Temuka River at Manse Bridge (Source: Griffiths *et al*., 2011).

Average recurrence interval (years)	Annual exceedance probability (%)	Temuka at Manse Bridge flood flow (m^3/s)
2	0.5	140
5	0.2	354
10	0.1	499
20	0.05	653
50	0.02	872
100	0.01	1091
200	0.005	1251
500	0.002	1530
1000	0.001	1759

3 Theoretical framework and research approaches

This section summarises **Complex Systems Theory** (also referred to as Complex Systems Science) as a theoretical framework to organise and appreciate the complex interactions and feedbacks that are part of human-environment systems. The framework can be thought of as a set of presuppositions that help to understand inherent system dynamics as well as the issues to be addressed. Nested within this framework, an inductive-based methodological approach commonly referred to as **Grounded Theory** was applied in constructing and completing this project. Deliberately the research team and community partners also formally incorporated a **Community-Based Participatory Research** approach which was informed by Māori-centred research principles. Commentary on the assumptions underpinning the theoretical framework and these reinforcing research approaches, as well as the approval of human ethical standards in working alongside the community at Arowhenua, are described below.

Note the use of qualitative and quantitative research methods for this study are covered in Sections 4 and 5.

3.1 Complex systems theory

A common dilemma in environmental change studies centres on the issue of integrating complex processes and feedbacks across different temporal and spatial scales to understand earth as well as human-based systems[17] (Hanson, 1958; Engelhardt and Zimmermann, 1988; Rees, 2010). Complexity of course is inherent within earth (hereafter ecological) systems (e.g. the ocean, the atmosphere, the climate systems, etc.), and is equally a defining characteristic of human (hereafter social) systems which are dependent on different scales and differentially affected by linear and non-liner system outcomes. More broadly still, complexity typifies the interactions and responses between ecological and social systems which also do not necessarily respond in linear, predictable, or controllable ways (Laerhoven and Ostrom, 2007). For example, physical processes within and across hydrological and coastal systems typically operate across different temporal and spatial scales, while simultaneously these processes can be modified (as well as modify) human-based systems and interactions.

Uncertainty is a central feature of the complexity of social-ecological systems and typically refers to the unpredictability of outcomes of complex systems, particularly non-linear causal relations. For example, if a system is influenced by a relatively persistent forcing function such as sea-level rise, there is no actual guarantee that the response will be straightforward or predictable (Cowell and Thom, 1997). Uncertainty also characterises social systems since “institutional arrangements leave open wide avenues for choice, and each individual’s outcome is dependent upon the action of others” (Ostrom, 2005: 48-49). Further, uncertainty is commonly used to refer to the unknown outcomes of complex interactions between social and ecological systems. This is particularly significant when human interventions have been found to drive social and ecological systems in directions contrary to those intended (Folke *et al*., 2002). Gregory (1994) argues that the selection of a theoretical framework should therefore offer explanations relating to the construction and conceptualisation of reality and

[17] The concept of ‘system’ is an organising concept to simplify complex structures and relationships between institutions, economy, society and environment.

the interplay of different factors in society such as the role of the individual and the role of politics and of meaning.

Complex systems theory has therein evolved as a response to the challenge posed by complexity, uncertainty and unpredictability (as well as risk) in social-ecological systems. It is particularly suited for empirical research concerned with processes of vulnerability and adaptation in such systems (Krupnik *et al*., 2010). Increases and shifts in scientific understanding have also pointed out the limitation of reductionist science, and highlighted the need for researchers to recognise that 'everything is connected to everything else'. Rather than thinking of social-ecological systems and processes as somehow separate and independent, complex systems theory submits that such systems are coupled, integrated and complex in their nature (Holling *et al*., 2002); and that people are embedded within ecological systems (Folke *et al*., 2002). This view is internally consistent with traditional Māori views of the universe and the 'interconnected' nature of all things expressed through elemental concepts such as '*whakapapa*' [ancestral and kinship linkages to people and place, genealogy, literally = to place in layers] (Marsden, 2003; Roberts, 2010).

Our understanding of social-ecological processes in this research study is therefore based on a complex systems position that recognises (i) social-ecological systems are a product of complex processes that are space and time-integrated, and (ii) there are limitations to addressing and reasoning complex problems. Our theoretical framework therefore requires that attention be paid to interdependent environmental, economic, social and institutional factors. Practicality of course urges us to integrate and communicate (as best we can) our scientific understanding of complex social-ecological systems and processes.

3.2 Grounded theory

Grounded theory is a methodological approach which denotes the practice of generating theory from research which is 'grounded' in empirical data (qualitative and/or quantitative). The theory itself was developed in 1967 by Glaser and Strauss in their seminal volume the *'Discovery of Grounded Theory'* and later applied in their own sociological studies. Since this time, other disciplines have engaged and applied this theory which is now well established in geography, anthropology and psychology, among other disciplines. The emergence of grounded theory was in large part a response to more traditional research approaches where theory was first generated and thereafter tested or validated through empirical field studies. In contrast, the grounded theory approach guides the researcher through the building of theories rather than the testing of theories (Bailey *et al*., 1999). Glaser and Strauss (1967: vii) hoped this new approach might close "the embarrassing gap between theory and empirical research". For further information on the emergence of Grounded Theory please refer to: Glaser and Strauss (1967), Strauss and Corbin (1990), and Pidgeon (1996).

In practical terms, grounded theory is a dynamic and process-orientated approach whereby data is collected and analysed simultaneously, allowing both processes to inform and focus the other throughout the entire research exercise, and thereafter for 'theory' to be discovered. In other words, theory is inductively generated from observations in the field and/or in the recurrent themes or issues in the data collected. As such, Glaser and Strauss (1967: 3) explain that grounded theory will: "…fit the situation being researched and work when put into use. By fit we mean that the categories must be readily (not forcibly) applicable to and indicated by the data under study; by work, we mean that they must be meaningful, relevant and be able to explain the behaviour under study. Grounded theory also places great emphasis on participants' own accounts of social and psychological events and on their associated local phenomenal and social worlds (Pidgeon, 1996). Further, grounded theory emphasises the importance of the relationship between the researcher and respondents; and therein the need to be aware of ethical considerations, based on obligations to those researched, obligations to society and obligations of relevance (Strauss and Corbin, 1994). Together, these features of the grounded theory approach have a track record of being particularly suited to the study of local interactions and meanings as related to the social context in which they actually occur (Pidgeon, 1996).

For this study, grounded theory was selected to ensure that those involved in the research remain open to issues which might otherwise have been obscured by a narrow focus on more conventional approaches. It is hoped that this approach will help to untangle the complex nature of factors that make-up Māori community vulnerability (and resilience) to climate variability and change and therein allow the truth to emerge through the voices of those involved - reflecting their meanings, values, goals and purposes. The grounded theory approach is also expected to assist the interrogation and analysis of the relationships and inter-relationships involved and to more fully contextualise complex processes of change. Research for this study therefore relies on detailed field enquiry designed to reflect the lived experiences of those who are directly involved in, and/or are influenced by processes of change - historically, socially and politically. Both quantitative and qualitative research methods were used (See: Section 4 and 5) to ensure that the research recognises the unique physical, social, cultural and other characteristics of the study area and explicitly recognises the complexities of everyday life.

3.3 Community-based participatory research

A community-based participatory research (CBPR) approach was used to reinforce the grounded theory approach adopted for this study. CBPR is an approach that aims to establish productive working and social relationships between previously unacquainted groups (i.e. the research team (and institute in this instance) and the community). Implicit in this approach is a commitment towards (and encouragement of) sharing of new information, resources and opportunities, and for learning, responsibility, action and shared decision-making concerning the project activities and goals. Typically, CBPR involves community members in all stages of the research, from project design to interpretation, review and the dissemination of results (Wallerstein and Duran, 2003). Crucially important to the overall process and success of the project was the role of the Arowhenua based project manager, who seamlessly organised project meetings and *whānau* involvement. The respondents' willingness to participate in the research, and the validity and depth of the material gathered were, to a large extent, based on trust and co-operation developed between the researchers and the respondents.

Note that while climate change was not regarded as the top research priority for the community at Arowhenua, the idea of investing 'community' time in such a project was recognised by Ngāti Huirapa as a way to create some initial space to plan, to strategise and to take greater control of climate-induced changes on river and coastal environments. Some of the other benefits to be gained from participation in this project include:

- Identifying present and future climate change impacts, risks, adaptive strategies and opportunities facing Ngāti Huirapa.

- Prioritising local values and vulnerability affected by existing climate and coastal processes and those likely to be affected by climate change.
- Raising the profile of key climate change issues facing Ngāti Huirapa and the wider community at Arowhenua.
- Improving the capacity of Ngāti Huirapa to speak the language of climate change and adaptation with local and central governments.
- Incorporating Māori vulnerability and adaptation options/responses into iwi management documents, local planning arrangements and regional plans.
- Recovering local stories and experience of climate variability and change from *whānau*, *hapū* and *iwi* history.
- Leading research and thinking. This study is a first for New Zealand – and although the findings are most relevant to Ngāti Huirapa, there are likely to be general principles and lessons that are of value to other Māori communities.

Human ethics approval was sought and granted through the social research team at AgResearch Ltd (29/09/2010). In association with this application the following ethical responsibilities were communicated through a work-plan to the community at Arowhenua Pā and applied throughout the project:

- **Honest and clear purpose**: The purpose of the research must be communicated honestly and clearly to an interviewee/s as well as provide an opportunity to clarify any questions s/he may have.
- **Confidentiality**: The information provided by an interviewee is private and confidential, and will only be used for the objective outlined in the purpose of the research. If the information shared is to be included in reports and/or publications this must be made clear.
- **Consent**: Once informed of the purpose the interviewee must agree (give consent) to participate in the research. Typically signed consent forms are used BUT verbal consent for acceptable.
- **Right of withdraw**: The interviewee may withdraw information at any time up to <a given date> without providing a reason.

Research conducted through NIWA's Māori Environmental Research Centre follows an additional set of ethical principles which researchers must observe when working alongside *iwi, hapū and whānau*. These principles are applied through an observance of *tikanga* Māori and recognition of the aspirations, rights, interests, values and sensitivities of the people involved in the research (Smith, 1990; Te Awekotuku, 1991; Smith, 1999; Pihama *et al*., 2002, Mead and Mead, 2003). The core principles include: *aroha* [sincerity, mutual-respect, love]; *kanohi kitea* [seen face, in person, literally means 'face to face']; *mana* [dignity, authority, control]; *manāki tangata* [to support, take care of, give hospitality to visitors, protect, look out for]; *whakapiki tangata* [empowerment]; *māhaki* [humility]; *whakatuia* [integration]; *tūpatotanga* [caution]; and *whakawhanaungatanga* [kinship, process of strengthening relationships].

Finally, the research conducted within the programme was expected to generate data, research analyses and knowledge of benefit to Ngāti Huirapa and the wider community. Maximising the benefits of this work therefore required agreement between parties to make this information available to a diverse range of interested stakeholders at the conclusion of the project (e.g. Māori authorities and local government). It was therefore agreed that public release of any collaboratively produced research findings would require the approval of both parties. Furthermore, it was agreed that any intellectual property developed jointly with Ngāti Huirapa or other providers will in principle be shared, and will be subject to a separate agreement between the parties, as necessary. All matters relevant to the project were agreed upon via a formal contract for services between NIWA and Te Rūnanga o Arowhenua Society Incorporated in September 2010.

4 Qualitative research methods

This section provides details of the range of qualitative research methods used in the first phase of this project to gather a suite of information about the contemporary social and environmental conditions at Arowhenua Pā. The main methods included (i) semi-structured and open-ended group interviews with a broad cross-section of the community, (ii) semi-structured and open-ended interviews with key informants, and (iii) land trips and personal observation. These different consultation methods were planned to ensure that a range of views and perspectives were considered. This information not only tells us about the community, its social-ecological context and opportunities but also feeds into the project's decision making processes for next actions.

Note that a lot of informal engagement underpins participatory involvement (whether engaging with an individual or a group) which is often not taken into account.

4.1 Group interviews

The first round of open and semi-structured group interviews was conducted within the *wharenui* [main meeting house at the marae] at Arowhenua Pā on the 8–9th December 2010. A total of 17 home-people were interviewed over three group sessions (with five to six interviewees per group). The interviewees were selected by the Ngāti Huirapa project manager, and largely comprised *kaumātua* [elders – not gender specific] and *mātaitai*[18] [seafood/shellfish] management group members[19]. These sessions lasted between 2-3 hours and were attended by two NIWA facilitators, the Ngāti Huirapa project manager and one transcriber from Arowhenua Pā.

All group interviews began with a *mihi whakatau* [formal welcome speech] followed by a *whakawhanaungatanga* exercise to enable time for introductions and the establishment of *whānau* and community relationships. The interviews were guided by a broad set of pre-determined vulnerability and adaptation-based questions that helped to explore people's attitudes, beliefs and experiences with the direct and indirect impacts of climate and coastal related changes. These questions were in turn supported by participatory mapping[20] and themed prioritisation exercises. At the end of each session informants were invited to identify any absent *whānau* members who they believed should be asked to participate in the project. All interviews were electronically recorded and transcribed in full. The semi-structured in-depth approach ensured some element of structure for key areas of interest while also allowing sufficient flexibility (in line with grounded theory methodology) to explore new areas and avenues of interest.

It is worthy of note that group interviews are useful for involving many sectors of the community – particularly from the point of view of sharing experience and hearing a variety of

[18] The term Mātaitai refers to 'reserves' which have been established under Part IX of the Fisheries Act 1996. These reserves are designed to give effect to the obligatiuons stated in the Treaty of Waitangi Fisheries Claims Settlement Act 1992 to develop policies to help recognise use and management practices of Māori in the excercise of non-commercial fishing rights.

[19] One of the major benefits of working with pre-existing groups of people (as opposed to a randomly selected group) is that they provide one of the social contexts within which ideas are formed and decisions are made (Lewis, 1992).

[20] Participants were encouraged to annotate the large aerial maps by identifying significant sites and places of change. This proved to be an effective technique to share experience and understanding due to the location-specific nature of much of the conversations/discussions.

thoughts and statements where participants can react to ideas and build-off of each other's comments (Lewis, 1992). Safety in numbers may also make some people more likely to consent to participate in the research in the first place. However, group dialogues such as these can be also impacted by personalities that dominate the discussion and/or group dynamics that discourage more reserved members to join in (Lewis, 1992). Further, this can lead to people censoring their ideas in the presence of people who differ greatly from them in power, status, education, and other personal characteristics. To supplement this research method, the research team additionally sought to interact with key community members or residents representing different perspectives on an individual basis (See: Section 4.2)[21].

Finally, the group interview method was augmented by many instances of informal discussion, as is the case in most qualitative research. For example, it was *tikanga* [protocol] that the workshop sessions and meetings finished with *kai* [food – lunch or dinner] for the group and researchers to share together. In debriefing sessions amongst the researchers, these important comments and observations were discussed and noted.

4.2 Individual interviews

The first round of open and semi-structured individual (and paired) interviews was again conducted within the *wharenui* at Arowhenua Pā as well as within the private homes of some informant's during the 9-12th December 2010. A total of eighteen home-people (including three participants from the group sessions) were interviewed. These participants comprised *kaumātua, pākeke* [adults] and *rangatahi* [younger generation, youth] and were selected by the Ngāti Huirapa project manager based on inter-generational experiences and relationships with Arowhenua Pā. Note most of these informants were unavailable for the group discussions and thereby made themselves available at the later dates.

All individual interviews followed a similar format to the group interviews (as described above), and were guided by the same set of vulnerability-based questions. Again, these interviews were used to examine in more depth people's personal attitudes, beliefs and experiences with the direct and indirect impacts of climate and coastal related changes on the environment and community. Each session lasted between 1-2 hours, and was attended by one NIWA facilitator and the Ngāti Huirapa project manager. All interviews were electronically recorded and transcribed in full. Note that implementation of this method of data collection resulted in a considerable quantity of raw data being gathered.

A second round of semi-structured individual and paired interviews was conducted within the *wharenui* at Arowhenua Pā during the 22-24th September 2011. A total of twelve home-people were interviewed, eleven of whom were involved in the first round of interviews. These participants comprised *kaumātua* and *pakeke* who were purposefully identified by the Ngāti Huirapa project manager and the NIWA research leader. The principal criteria for participant selection related to the need to follow-up on specific comments made by key participants during the first round of interviews as well as new questions that emerged following the analysis of specific interview transcripts. This process also permitted the research team to ensure that our interpretations had accurately captured the expressed insights and concerns of participants during the first round of interviews – otherwise adjustments were made. Furthermore, it provided an invaluable opportunity to deepen our

[21] Note that individual responses are not independent of one another and the results are never guaranteed to be representative of the general population – rather, ultimately they represent the view and experiences of those people who have been engaged only.

understanding of community realities, aspirations, attitudes and perceptions, that otherwise cannot be observed. Interviews lasted between 1-2 hours, and were complemented by on-land visits. The second formal visit to the Pā also provided an opportunity to present maps which illustrate future climate projections and possible impacts of sea-level rise and inundation in and around Arowhenua Pā. This afforded an opportunity to explore how perceptions of risk changed when presented with new information.

Overall, these interviews provided comprehensive information from individuals that resulted in an in-depth, if not sometimes isolated, view of the subject. That is, just as there are potential limitations with group settings, individual interviews have potential for undue emphasis to be placed on issues specific to the individual. Recognition of such strengths and limitations underpinned the decision to use multiple methods for information-gathering.

4.3 On-land walks and observations

On-land walks and observations were made on successive visits to Arowhenua Pā – and these opportunities were taken to discuss in greater depth and view first-hand some of the many places and phenomena highlighted during the group and individual interviews. The information gained through this action was supplemented by field notes taken by other members of the research team. Photologues are provided in Appendix A.

4.4 Analysis of information

The analysis of the data collected through group, paired and individual interviews was open-ended, inductive and consisted of 'content analysis' where ideas or words were identified along with the frequency of their use and 'thematic analysis' whereby the principal themes emerging from the data were examined (King *et al*., 2008). Identifying the principal themes involved sorting, coding and categorising data directly from the interview transcripts. The themes that emerged provided sufficient information to understand the contemporary exposure and sensitivity of the community to variations in climate and coastal processes, as well as the adaptive capacity of the community to deal with the impacts of social and environmental changes. Secondary sources provided further context to the interview data and offered additional information which enriched our understanding of the present human and biophysical landscape at Arowhenua.

The transcribed interview were examined thoroughly, and divided into stand-alone pieces of information, which were then sorted into categories. As each piece of information was categorised, it was compared to other entries within that category which enabled the identification of similarities, discrepancies, and dissenting opinions. As the research progressed, categories (identified from both the written and interview data) emerged, merged, and disappeared, until a set of principal themes were distilled. Some of the themes were also established *a priori* based on issues identified through the draft discussion document and previous studies. Once relevant conditions were identified, information from other scientists, policy analysts and decision-makers were integrated into the analysis to identify potential future exposures and sensitivities (what conditions or risks the community may be facing) and future adaptive capacity (in what ways the community may potentially plan for or respond to these conditions) to determine whether the community's present coping strategies are capable of dealing with these risks.

5 Quantitative research methods

This section outlines the quantitative research methods used in the second phase of this project to generate information about 'current' and 'projected' changes in Temuka River flooding and inundation of the coastal zone surrounding the Opihi River mouth due to sea-level rise. These settings were selected for analysis based on existing community knowledge and concerns about present and future climate hazards and risks. Before proceeding to the methods applied in this study, further background information is provided on the use and selection of climate change scenarios to explore possible future climates and related outcomes.

5.1 Climate change scenarios

Climate change scenarios are commonly used to explore possible future climates and related outcomes. The need for scenarios is due to the uncertainty over future emissions of greenhouse gases and aerosols which themselves depend on changes (and uncertainties) in population, economic growth, technology, fossil fuel use and national and international policies, among other factors. Future climate changes generated from scientific analysis and computer models are therefore called projections, not predictions.

IPCC emission scenarios

In its Fourth Assessment Report, the IPCC presented projections from six emissions scenarios that covered a wide range of possible future economic, political and social developments during the 21st century. These scenarios are known as the "SRES scenarios" after the name of the report, the *IPCC Special Report on Emissions Scenarios* (Nakicenovic and Swart, 2000). Climatologists use model-based 'scenarios' to provide plausible descriptions of how the future might unfold when evaluating uncertainty about the effects of human actions on climate. The SRES scenarios are divided into four families, or storylines, that describe distinctly different future developments of economic growth, global population, and technological change. These four families are known as A1, A2, B1, and B2. The A1 family is further subdivided into three groups (A1FI, A1T and A1B), resulting in 6 scenario groups, for which emissions scenarios were developed by the IPCC Working Group III in 2000. The storylines behind the emission scenarios are described in more detail Box 1. Note the IPCC does not promote any one SRES scenario as being more likely than any other.

All scenarios describe futures that are generally more affluent than today, and in many of the scenarios, a narrowing of income differences between world regions is assumed. In most scenarios, global forest cover continues to decrease for some decades, primarily because of population and income growth. This trend is eventually reversed, with the greatest increase in forest area by 2100 occurring in the B1 and B2 scenarios. Behind these scenarios are assumptions about how demographics, energy use and technology might change. The scenarios do not describe how the particular emissions track might be achieved and, indeed, New Zealand is too small a geographic region to be considered explicitly. Furthermore, as required in their Terms of Reference, the scenarios do not allow specifically for political climate initiatives to reduce greenhouse gas emissions, such as implementation of the United Nations Framework Convention on Climate Change or meeting the emissions targets of the Kyoto Protocol.

Global model simulations and down-scaling

For the IPCC Fourth Assessment process, a set of standard experiments was run by science institutions that operated global climate models (GCMs). A control simulation was made of what was called the 20th century climate, although runs actually started as early as 1860 for some models. The 20th century model simulations used 'observed changes' in solar radiation and volcanic aerosols, in addition to the observed greenhouse gas increases. From the year 2000 onwards, the models were forced by the SRES scenarios. Owing to computing and data storage constraints, only three of the SRES scenarios were studied in detail: all models (a total of 24) examined the A1B mid-range scenario, and most models also completed B1 (low emissions) and A2 (high emissions) simulations.

Box 1: SRES Storylines

A1: This scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. A major underlying theme is convergence among regions of the globe, with a substantial reduction over time in regional differences in *per capita* income. The A1 family is split into three groups that describe alternative directions of technological change in the energy system: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B).

B1: This scenario family describes a convergent world with the same population trajectory as in the A1 storyline, but with rapid changes towards a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies.

A2: This scenario family describes a very heterogeneous world, with the underlying theme of self-reliance and preservation of local identities. Global population increases continuously, economic development is regionally oriented, and *per capita* economic growth and technological change are more fragmented and slower than in the other storylines.

B2: This scenario family describes a world that emphasises local solutions to economic, social and environmental sustainability (i.e., a heterogeneous world as in A2). Global population increases continuously at a rate slower than A2, with intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines.

Source: IPCC, 2007

The output of a global climate model is generally too coarse in terms of spatial resolution to be directly applied within New Zealand. Consequently, NIWA validated the performance of the GCMs in simulating 20th century climate in the New Zealand-South Pacific region, and selected 12 of the models for 'downscaling' over New Zealand (MfE, 2008). Downscaling is a technique for building in local scale detail that is consistent with the global model output at a much larger spatial scale (GCMs typically have grid-points spaced 1 – 3 degrees latitude apart). The downscaling procedure uses historical monthly data anomalies to develop regression equations for precipitation and mean temperature, and is applied to a NIWA gridded data set that covers all of New Zealand with 0.05° latitude-longitude (approximately 5 km) boxes. This is more commonly known as the Virtual Climate Station (VCS) network (Tait *et al*., 2006). There are approximately 11,500 grid-points over the New Zealand land mass, and about six covering the Arowhenua area[22]. The methodology for downscaling temperature and precipitation to the VCS grid is described in MfE (2008b), and the scientific details are provided in Mullan *et al*. (2001). Note that in the reference MfE (2008b), downscaled projections of temperature and precipitation were derived only for the 12 A1B simulations. Since that time, the same downscaling has been applied to GCM output from the B1 (low) and A2 (high) scenarios. All 12 models have been shown to perform adequately in simulating the past climate of New Zealand and the South Pacific. However, the downscaled global model results do sometimes differ significantly from one another (See: MfE (2008b)).

The scenarios adopted for this study are based on the downscaling results from the 12 most appropriate models (MfE, 2008b), with attention given to the 12-model average for '2040' (actually 2030–2049 time period) and for '2090' (actually 2080-2099 time period), based on the A1B and A2 emission scenarios. A1B can be thought of as the 'middle of the road' emission scenario relative to other IPCC scenarios, neither particularly high nor particularly low in terms of future GHG emissions. A2 can be described as a slow but continuous increase in emissions due to a slow continuous increase in population and regionally-oriented economic growth. Note that while the A2 scenario is regarded as 'high' it is not the most extreme SRES.

The directly downscaled changes were expressed in terms of changes in monthly mean values of temperature and precipitation. That is, the changes refer to the difference between the base period of 1980–1999 and the future periods 2030–2049 and 2080-2099. Tables 7 to 10 in Appendix B show the percentage change in precipitation for the Temuka catchment as derived from the 12 GCM models for monthly statistics based on moving three-month averages for the A1B and A2 emission scenarios for 2040 and 2090. These averaged data were explored due to the large month-to-month variations in the monthly projections. Next, in order to apply the hydrological model the projected 'monthly' scale data was converted into daily resolution data following procedures outlined in the reference MfE (2010). This included (i) temporally downscaling the monthly changes to daily 'base' data - a time step compatible with VCS data, and (ii) empirically adjusting the change in frequency in rainy days in a month. Note the daily rainfall data was disaggregated into hourly data within the hydrology model TopNet (see next section) using observed hourly rainfall data from the local climate station 410010.

Changes in temperature under climate change conditions over base data resulted in:

- Annual average temperatures about one degree warmer than 1980–1999 in the 2040s, and about two degrees warmer than 1980-1999 in the 2090s for emission scenarios A1B and A2.

These changes were assumed to be constant across the entire catchment for the two future time periods.

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[22] For each climate element, the grid-point anomaly is related to three predictors: the large-scale zonally-averaged anomaly over 160–190°E at the same latitude as the grid-point, and the anomalous components of two wind indices known as the Trenberth Z1 and M1 indices (Trenberth, 1976). If there is very low explained variance in the regression at some location, the climate change at that point will effectively be the same as the latitude-average evaluated at the model grid scale. In applying the regression to the future projections, the changes in circulation (Z1, M1 indices derived from model pressure field) and in latitude-average climate (from model precipitation or temperature field), relative to the base period of 1980-1999, replace the observed monthly anomalies.

5.2 Flood simulation modelling

To simulate "present-day" flood flow conditions in the Temuka River, observed climate and river flow data from a large and relatively recent flood event were incorporated into the hydrological model - TopNet. The chosen flood event occurred on March 13-14, 1986, causing large scale property and infrastructure damage in and around the Arowhenua region. This event was estimated to have a return period of 100-150 years (Oliver, 2009). More detailed information on this flood event can be found in Sections 2.3 and 6.1. The selection of the 1986 flood event for this study was driven by the following hydrological and social factors:

(i) The 1986 flood event breached banks and inundated large expanse of lands in the Arowhenua region, and hence was considered hydrologically significant;

(ii) The relatively recent occurrence of the 1986 flood event permitted the collection of flood levels (based on community experiences) to verify the results from hydrodynamic model; and

(iii) The relatively recent occurrence of the 1986 flood event, still 'fresh' in people's memories, permitted an opportunity to demonstrate the likely climate change impacts for similar flood flows in the Temuka River.

TopNet hydrology model

The hydrology model 'TopNet' was used to simulate flood flows in the Temuka River. This was then used as input to a hydrodynamic model to simulate floodplain inundation (see Section 5.3). The model allows calibration of discharge using observed rainfall and flow data to closely represent the hydrological processes. TopNet is a distributed parameter, continuous simulation model designed to predict water balance at multiple spatial and temporal scales. It has been widely applied in many New Zealand catchments (e.g., Bandaragoda *et al*., 2004; Ibbitt *et al*., 2005; Clark *et al*., 2008; Woods *et al*., 2008, Zammit and Woods, 2011), and had been primarily developed as a flood prediction model (Henderson *et al*., 2007). This model is equipped with routines to move rainfall-runoff overland to streams. Stream flows are typically generated using infiltration-excess and saturation-excess runoff generation mechanisms across the landscape during rainfall events and from soil storage during base-flow periods. TopNet includes catchment characteristics (i.e. topography, drainage area and slope), soil characteristics (i.e. depth, field capacity, and wilting point), land-cover characteristics (i.e. vegetation, interception and evapotranspiration) and stream network and topology. A detailed overview of the model is provided by Clark *et al*. (2008).

TopNet data requirements

TopNet uses temporal and spatial data. The temporal data used are precipitation and temperature. Spatially distributed information on topography, soils, land use and vegetation are used to describe the catchment physical characteristics within TopNet. In this study, all the physical data were assumed to be the same between current condition and climate change scenarios to enable a direct comparison of flood impacts. The main sources of spatial data are the New Zealand River Environment Classification (Snelder and Biggs, 2002), the Land Resources Inventory (Newsome *et al*., 2000; Willoughby *et al*., 2001) and the New Zealand Land Cover Data Base (MfE, 2004). The temporal data were derived from climate maps (VCS data) developed by Tait *et al*. (2006). These maps include daily precipitation and temperature (minimum and maximum) data, at a spatial resolution of 5 x 5km. Since TopNet is operated on an hourly time scale, the daily precipitation was disaggregated using hourly precipitation data from Climate Station No. 410010. This was the only rain gauge that was recording rainfall at hourly intervals during the March 1986 flood event within the Temuka catchment. While the hourly distribution of rainfall across the catchment might have varied, in the absence any specific observations, the same rainfall distribution was applied everywhere within the catchment.

TopNet calibration and evaluation

TopNet was calibrated for the period 1-31 March 1986 using measured precipitation and stream flow data in the Temuka catchment. The model was calibrated within two sub-catchments of the larger Temuka catchment (Te Moana gauging station No. 69644 and Kakahu gauging station No. 69645). The resulting calibrated model was validated for flood flow simulation at the catchment outlet (Manse Bridge gauging station No. 69602). During the model calibration, soil storage, hydrological-transfer (rainfall to runoff), and hydraulic-routing (overland flow, base-flow recession, in-stream flow) parameters were altered to match the volume, rate and timing of measured and predicted flows. The model performance was statistically evaluated using the Nash–Sutcliffe (NS) coefficient calculated based on observed and measured flows and on the logarithm of the discharge (NS Log). The Nash-Sutcliffe efficiency represents a measure of the residual variance versus the data variance. Following the satisfactory evaluation of model performance, it was applied to simulate the flood hydrograph at Manse Bridge on the Temuka River for the March 1986 flood event and for a similar flood event under climate change scenarios.

Flood simulation modelling

Model simulation of the 1986 flood event in Te Moana River, an upstream tributary of the Temuka River, showed a good match between observed and simulated flow volumes, rates and timing of peak flow. Results from the calibration of the hydrological model are shown in Table 2 and Figure 10. The calibrated model was then applied to simulate flood flows in the Temuka River at Manse Bridge for a flood event that had occurred in August 2000. This event had well recorded observed flow records at this location. The resulting model application showed a satisfactory match between observed and predicted hydrographs (Figure 11).

Table 2: Hourly Nash-Sutcliffe efficiencies measured in the Topnet model

Location	Calibration NS	Calibration NS Log	Peak flow Observed (m^3/s)	Peak flow Predicted (m^3/s)	Total flow Observed (m^3)	Total flow Predicted (m^3)
Glentohi March 1986	0.671	0.816	301	313	2990	3810
Manse Bridge August 2000	0.940	0.891	656	669	27652	31196

Following these validations, the calibrated model was applied to simulate flood flows for the March 1986 event but under climate change scenarios. The flood flow hydrographs developed for future conditions under different climate change scenarios are discussed in detail in the following sub-section. Analyses of model results indicated the following:

- The various projected increases in precipitation due to climate change could result in an increase up to 30% of the peak flow in the Temuka River at Manse Bridge
- The A2 emissions scenarios produced more extreme flood peaks than the A1B emission scenarios
- The rate of peak flow change over the period current-2040 AD is slightly lower than change over the period 2040-2090 AD. This result reflects expectations for increasing precipitation intensity due to continued atmospheric warming as well as concomitant growth in global population and economic development.

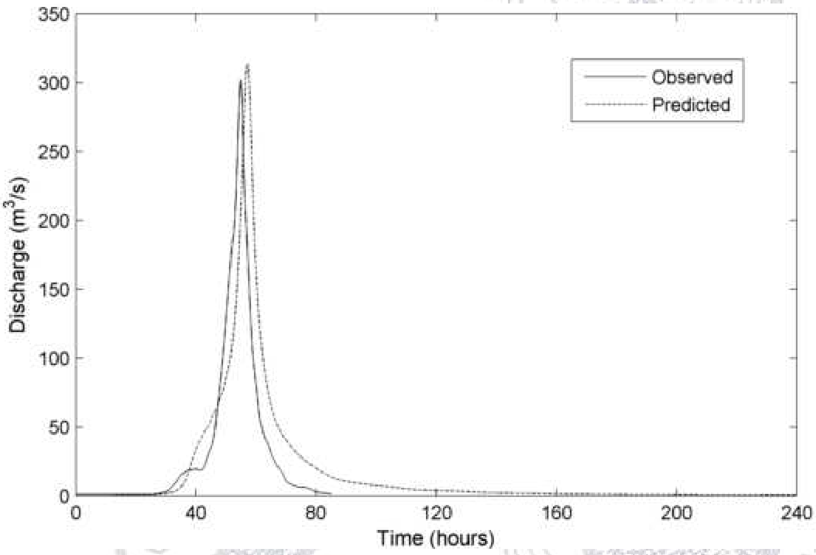

Figure 10: Model calibration – comparison between observed and modelled hydrograph for Te Moana at Glentohi (March 1986).

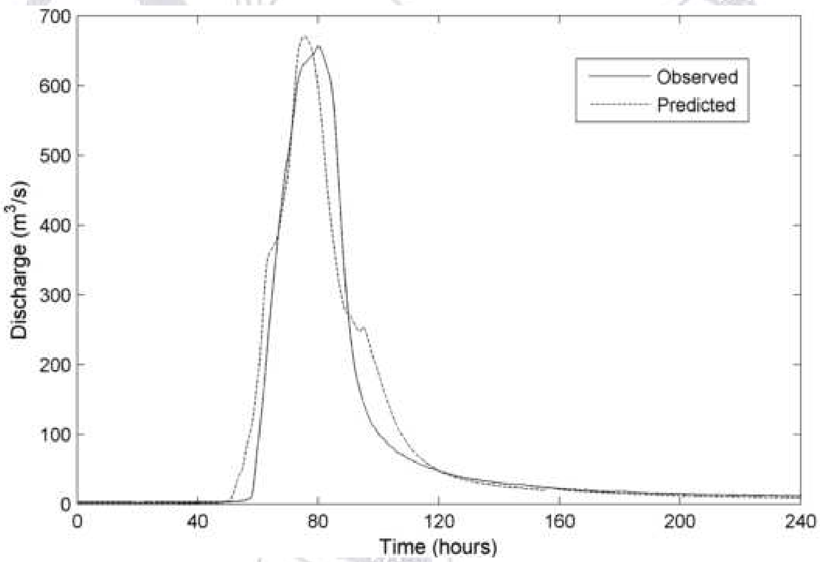

Figure 11: Model validation – comparison between observed and modelled hydrograph for Temuka River at Manse Bridge (August 2000).

5.3 Flood inundation mapping

The 2-D hydrodynamic model used to simulate inundation of the Arowhenua flood plain was "Hydro2de" (Beffa and Connell, 2001; Beffa, 1996). This model solves the depth-averaged shallow-water equations for a grid using finite volume schemes where the flow variables are located at the cell centre. A notable feature of the model is that it is numerically stable in the presence of hydraulic jumps. The model for this study was based on its previous application in braided rivers and flood plains (Duncan and Carter, 1997; Duncan and Hicks, 2001; Duncan and Shankar, 2004; Duncan and Bind, 2008). This section describes the key elements and data processing required to run the Hydro2de model.

Topographic survey

The Hydro2de model is based on a digital elevation model of the model domain. The elevation of the model domain was measured using data from airborne laser survey (LiDAR) and digital photogrammetry. The LiDAR data were captured by New Zealand Aerial Mapping for Canterbury Regional Council in March 2010. LiDAR data were supplied in New Zealand Transverse Mercator projection and referenced to LVD-37. These data sets do not provide elevation information for wet parts of the river bed, and so, a uniform depth of 0.5 m below the adjacent dry river bed was assumed. Given the relative depths and limited extent of the low flow (0.5 m deep) channel and maximum depth (>3 m) of the flood flows to be modelled, this assumption is unlikely to materially affect maximum flood levels. The spatial extent of the model domain would have been ideally extended further west but was limited by the availability of digital photogrammetry and ALS data.

Model extent and survey grid

The domain for the Hydro2de flood inundation model was 3.38 km from west to east and 2.3 km north to south (Figure 12). The Opihi River stop bank was the effective southern boundary to the modelled flows. The regular 1.5 m square grid of the topography for the model was obtained by sampling a Triangulated Irregular Network (TIN) surface from the LiDAR dataset and then combined with the digital photogrammetry in areas where no LiDAR data were available.

Hydraulic resistance assessment

Hydro2de requires an estimate of hydraulic resistance for each model cell (1.5 x 1.5 m). For river beds, this is often based on an estimate of the dominant grain size of the surface bed material. The model offers a choice of several flow resistance parameters. In this study a hydraulic resistance parameter, z0, was used following the work of Smart *et al*. (2002) and Smart (2004)[23]. The land cover in the domain was categorized with the z0 values assigned based on experience with other inundation 2D models of Canterbury braided rivers and the Buller River flood plain (Table 3) (Duncan and Hicks, 2001; Duncan and Shankar, 2004;

[23] An advantage of using z0 is that it is a parameter of the velocity distribution rather than a description of the boundary material. Hence, z0 gives hydraulic roughness, as seen by the flow, rather than relying on a boundary resistance characteristic such as bed material grain size. A further advantage is that it changes less with flow depth than some other flow resistance parameters. It uses a log-log relationship that makes flows insensitive to the choice of z0 value.

Duncan and Bind, 2008). The boundaries between significant areas of each land cover type were digitized and appropriate values assigned to the cells in each cover type polygon[24].

Figure 12: The red box shows the approximate extent of the flood model domain.

It was also necessary to model debris build-up on the SH1 and railway bridges (as reported by Hall (1997)) to correctly simulate recorded levels of inundation upstream and downstream of each bridge. This was achieved by widening the bridge piers to simulate the build-up of debris on the piers and increasing the hydraulic roughness (z0) underneath the bridge. The effect of these changes was to increase the depth and extent of inundation immediately upstream of the bridge, and to reduce the inundation down-stream of the bridge.

Table 3: Hydraulic roughness values (z0).
Source: Smart *et al*. (2002), Smart (2004).

Cover type	Hydraulic roughness z0 (m)
Grass/meadow	0.015
River bed	0.01
Road	0.003
Town/scrub	0.05
High vegetation/trees	0.1

[24] Note that some polygons treated as homogeneous may not be so. That is, areas classified as pasture may have fences, hedges and individual trees or small groups of trees which would all increase roughness but which have not been taken into account.

Inundation model inflows

Previous studies (Scarf *et al*., 1987; Connell *et al*., 1993; Hall, 1997; Oliver, 2009, Griffiths *et al*., 2011) were reviewed to determine the best flood peak estimate for the March 1986 flood in the Temuka River to use for the 2D hydrodynamic model calibration. The flood estimates and comments are summarised in Table 4. One of the main issues was that not all of these reports specified the location of the reported or estimated peak flood. This is critical as there are four right bank tributaries between the north end of Temuka (upstream model boundary) and the SH1 Bridge (towards the downstream model boundary). Furthermore, during large floods (>450m^3s^{-1}) there can be breakouts from the river (Scarf *et al*., 1987; Connell *et al*., 1993; Hall, 1997; Oliver, 2009), and it is often not clear whether or not the breakout flows were included in the flood estimates. Subsequently, the Topnet – simulated flows for the March 1986 flood event were calibrated to the Scarf *et al*. (1987) flood peak estimate of 1100-1200m^3s^{-1} at Temuka to give a peak flow of 1174 m^3s^{-1} at the model boundary as that study provided the most comprehensive description of the flood. However, given the discrepancy between this value and the 1550 m^3s^{-1} flood peak estimated by Hall (1997) a more intermediate value of 1378 m^3s^{-1} was adopted for the 2D hydrodynamic model calibration to equate with the most common estimate of the 0.01 AEP flood (Table 4). Importantly, the Topnet model was not recalibrated to this revised flood value, for the derivation of the effects of the climate scenarios. Instead the climate change scenarios hydrographs output from Topnet were scaled by the ratio of the calibration peak flow to 1378m^3s^{-1}.

Table 4: Flood size estimates for the Temuka River.

Author	Flood size (m^3s^{-1})	Average recurrence interval (years)	Location	Comment
Scarf *et al*., 1987	1100-1200	NA	Temuka	1986 flood
Scarf *et al*., 1987	1100	NA	SH1 Bridge	1986 flood
Connell *et al*., 1993	1378	0.01	NA	
Connell *et al*., 1993	1558	0.005	NA	
Hall, 1997	1378	0.01	Manse Bridge	
Hall, 1997	1550	0.007	Railway Bridge	1986 flood
Oliver, 2009	1400-1600	0.01	Temuka	
Oliver, 2009	1450-1700	0.002	Temuka	
Griffiths *et al*., 2011	1440	0.01	Manse Bridge	At site data
Griffiths *et al*., 2011	1091	0.01	Manse Bridge	Regional analysis

Calibration of modelled inundation

Calibrating the hydrodynamic model performance by comparing 'simulated' with 'observed' inundation extents for the 13-14 March 1986 flood event poses problems where landscape is relatively steep, since it is possible to model the extent of inundation reasonably well, but to have the water level outside acceptable model uncertainty. For this reason, calibrating against multiple sources of information was adopted.

First, the simulated flood inundation extents were compared with the extent of the March 1986 flood as presented in Scarf *et al.* (1987) (Figure 13). While there are some differences in detail the modelled extent is generally very similar to the observed extent. Explanations for the largest departures between the modelled and observed flood extents are offered below.

- In the bottom right of Figure 13 the model shows less flooding because flooding caused by the Opihi River was not modelled, though it also flooded in 1986.
- At the centre bottom of Figure 13 the modelled extent is greater than the observed, possibly because there was more debris build-up simulated on the rail bridge than actually might have occurred.
- Immediately to the left (and to the left of SH1) is another area where flooding was observed but not modelled. We speculate that the area immediately to the left of the road was flooded by local surface water and was not connected to the Temuka River. The elevation levels in the Digital Terrain Model (DTM) suggest that such a connection is not possible. The model shows that some water does cross Huirapa Road, but flooding is unlikely to have occurred to the extent shown in Scarf *et al.* (1987) inundation maps.
- At the middle left in Figure 13 where the unnamed tributary enters the model domain, the modelled extent of flooding is less than observed. This is attributed to the TopNet modelled flow entering the hydrodynamic 2D model domain being underestimated. In the process of calibration, models with larger flows in the unnamed tributary showed similar extents and patterns of flooding to those observed in this area (blue hatching in the middle left of Figure 13).

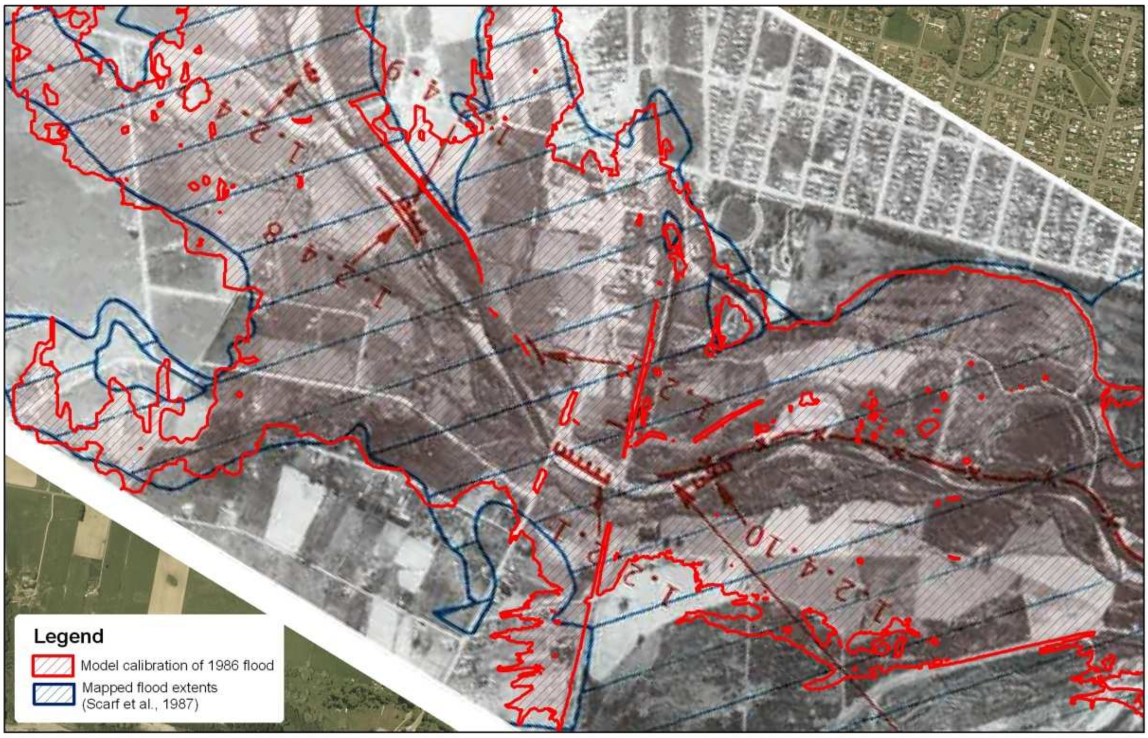

Figure 13: Hydrodynamic modelling - observed and modelled extents for the 13-14 March 1986 flood event. Source: Scarf *et al.* (1987)

Second, the simulated flood inundation extents for the 13-14 March 1986 flood event were calibrated against five surveyed flood levels identified by residents from Arowhenua Pā on 11-12 May 2011 (Figure 14). Location points were surveyed using a survey grade RTK GPS.

- Point one - Backyard. The calibration model water level was 0.4 m below the surveyed location but the extent of flooding was very comparable. Both can be explained by the slope of the land at the measurement point as the backyard is quite large and steeply sloping, so a difference of the exact location of the point by as little as 10 m could result in a surveyed water level error of 0.4 m.
- Point two - Upper wetland. The calibration model water level was higher than the observation point, but the flooding extent was again comparable. This discrepancy could also be explained by the steepness of the land. In addition, the measured flood level point is inconsistent with, and lower than, those at points Backyard and Back-step.
- Point three - Back-step. The calibration model water level was consistent with the measured point. The house was reported to be partly surrounded by water which is consistent with the modelled flood extent. We also have a good ALS based digital elevation model of this area, which allowed a better representation of micro-topography in this area. Back-step is probably the most reliable of the Pā-based flood points.

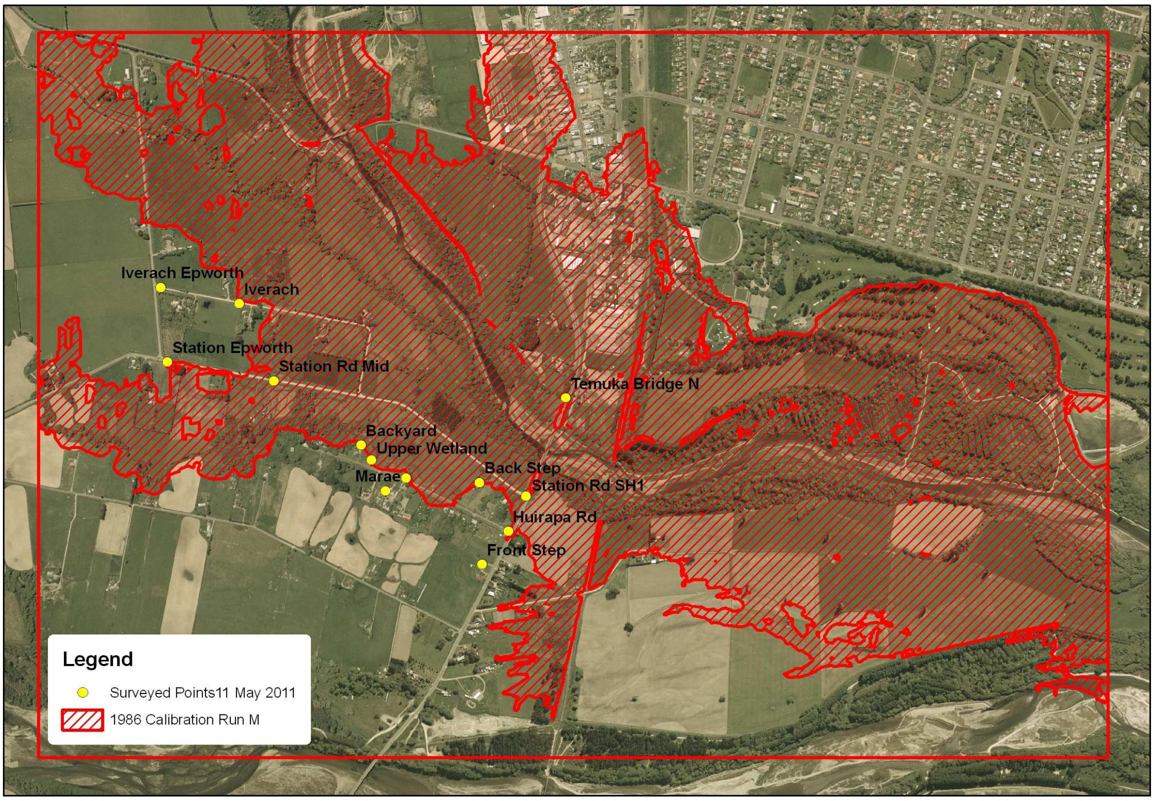

Figure 14: Calibration model results map and surveyed points across the extent of the model domain.

- Point 4 - Front-step. The calibration model did not simulate this inundation. The authors concluded that this flood level was most likely due to flooding from a local stream and not the Temuka River. This is consistent with Hall's (1997) modelling of the 100 year flood extent and the aerial photo in Figure 9. The elevation of this flood mark, which is known with some certainty and the elevated topography between the house and the Temuka River, would require the river water level to be at least 1 m higher than the modelled flood levels, which in turn would be inconsistent with the other levels and observations.

There is some inconsistency in the flood levels reported from the Pā and those produced by the model. Notwithstanding this, the modelled flood levels are similar to the most reliable levels and there are plausible reasons for the discrepancies between reported and modelled peak flood levels for the other points. The authors consider that the calibration is as good as can be achieved given the uncertainty in the peak flood flows, the quantity of debris on the bridges and the observed flood levels, among other sources detailed in the sub-section.

Climate change scenario modelled inflows

TopNet-derived hydrographs for the flood flows in Temuka River at Manse Bridge under climate change scenarios A1B and A2 were used as input to Hydro2de to develop inundation maps for each emission scenario. Figure 15 shows the average projected flood peaks for the A1B and A2 scenarios and for the present day at the model boundary upstream of Manse Bridge. The projected hydrographs for the average of the two climate change scenarios in 2040 AD and 2090 AD are greater than the present day for this particular flood event. Further, the flood peaks for the climate change models are higher for A2 than the peaks for A1B, respectively.

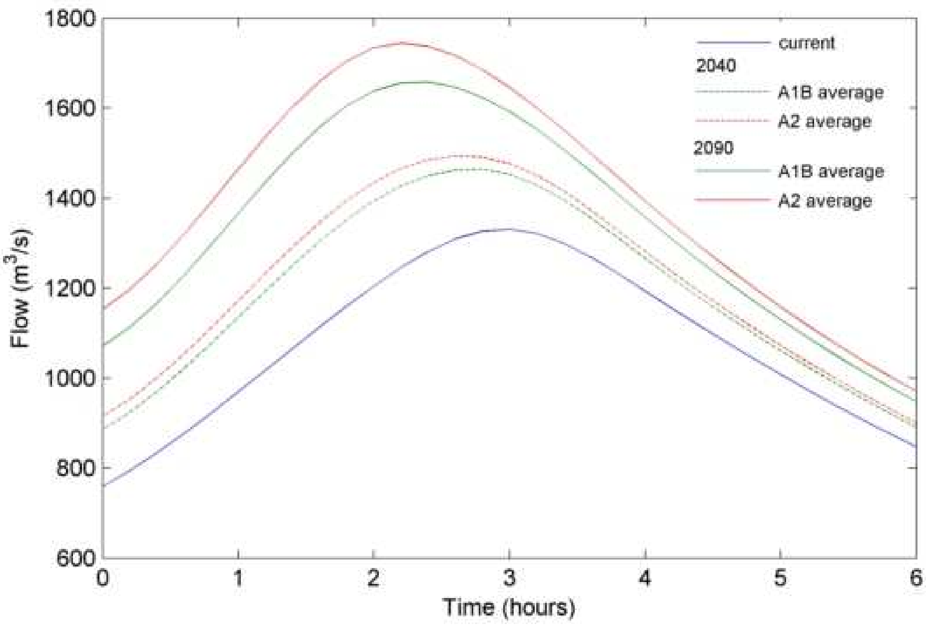

Figure 15: Simulated TopNet floods peaks shown for A1B and A2 scenarios for 2040 AD and 2090 AD at Manse Bridge and the current climate scenario based on the March 1986 flood event.

Inundation model uncertainty

There are a number of areas of uncertainty associated with the inundation modelling:

(i) Uncertainty as to the size of the flood in the main river and in the tributaries. There is a large degree of confidence in the modelled hydrograph shape as it is very similar to that for the recorded hydrograph for the Opihi at Saleyards, but there is uncertainty about the flood peak flow.

(ii) Uncertainty in the DTM. The DTM for the lower third of the modelling domain (including Arowhenua Pā) was derived from highly accurate ALS measurements, but the rest of the modelling domain relies on less accurate photogrammetry data.

(iii) Uncertainty in the hydraulic roughness values chosen for the various cover types. Some polygons may not be homogeneous, e.g., areas classified as pasture may have fences, hedges and individual trees or small groups of trees which would all increase roughness but which have not been taken into account.

(iv) Uncertainty about the ground cover at the time of the calibration flood as the cover was taken from recent aerial photographs. This could affect the hydraulic roughness of the flood plain and the extent of vegetation adjacent to the river fairway and the width of the fairway.

(v) Uncertainty as to the flood levels and locations as recalled by Pā residents. While there is more confidence in some levels than in others there appears to be incompatibility between some readings.

(vi) Uncertainty as to the degree and timing of debris obstructions on the bridge piers.

5.4 Sea-level rise mapping

Climate induced sea-level rise (SLR) and projected coastal inundation extents for long-term changes in mean and extreme conditions across the coastal margin around the Opihi River mouth were investigated for 2040AD and 2090AD[25]. In this study, SLR projections of 0.4 m and 0.8 m for 2040 and 2090 were selected. This is consistent with the risk-based approach suggested by the Ministry for the Environment in their 'Guide for Local Government: Preparing for coastal change' (MfE, 2008b)[26]. While large sea-level rise scenarios above 1 m are generally considered as having lower probability during the 21st century, they cannot be ruled out based on current scientific understanding.

During the 20th century global sea-levels increased by an average of 0.17 m ±0.05 m (1.7 ±0.5 mm/year rise) (IPCC, 2007). Between 1963 and 2003, the rate of global sea-level rise was 1.8 mm/ year (1.3 to 2.3 mm/ year) and between 1993 and 2003 it was 3.1 mm/year (2.4 to 3.8 mm/year). Whether this recent faster rate reflects decadal variability or an increase in the longer term trend (or both) is at present unclear. There is limited information available yet on whether acceleration in global mean sea-level rise has commenced. In New Zealand, tide gauge records from our four main ports average out to a linear rise in relative mean sea-level with respect to the land surface of 1.6 mm/ year (or 0.16 m per century) over the 20th century (Hannah, 2004). Up until 1999 (when the last formal analysis of sea-level was conducted) no statistically significant long-term acceleration was detectable.

[25] The Temuka River joins the Opihi River and the lower Opihi River flows into the ocean.

[26] The MfE guidance recommends for planning and decision timeframes out to the 2090s (2090–2099): (i) a base value sea-level rise of 0.5 m relative to the 1980–1999 average should be used, along with (ii) an assessment of the potential consequences from a range of possible higher sea-level rises (particularly where impacts are likely to have high consequence or where additional future adaptation options are limited). At the very least, all assessments should consider the consequences of a mean sea-level rise of at least 0.8 m relative to the 1980–1999 average. That is

Opihi River mouth and coastal inundation

The Opihi River mouth is connected to the open coast through a coastal lagoon (also referred to as a hapua) enclosed by a gravel barrier with associated outlet channel(s). Such lagoons consist of mainly fresh water, and are common at the mouths of many braided gravel-bed rivers along the east and south coasts of the South Island of New Zealand (Kirk and Lauder, 2000). They are often oriented coast-parallel with outlets that can be offset by a considerable distance from the river mouth. Configuration of the outlet channel is influenced by river flows and wave energy – that is, rivers with low and moderate flows are generally subject to long periods of wave dominance, and result in frequent changes in outlet configuration, while rivers with high flows tend to maintain a stable configuration for extended periods of time (Hart, 2009). Most coastal lagoons in the South Island also occur on long-term eroding coasts, and typically these coastal systems respond by moving landward through coastal erosion with little change in size and shape (Kirk and Lauder, 2000). Leckie (2003) suggests an erosion rate of 0.63 m/year for the Orari Coast. The Opihi River mouth is also understood to be experiencing similar dynamics. Todd (1983) confirmed the area occupied by the Opihi Lagoon has decreased by two thirds since 1866 due to barrier retreat as well as truncation of parts of the estuary by the construction of stopbanks.

Water levels in the Opihi Lagoon are dependent on both river flow and sea-level and to a lesser extent on wave height. During periods of high wave energy, water can spill over the barrier, causing seawater to enter the lagoon. The lack of an existing water level record for the Opihi Lagoon makes it difficult to establish a direct relationship between lagoon and open sea-water levels, but observations from similar lagoons such as the mouth of the Conway River suggest that lagoon levels mimic tide levels fairly well as long as the outlet is open (Golder Associates, 2010) whereas at the larger Rakaia River mouth, lagoon low tide levels are suppressed and high tides elevated somewhat by the velocity head through the entrance channel (Goring, 1984; Goring and Valentine, 1995). This assumption of closely related lagoon water levels and the open sea is considered reasonable for situations where the outlet channel is open to the ocean since the ocean. When the outlet channel stretches over a long distance or velocities through the entrance channel are strong (e.g., Rakaia River mouth), tidal influences on water levels in the lagoon may be somewhat moderated. In the case of the Opihi Lagoon, while the position and length for the outlet channel is understood to vary, it nonetheless remains open most of the time (Todd, 1983).

Flooding at the Opihi River mouth and the surrounding coastal land occurs mainly as a result of raised water levels in the lagoon when high tides and storm surge couple with elevated river levels (Todd, 1983; Kirk and Lauder, 2000). Since the projected sea-level rise estimates of 0.4 and 0.8 m for 2040 and 2090 respectively do not overtop the current levels of the beach barrier, it is assumed that any inundation resulting from elevated sea-levels will be primarily dependent upon water transfer to the lagoon through open channels in the coastal barrier. As sea-level rises, the gravel beach barrier is expected to adjust in height and position maintaining a configuration similar to current conditions. The sea-level is crucially important to Opihi River flooding because the high tide range governs the magnitude and likelihood of coastal inundation, especially when combined with storm surge (and waves/swell), or where storm-water, river or stream network levels back up during high intensity rainfall events. The level of the sea also determines the degree to which waves may be depth-limited at the coastline, and hence, is important in determining factors such as the magnitude of wave run-up and overtopping of natural coastal defences. Note that consideration of wave influences on coastal inundation is beyond the scope of this study.

High tide and extreme water levels

The Mean High Water Spring (MHWS) level exceeded by 10% (MHWS-10) of all high tides was used as a baseline to determine the present-day coastal inundation extents. This upper-tide level in Canterbury is governed largely by a combination of the twice-daily lunar tide (M_2) and the effect of the Moon in its perigee[27] (N_2) as it travels in an elliptical orbit around the Earth each month. The solar tide (S_2) is much smaller, so the fortnightly spring/neap tides are much smaller than the higher monthly perigean tides in Canterbury. Relative to Lyttelton Vertical Datum-1937[28] (LVD-37), the MHWS-10 for Timaru based on astronomical tides for current sea-level is 1.13 m (Figure 16). Based on the NIWA Tide Forecaster, the tide range off Opihi mouth is only about 1 cm larger than at Timaru. MHWS-10 was used as the current baseline and future sea-levels were determined by adding assumed sea-level rises of 0.4m by 2040 and 0.8m by 2090 resulting in 1.53 m for 2040 and 1.93 m for 2090 above LVD-37.

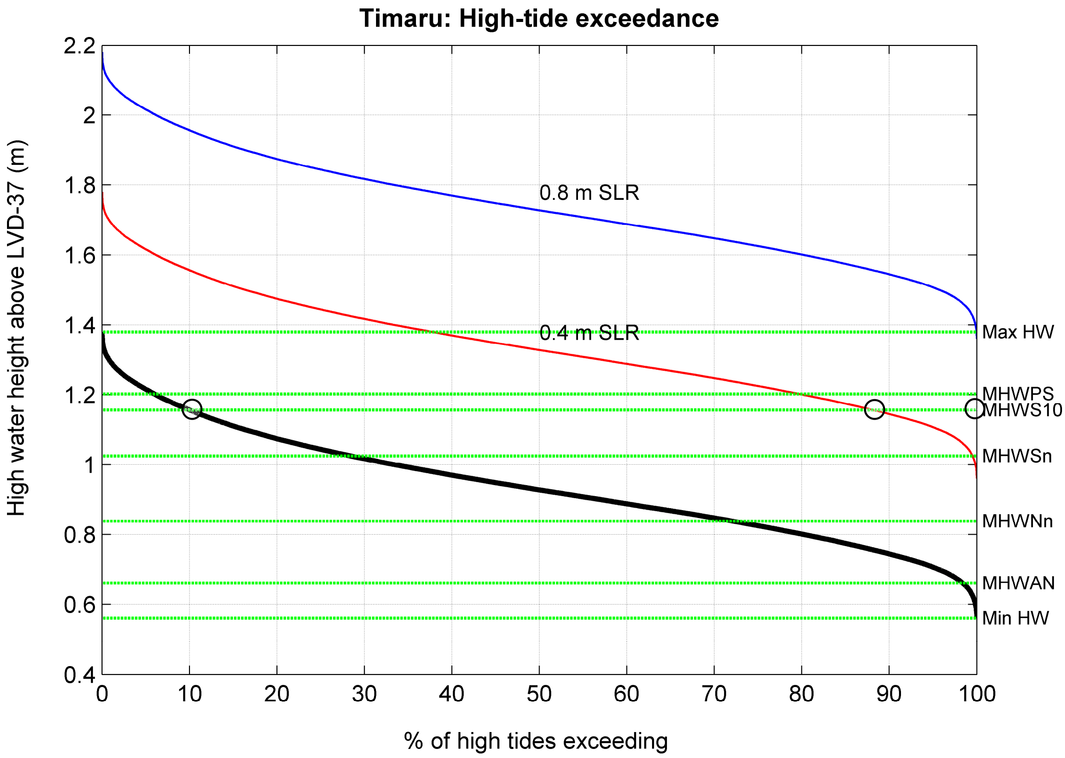

Figure 16: The predicted high-tide exceedance curve for Port of Timaru for present-day high tides. This is based on predicted astronomical high-tide levels and excludes non-tidal components such as storm surge and wave set-up and run-up. Note that the present MHWS-10 level of 1.156 m (exceeded by 10% of all high tides) will be exceeded by 88% of all high tides with a 0.4 m SLR - see circles where it intersects the present MHWS10 line and exceeded by 100% of all high tides once sea-level rise exceeds ~0.6 m, leaving aside any long-term morphological change.

[27] Perigee is when the Moon is closest to the Earth during each month's orbit

[28] For the Canterbury region, the local vertical survey datum is Lyttelton Vertical Datum-1937 (LVD-37), which was derived in 1937 from measurements over 9 years (1917–18, 1923–27, 1930 and 1933). Due to sea-level rise over the intervening period, the present mean level of the sea is several centimetres higher than the zero height for LVD-37.

To map the progressive extent of coastal flooding as a result of sea-level rise, the MHWS-10 tide levels for the present, 2040 and 2090 were overlain onto the LiDAR derived topography of the coastal plain. Areas with land elevations below the relevant MHWS-10 level were assumed to be inundated and areas with elevations above MHWS-10 level were assumed to be dry. It is acknowledged that this technique is a simplified approach and only accounts for potential coastal-related (saltwater) inundation. It is likely when high flood flows and high tide or sea levels combine this may result in a larger inundation extent. The inundation extents shown in Figures 21 and 22 should therefore be viewed as normal future high tide extents when the Opihi River is not in flood.

A further set of coastal-related inundation scenarios was also calculated, associated with an extreme tide level due to storm conditions with a 1% Annual Exceedance Probability (AEP) or an average recurrence interval of 100 years. The 1% AEP storm tide level was estimated from an extremes analysis of observed sea-level data from the Port of Timaru tide gauge (Goring *et al*., 2010). The extreme storm-tide levels incorporate not only the astronomical tide but also storm surge which is the local response of the ocean to changing atmospheric pressure and wind conditions. In New Zealand, changing atmospheric pressure is typically the dominant cause of storm surge, but adverse winds (easterly and southerly quarters for Canterbury) can also cause a local increase in sea-level. The 1% AEP storm-tide level calculated for the present-day was 1.72 m above the 1937 LVD. Assuming climate change does not result in any significant change in storm-surge characteristics, the corresponding 1% AEP storm-tide level for 2040 and 2090 is 2.12 m LVD-37 and 2.52 m LVD-37 respectively.

6 Exposure, sensitivity and adaptive capacity

This section comprises the results derived from the analysis of individual, paired- and group interviews with members of the community from Arowhenua Pā. Current (and past) exposures to climate hazards and change (includes coastal and fluvial processes) are identified based on participant observation and collective experience (assisted through a participatory mapping exercise) and information derived from the review of secondary sources in Section 2.3. Connected with this phase of interviewing, the role of current coping and adaptive capacities is also explored – which necessarily includes consideration of the social, economic and cultural factors that influence community sensitivity to coastal hazards and change. Again, the aim here is to develop an understanding of how people interact with the environment and to characterize the role played by biophysical and human processes.

6.1 Exposure to climate hazards and change

Questions surrounding the nature of climate hazards and change that *whānau* and individuals have to deal with in and around Arowhenua Pā (including surrounding settlements), led to in-depth discussions over river flooding and associated storms – including reference to high-winds, gales and heavy snow-falls. To a slightly lesser extent drought and the accompanying impacts of lower river levels, drying springs and fire risk were also identified. A number of community members also acknowledged the increasing coastal erosion (and land-loss) due to storm surge and large waves as an important but sometimes overlooked climate related hazard and stress.

From 35 participants that took part in the first round of interviews 30 regarded flooding as the most prominent hazard issue facing the community. This recognition was declared through personal accounts of recent flooding at Arowhenua Pā as well as at other points along the Temuka and Opihi Rivers (including tributary streams and water-ways). The frequency of occurrence and the relative size of one flood event to another were often remarked upon – as well as historical stories about extreme conditions based on the lived-experiences of older family members. Some of the testimonies below illustrate the diversity of experience, perceptions and knowledge surrounding the risk and exposed nature of local places and *whānau* in and around Arowhenua Pā to flooding (See also: Figure 17):

> *"The only danger that we've got is this river [Temuka] here" (9 December, 2010).*
>
> *"An old kōrero [account, narrative] that I've been told is when the very first settlers came in here and were living in this area, they were told don't build here and here because it floods… Our people knew where the safe ground was" (8 December, 2010).*
>
> *"There was an old Irishman who married one of the Māori ladies and he used to live down there and stand on the banks of the river and say 'see the silly bastards? They want to put a pint of water into a half pint jar' (laughs). That was when the Catchment Board started straightening the rivers". (9 December, 2010).*
>
> *"It floods about 3-4 times a year. This year alone, that paddock [over there] would have filled up and covered the road 4 times" (8 December, 2010).*
>
> *"The people who put us here made a good choice - its dry. And like most Māori they picked a good spot to live in rain, hail or shine" (9 December, 2010).*

Underlining many of these accounts a number of participants commented upon the physical location of Arowhenua Pā – emphasising that some *whānau* were physically more exposed than others because of their homes being situated on low lying areas across the Pā, while also proudly pointing out that Te Hapa o Niu Tīrini Marae is on the highest point in the local area and that to date this has saved it from being inundated during the most extreme flood events. Questions however remain about how it might be affected in the future as climatic conditions and regimes change. Furthermore, a number of participants remarked that they had 'always' lived under these conditions and that it was *manākitanga* and *kotahitanga* [togetherness] that helped people 'deal' with the adverse moments and challenges posed by different flood events. In spite of this, one of the well-known risks (and fears on occasion) associated with flooding for *whānau* at the Pā and at other more isolated settlements relates to access being impeded by flood waters and therein a heightened risk for *whānau* who find themselves in trouble. For instance:

> *"I was trying to get my family out of the flood. We came through here and all the fences were across the road and there was all sorts of debris out through there" (8 December, 2010).*

> *"Well [during] that flood the south end of the bridge went completely so we couldn't get to people with food" (8 December, 2010).*

> *"Pā road gets water across it locking in whānau west of the Marae. Also, the Marae area gets marooned if both rivers [Temuka and Opihi] flood" (8 December, 2010).*

Interestingly, human modification of the environment was widely considered as having amplified community exposure to flooding risks. Many participants spoke of the construction of stop-banks along local rivers and the consequences of this for flood vulnerability and ecosystem well-being. The large amount of land modification that has occurred in order to accommodate the growing agriculture industry in the area has also led to widespread draining of wetlands and water abstraction for irrigation. A number of interviewees considered many aspects of these activities to be causing erosion and general degradation of habitat for *mahinga kai* species. The remaining unmodified areas/resources are therefore all the more important to Ngāti Huirapa. Some key commentary on these themes includes:

> *"Probably the thing that's changed is the stop banks [which] have made the problem worse. It becomes a real hazard…dangerous because the river [Temuka] was straightened" (8 December, 2010).*

> *"We get floods because they've put stop banks on the north side of the river to protect Temuka but they haven't done anything down this side of the river. Down where we are at Waipopo there's a bottleneck down there when the floods come through and it goes over the stop-banks either one side or the other" (Wednesday 8 December, 2010).*

> *"They put stop-banks here and here (indicates to map) but they were putting it in the wrong places. The way they were putting it was pushing the water back to this side and then we started complaining. And when they put in another stop-bank it stopped the water from coming into the river and it banked up and went right back through the [Temuka] town" (9 December, 2010).*

"It was all wetland here. The whole place was drained by the Pākehā for where they lived. They lived in swamps and drained the whole lot to make towns. On the bottom side of the river and they'd get flooded out every time the floods come up and over the top of the banks and through the main streets" (9 December, 2010).

"It's a risk that we created too, we can't just blame climate you've got to put it down to human error too" (10 December, 2010).

Incidentally, a small number of participants viewed flooding not as a hazard but rather as an 'opportunity' and perhaps even more importantly as part of the 'natural order' which helps to maintain the integrity of the water-ways and the life-forms that depend on these systems. These sentiments are conveyed in the following statements:

"There were advantages before they had the stop bank down there for us as well because when our whenua started [to flood], Dad used to say 'right go and get the sacks' and we used to go and pick up the tuna that were left stranded out in the paddocks… Yep and we're not talking about one or two I'm talking we were filling sacks, either side of the lagoon, somewhere in that area (indicates to map) it was a good time to get easy pickings" (8 December, 2010).

"Flood events bring out the tuna and 'cleanse' the river of debris and 'paru' [dirt, mud] (8 December, 2010).

In contrast to the flood hazard, almost all interviewees recognised the potential harm for *whānau* and the wider community from drought which often included discussion of the physical impacts such as low river-levels, drying springs and wells, fire, heat-stress as well as the adverse social impacts on local farms and agricultural businesses. On the one hand it was accepted by a number of interviewees that drought has always been a part of living in this region, but on the other these interviewees remained mindful of the influence of human activities and current land uses which they consider to have increased the severity and frequency of the droughts experienced.

"The other change I see is in the water tables. You see puna [springs] and small awa [streams, rivers] drying up now which never used to be dry" (8 December, 2010).

"The dairy farming and increasing of irrigation which is lowering our rivers if not drying them up at crucial periods and our puna are drying up so these are all contributing factors to the diminishing kai that is available" (8 December, 2010).

"It could be climate change but there's also the aspect of water take from industry and irrigation and all that. It plays a major part of it - but it's still happening... There is a creek down at the Puhurau. Last year was the first time I've ever seen it dry in my life. To me our weather patterns are all up-the-wop. They've changed so much, our winters used to be bitterly cold, hard frosts going through from April-May right through. Now we have these balmy winters and a small window of frost and we're having north-westerly's during winter when we normally have north-westerly's this time of year. All those weather patterns seem to have changed" (8 December, 2010).

"We would camp down there and sleep under the bridge, we could jump off the railway bridge and into the river in those days because the river was so high in those

days it was bank to bank. Today it's a mere trickle, it is so sad" (10 December, 2010).

A final climate related hazard that *whānau* and individuals have to consider and deal with is increasing coastal erosion from storm events, leading to loss of land, *wāhi tapu*[29] and traditional *mahinga kai* areas. A small number of *whānau* continue to live close to the coast and some multiple owned land-blocks in Māori title are also located along the coastal margins. Much of this *whānau* owned land is currently being leased to non-Māori farmers, however, there are instances where leasable land is being lost to the sea through erosion. The risks were identified to have increased in the last 10 years – with concern centred on what this might mean for future safety and longer-term economic opportunities. For example:

> *"I tell you what - there is erosion though. I should say they've lost about 10-15 acres along the coast. People don't worry about it but the farmers are paying..." (10 December, 2010).*
>
> *"Raukopoka [Māori owned land – 'Reserve' status] is on the seaward side and Kapunatiki is on the other side, it goes out on that road there that comes in as a big paddock. But it's being eroded away" (8 December, 2010).*
>
> *"The sea is coming in at a fast rate; we're losing the lagoons and the coastal wetlands" (8 December, 2010).*
>
> *"Now there used to be tracks that we could walk along the beach, the sea's so high now it's eaten the bank away so we are affected by climate" (10 December, 2010).*
>
> *"The old people say that it's from the time that they dammed Waitaki River, that the shingle that came out of the Waitaki naturally came along the coast and built our coast line up and it's in a natural drift northward that coast line. Timaru built a breakwater. If you look along the south side of that it's built up with shingle right the way along. We believe that is robbing the coast line here of the shingle that needs to keep going" (8 December, 2010).*

Note that discussions also regularly covered concerns about earthquake risk. This was not unexpected given the occurrence of recent events (2010 and 2011) in Christchurch City. These details are not provided within this report.

[29] During engagements throughout this study *hapū* members shared considerable *kōrero* about the location of *wāhi tapu* [revered place, shrine]. This information is regarded as private; therefore, specific details surrounding *wāhi tapu* have not been made available in this report.

Figure 17: Community identified social-ecological risks from climate induced hazards and change.

6.2 Determinants of community sensitivity and adaptive capacity

Four principal themes emerged from the analysis of community interviews which focussed on the ‘things’ that contribute or influence the degree to which people find themselves directly and/or indirectly affected by climate hazards and change. These themes emerged through sentiments that appeared repeatedly in the interviews; and therein represent the things that people recognise as barriers, challenges and strengths. The matters discussed often intersect environmental, economic, social, political and cultural aspects of community life; and there is considerable over-lap between the themes, which reflects the interrelated nature of social and biophysical processes. Drawing lines between such themes was sometimes an exercise fraught with never-ending exceptions. In spite of this, the authors isolated the key determinants in a way that helps to make sense of community sensitivities and adaptive capacity.

The key determinants considered in this section include:

- Social networks, conventions and transformation
- Knowledge, skills and expertise
- Resourcing and finance
- Institutions, governance and policy

6.2.1 Social networks, conventions and transformation

The importance of social networks, related cultural conventions and community change were often referred to when questioned about the ‘things’ that influence the degree to which people find themselves directly and/or indirectly affected by climate hazards and related stresses. A key feature often shared by Arowhenua community members was the intricate network of social relationships that exists internally between *whānau*, *hapū* and iwi, as well as externally with government authorities and agencies across a range of scales. The complex network of whakapapa-based relationships within the community was widely recognised as an important aspect of setting and achieving collective goals, facilitating mutual support and collective action to cope with challenges such as adverse climate conditions and associated stresses, as well as a fundamental element of *tikanga* (traditional values) and thereby community well-being. For example, one participant assessed the coping capacity of each sector/or grouping of the community by distinguishing who resided in the dwellings of the area and whether there were enough young people to respond to the needs of the *kaumātua*.

> *“We’ve still got whānau around that can get to each other which is good, we’ve still got a lot of whānau at Waipopo that can access each other in times of trouble, [whānau] that are young enough still to do it and to look after any kaumātua that are in the area. [Indicating on the map]…around here is the same, when I say around here I mean over the bridge and into the township, we’ve got enough young ones around and not so young and kaumātua that they can keep an eye on each other. Around this particular block it isn’t too bad…It’s always informal” (10 December, 2010).*

Many of the interviewees believed groups such as the Arowhenua Mātaitai Roopū, which was established in 2006 to conduct cultural and environmental assessments of the waterways across the Arowhenua area, were a good example of internal relationships bringing people together to ‘get things done’. Furthermore, the *marae* was acknowledged as a key element in establishing and maintaining internal relationships through the traditional principals of *whakapapa* and *whanaungatanga*:

> *“The skill-set you learn back on the marae with your poua [grand-father] and taua [grand-mother] and with your kaumātua have been one of those precious things in your life, you know when you talk about role models and for me my kaumātua have had a very special part for my upbringing and to be…” (10 December, 2010).*

The concepts of mutual support and collective action were identified as the primary coping mechanisms applied at the individual and household level, where these informal relationships assisted short term coping mechanisms such as sharing energy (when electricity was cut off), water during times of drought or shelter when infrastructure was compromised.

> *“I think that we would be much better prepared than some people living up around here. If you were really starving you wouldn’t starve because we’d manaaki each other… And again that’s about the relationships that we have within the hapū” (10 December, 2010).*

> *“I think we cope with anything that comes along because we’ve had to; we’re brought up like that. There’s the old saying ‘don’t sit there and cry, do something’…That comes from our parents who were bought up with it before us, they showed us how to go about and what to keep an eye out for and what hazards to look for, that all comes from our folks…It was that kaupapa [plan, policy, scheme, agenda, subject, programme] that has pulled us right through even until today and we’re handing it right down to ours. How to do it, who to look for afterward, what we have to do, the most essential things and we’re still doing it” (8 December, 2010).*

> *“When the teko [waste, effluent] hits the fan, everyone, doesn’t matter who you are, everyone joins in together to look after each other” (8 December, 2010).*

Notwithstanding the high value placed on internal relationships which exist within the community, a small group of participants expressed unease when discussing the status of internal relationships. These interviewees were not convinced that all *hapū* members were encouraged to engage equally in the decision making process and questioned the effectiveness of some of the formal structures which were currently in place. Further, a couple of participants expressed some uncertainty regarding the criteria used during internal elections for *hapū* representatives. These interviewees believed the skill set held by some of the past and present elected representatives lacked practical experience and knowledge of both the local ecology and its cultural significance on the one hand as well as the rapidly changing character of economic and political realities taking place beyond the borders of the Pa. In spite of these criticisms, it must be noted that other interviewees acknowledged the importance of maintaining an accountable and legitimate decision-making process – one that is rooted in the past and the present. Furthermiore, these interviewes recognised that the complex ideological spread of the *hapū* was also a potential barrier to achieving total consensus at every point.

Interviewees spoke also of the complex relationships with external actors, and the important role that relationships with these external actors can play in local development and planning, regulation of human-environment interactions, provision of infrastructure, technology and information, as well as management of community risk. Maintaining existing relationships based on trust and respect as well as forming new relationships was highlighted by a number of participants as a priority for Ngāti Huirapa.

> *"Continued efforts in this area are vital to iwi development and well-being" (22 September, 2011).*

> *"You have to have the ability to be able to rip into someone, but at the end of that kōrero, that raruraru [problem, trouble], you walk away with your mana and that person still carries their mana...but they have a clear understanding that there will be changes and that its actually not detrimental to their aspirations" (23 September, 2011).*

Further, there was extensive discussion surrounding the need for equality in all external relationships, however, many participants felt that existing arrangements often fell short of success as conflicting values and unequal power arrangements caused conflict over development pathways and management of the environment. Further still, there was a widely held feeling of frustration among many of the participants as they felt that Māori were expected to recognise and comply with Pakeha societal values, structures and rules, while the Māori world view was often misunderstood, dismissed or paid 'token' regard. This is illustrated in the following quotes:

> *"I've been involved in the marae for many years ever since I was a kid, listening to the old people. We're still fighting for the same things today, we're still fighting for the same values today and it's being overlooked, not heard, ignored, you feel like you're banging your head against a brick wall. Money rules everything and it doesn't matter what we think. We're pushed aside and put in little boxes" (8 December, 2010).*

> *"Probably 80 % of those people that want to have a relationship really just want to tick the box, so that they are compliant with the Treaty of Waitangi." (22 September, 2011).*

> *"I have to wonder exactly what motivates some of those politicians or people who have a bit of clout…what motivates them to keep coming back and having consultation with us. Because they don't actually take our kōrero and opinions anywhere…or nowhere that we can see. [They just come] to tick their boxes and say that they have been [to consult with us]" (22 September, 2011).*

A couple of participants also raised the issue of staff turnover and structural change within external organisations as a barrier to sustaining effective relationships. For example, the realignment of positions or change in personnel within external groups often means the goodwill, trust and understanding which has been established (often over a period of many years) moves with that individual, thus, the relationship is often lost and the process of constructing a new relationship with a new individual must be created again.

> *"You may build a relationship up with a structure, say within ECan…and you've built this lovely relationship up and suddenly the committee is gone… staff have disappeared and the people that you've had a 10 year association with are gone…and you have to go back and build a whole new thing up. So that's a common thing" (22 September, 2011).*

Interestingly, personal and informal relationships with individuals within external organisations were identified as more practical ways for the community to get past the systematic issues which slow down progress and/or interfere with finding solutions. One participant referred to such relationships as ‘fast-tracks’ but also identified ‘long-tracks’ (more formal) relationships as needed so that when an individual leaves an organisation your relationship doesn’t go with them. Trust was identified as the key to creating and maintaining all of these different relationships.

Notwithstanding these frustrations, a number of participants reported good relations with the various authorities in their area, and this led onto recognition of a change that has taken place within external organisations that is helping to produce more effective relationships.

> *“What we are finding…is that we have a lot of young ones coming through now with the degrees and all the different areas and stuff who have been through that education system at university and high-school and they have been involved with things Māori... They actually have, not a complete, but a bit of an understanding of where we are coming from. Some of them of course think they know a wee bit too much, but a majority of them are easier to work with than the guys we were working with 20 years ago who were just straight out red-necks – and we were nothing” (23 September, 2011).*

Note that inherent within many of these conversations, the effort and resources required to achieve and maintain sustainable and meaningful relationships with external entities was recognised as an on-going challenge. Further consideration of this determinant is provided in Section 6.2.3.

A common thread to run through many of these discussions was the changing character and structure of the community at Arowhenua. According to many accounts this phenomena has occurred relatively rapidly - in the space of one to two generations - in line with wider social, economic and technological transformations that have taken place across New Zealand. The implications of these changes for community vulnerability and resilience to climate related hazards and stresses are wide ranging – but nonetheless, when reflecting on the things that either enable or make it difficult to deal with climate related hazards and stresses, commonly interviewees touched upon the tensions and challenges surrounding greatly altered living arrangements and the associated decline in social networks, environmental relationships and traditional values.

> *“We were like little villages – it was a different way of life, a better life because everyone knew everyone and they were always talking to one another…it changed in a short space of time…” (23 September, 2011).*

> *“I think you need to realise that in the past we were not all working so the community was bigger and you had more aunties and uncles all around. It was a community. As children growing up we could go to any house you wanted and we were safe – and you knew which ones weren’t safe too. So that whānau, hapū, iwi stuff that was gone when we all started heading into town to go working…you need two people today to work just to eat…” (23 September, 2011).*

"The fact of the matter is…for people to survive they are going to have to leave here…unless Christchurch moves South a little more" (23 September, 2011).

Emphasis was also placed on the present composition of the Pā community which in recent years has seen many families migrate to cities and urban areas (such as Temuka and Timaru, and further a-field to Christchurch and Australia, among many others), and thereafter many younger people spending more time away for secondary and tertiary education as well as employment opportunities. These demographic changes were acknowledged to have impacted unfavourably upon internal relationships as well as the connected values of *manaakitanga*, *whanaungatanga* and *kotahitanga* that traditionally ensured people were cared for in times of hardship or adversity. These values have not disappeared but the declining numbers of *whānau* in and around the area challenge the maintenance of such traditional conventions.

"…you like to keep your whānau close and teach them some of the things you were taught… But because of the way we are now…most of your children end up going to high school and heading away and going to other places. So you don't get the close-knit whānau like you use to have. When I was a kid – we would go to school and then Monday night we were all here on the Marae…each night we were here and then we would go straight from here to school and we would be here for the whole weekend…So we were always here, we were with the old people and everything else [that went with being on the marae]…which we don't see here now. I mean the biggest social [change] I've seen here is that there's no children on the marae… The young people aren't on the marae. We see them come on every now and again, either at a tangi or some function that's here, but that's the only time we ever see them…So therefore the values of the marae and everything else are really up to the whānau themselves to try and keep going. And it's pretty hard when you haven't got that social structure" (22 September, 2011).

Other transformations in community lifeways identified by interviewees included decreases in Māori-owned land holdings, a growing reliance on modern services, markets and employment, and increasing individualism. Together these changes are commonly understood to have created new tensions as well as contributed to the decline of traditional ways of being, including knowledge of wild-*kai* and closer human-environment relationships that previous generations have relied upon to cope and adapt to past stresses and challenges. Drastic alteration of the physical environment and increased competition for resources from a growing agricultural industry and new 'community' members have also affected the way the community can engage with traditional lands, waters and other resources.

6.2.2 Knowledge, skills and expertise

Consideration of how the community deals with, and is affected by, climate hazards and related biophysical changes resulted often in focussed discussions surrounding the loss (and significance) of *mātauranga Māori* [Māori knowledge]; the benefit of contemporary science, education and new skills; and, shortages in community capacity and expertise (includes leadership) to deal with the increasing complexity (and number) of challenges being faced by the community.

The loss of *mātauranga Māori* and the accompanying decline of environmental skills and cultural practices that previous generations have relied upon to guide awareness and manage environmental risk as well as cope with (and adapt to) past climate related stresses and challenges was echoed on multiple occasions by many of the interviewees. In particular, the loss of knowledge surrounding *mahinga kai* (species and techniques) and the *kawa* and *tikanga* associated with such practices dominated these discussions – with associated acknowledgments frequently made of the importance of such knowledge and traditional skills for overall well-being and community resilience:

> *"There are a lot of whānau here who don't go out and get kanakana and therefore their children don't know. There are a lot of people who don't even know when to get kanakana. It's the same as bobbing. Bobbing was done greatly in this area; there was tikanga and kawa as to how you make a bob, what you do to make the bob, what the women do when they make a bob..." (8 December, 2010).*

> *"A very good example is down at the Hui ā tau [annual Ngāi Tahu meeting] we were given this kai, kai that was koha'd (sic) [gift, donation, contribution] to the marae. A huge percentage of our whānau didn't know how to cook it, or even what is was… [I had to say] 'These are kanakana', (then they asked) 'Oh what are those?' So I had to actually take one out, show them what a kanakana was and then give them cooking lessons that night and show them how to cook kanakana, and how to pawhara tuna [process of preparing and drying fish]." (8 December, 2010).*

> *"For me on a personal level, all these [environmental] impacts [mean] I cease to be able to live the life that I know. It impacts getting my kai, it impacts on my wairua, [and] it impacts my mana…. your ability to tautoko your mokopuna [grandchildren] in the ways that you've been bought up by your Poua and Taua and your whānau…. Āe, and it impacts on my ability to manaaki this marae, to uphold the tikanga and mana of this marae. Now if that all disappeared, the ability to [provide], then it's pointless me being here, because that's what I am" (8 December, 2010).*

Many of the interviewees commented in depth about the significance of maintaining a cultural connection to the environment through *kai*. Participants referred to *kai* as something more than 'food', describing the act of collecting and consuming traditional kai species (although significant in its own right) as key to the transfer of *tikanga* and *kawa* and therein cultural well-being and community resilience:

> *"Well it's so important, because your reo [voice or language] is supposed to express your culture, and if your culture is mahinga kai you need that mahinga kai to express your reo" (10 December, 2010).*

Frustration among interviewees was common (including deep concern) about the drastic alteration of the physical environment and increased competition for resources which has affected the way the community can engage with traditional lands, waters and resources. These challenges were identified as affecting the upholding of *tikanga* and *kawa* and therein responsibilities of *kaitiakitanga* [stewardship, respect, identity] and *manākitanga* as well as concomitantly the maintenance and inter-generational transfer of *Mātauranga Māori*. Transmission of such knowledge to the next generation is regarded as an important part of ensuring that Māori lifeways continue and that *whānau* are able to sustain themselves and keep safe.

"…because that kai's (sic) not there, whānau have lost the ability to teach the tikanga and pass it on…cultural practice" (8 December, 2010).

"Till I take my last breath, my whole focus in life is…I need to make decisions for my moko's, that's all I do. I make my decisions so that my moko's will benefit from it. In making those decisions I need to train those moko's as well in what I'm talking about. So that they hand it on to their moko's…it's like a working document. Mātauranga is a working document that needs to carry on…" (9 December, 2010).

***"**We've just got to make sure that we keep our kōrero up to the mokopuna" (23 September, 2011).*

Notwithstanding these commentaries of loss, some of the participant's spoke of the accumulated knowledge they held as a community of local hazards and environmental processes. High risk areas and traditional safety zones were identified (See: Figure 17) as were abilities to ready and prepare the *whānau* for hazardous conditions by maintaining awareness of environmental signs that indicate when extreme weather/climate conditions and associated impacts are imminent and most likely. Together with collective-based values and conventions, these insights and skills were widely recognised as the 'Māori-way' of managing risks and mitigating harms.

"I think our old people knew where they were living; they had plenty of time to study the weather and the conditions they live in. I think they picked probably the best place in the district" (9 December, 2010).

"I think every generation has been bought up with floods in this area and that's just become a part of us" (8 December, 2010).

It is important to acknowledge at this point, that with increasing numbers of Ngāti Huirapa (particularly younger people) spending more time away from the Arowhenua area for work and education, that new knowledge, skills and expertise are being acquired. Many of the *kaumātua* spoke of a marked change in skill set and knowledge held by the younger members of their *whānau* and the positive contributions these young people were making (and would make) to the community. For example, one *kaumātua* had four grandchildren who had been to university and attained degrees in varying disciplines.

"There's more mokopuna who have gone to university and got degrees now…business brains running their own businesses. There's a big leap over the past three generations… About four of them have got degrees. It's a totally new world" (9 December, 2010).

It was acknowledged by many of those interviewed that the new skill set held by the younger generation is (and would be) needed to deal effectively with the increasingly changing environment, not only physically, but socially, politically and economically. Furthermore, a number of interviewees argued that new expertise and strategies for dealing effectively with complex challenges such as climate change were required, and that "business as usual" approaches were unlikely to be sustainable in the long term. However, most interviewees considered that there was a serious need to find ways to benefit from the strengths that come from advancements in modern science and technology as well as Māori knowledge of *tikanga* and *kawa*.

> *"…our young ones, I admire a lot of them, they are amazing young folk. I just get hoha [angry, frustrated] when it comes to the tikanga side of things and I think they get a bit hōhā with me too. But the two go together (education and tikanga), and we cannot keep going forward and keep pushing our tikanga back (23 September, 2011)".*

A closely linked sensitivity issue identified by almost all of those interviewed was the lack of community capacity to deal with a number of matters being faced (as well as the growing amount of information) and the related shortages in expertise (includes leadership) to interpret and respond to the increasing complexity of the challenges confronting the community. At present, some individuals and *whānau* are carrying multiple responsibilities, and while there are advantages of having *whānau* working across different community matters, the risk of 'burn-out' was recognised as high. Some of the following commentaries illustrate the nature of these challenges:

> *"We've only got a maximum of a dozen people here that can work on the marae and they are putting a hell of a lot of work in, and they go between one committee and another. So their time is taken up largely battling government departments….So inevitability… some of the actions you want to take don't get done, and when you step out of the loop, you get bypassed" (23 September, 2011).*

> *"…as you well understand most Rūnanga or iwi…the personnel that have the actual knowledge and skills in those areas are very fine on the ground. So what you've got is a whole lot of us overloaded…" (23 September, 2011).*

> *"…issues arise when you've got so many problems or so many areas to cover to come right…and then there are the resources, as in people that you don't have". (22 September, 2011).*

> *"Again, we haven't got the resources and the capacity to be able to deal with all of the organisations that want to 'have a relationship with us'. (22 September, 2010).*

> *"Our advantage is we've got people working for us on a mātaitai on our rivers as kaitiaki [trustee, minder, guardian, custodian] all of that about our coastal way of life and our forest way of life and our mahi kai way of life, but they've been there for years, who's going to follow them? Where's our next lot coming through?" (10 December, 2010).*

> *"We don't have enough resources in our community. They burnt our elders out - because they were fighting all their lives. I guess it's up to us to bring that leadership up alongside so that we have support… [10 December, 2010].*

Information and messages specifically about climate change were also often regarded as confusing, leading to misinterpretation and sometimes confusion. Knowing where to access the right information was raised repeatedly including questions over who to trust. For example, one participant commented it was hard to understand and process the information and decipher what is fact and what is fiction:

"I really don't know what to believe, I've heard so much for it and so much against it, I'm just staying neutral" (10 December, 2010).

Lastly, a select number of interviewees believed that the 'right' decisions regarding future community well-being will require drawing upon a range of skills and expertise that cross a number of disciplines including science, law, tikanga and language (among others). Further, acquiring new knowledge about climate change and increasing the skills and information for dealing with associated challenges were regarded by many participants as key priorities for Ngāti Huirapa. Notwithstanding these ideas one elder considered that enough is already known to make informed decisions about climate hazards and change and the associated challenges of more sustainable life-ways:

"There's enough knowledge out there to start making a good basis of what to do. This kind of knowledge [bio-physical science] and knowledge of tikanga and kawa... The other thing is a fuller understanding of our kaitiakitanga our manākitanga and our relationship with Papatūānuku and Rangi, Tāne, Tangaroa - all of them, because basically they're screaming out for our help. They're saying this is happening now, this is what's going to happen, if you don't do it, we're going to have to clear the field and it's as simple as that" (10 December, 2010).

6.2.3 Resourcing and finance

Insufficient resourcing and finance were identified by some of the interviewees as a key driver of how people are affected by, and deal with, climate hazards and related stresses. The three main topics discussed, included: financial investment to upgrade life-line services and substandard infrastructure within the rohe; employment type and associated income levels to prepare (ready for) and reduce risks associated with climate hazards and stresses; and focussed conversations surrounding insurance issues.

Concerns regarding inadequate resourcing of life-line services and infrastructure were echoed by a number of interviewees. Lack of maintenance and upgrades of essential life-line services were highlighted as critical to not only the reliability of these systems to handle changes in environmental conditions but also the capacity of whānau who rely on such systems to cope with climate hazards and events. Many participants recalled previous flood events and the resulting need for back-up provisions as essential infrastructure (including electricity, telecommunications, water and roading) were often compromised or even disconnected for prolonged periods of time. One participant recalled a major snow storm in 2006 which caused large-scale power outages for up to two weeks for many whānau living on and near to Arowhenua Pā.

"Civilisation was put on hold. It was from Aoraki (Mount Cook) down. All the way up and all the way down, right round... Ki uta ki tai [From the mountains to the sea]. All the power lines were down, most of the area was wiped out as far as electricity went, so therefore you were left on your own" (8 December, 2010).

The issue of rapidly diminishing water supplies was also strongly articulated when assessing which essential life-line services required upgrading and future-proofing. Historically water was collected from the Temuka and Opihi rivers by horse and cart until a pump was installed circa 1951, which provided running water to the Arowhenua Pā. Many of the homes now rely solely on springs, however with the intensification of dairy farming in the area, over allocation of water has become a central issue, affecting water availability for many of the whānau. A number of participants spoke of their springs completely drying up over the past few years due to less rain and an increase in farm irrigation systems. Subsequently, *hapū* members emphasised the urgency required in improving water storage infrastructure – i.e. installing water tanks, but noted the expense as a barrier to *whānau*. One participant, spoke of being unable to afford the expense of installing a water tank while stating that they (along with others in the community) had gone months without running water during the last summer.

> *"I would see the irrigators going flat-tack [at the farm next door] and we had no water at our house" (10 December, 2010).*

Purposefully many of the interviewees also took the opportunity to comment on the importance of reliable waste-water services. While there was overall agreement that the newly installed system at Arowhenua Pā is considerably better than the original systems (which simply discharged waste directly into the surrounding water-ways), there remained deep concern about the impact of flood events on the treatment plant in Timaru, which can lead to the holding ponds overflowing into the Opihi Lagoon. It was also noted that the newly installed sewage system was powered by electricity, thus in the event of a power outage the system would simply stop working.

In line with this, discussions also centred upon the vulnerability of *whānau* who occupy modern homes as they often relied entirely on electricity for heating, cooking and drawing water. Long standing residents of Arowhenua believed 'modern luxuries', such as flushing toilets, heat pumps and cordless phones meant whānau were more sensitive and less equipped to deal effectively during extreme events than they would have been historically. Participants stressed the wide reaching impacts of power failures, which can leave *whānau* exposed during such events. For example:

> *"Yeah all the neighbours with heat pumps came and stayed down at our place and sat around the potbelly stove" (8 December, 2010).*

A select number of participants also identified the most likely whānau to occupy these modern homes to be whānau who have recently returned to their *tūrangawaewae* [a place to stand, home ground through rights of kinship and *whakapapa*], thus they are often unaware of the need for practical alternatives.

> *[That family] "…has got a flash house with all the mod-cons, but when the power went off, that was it. After the snow they put in a wood burner and some solar heating" (8 December, 2010).*

Conversely, many *whānau* with homes in the Waipopo Huts area were identified by interviewees as being particularly vulnerable to river flooding. One participant spoke of the poor state of the roads leading into Waipopo (including delayed repairs and/or upgrades) as well as the highly variable standard of housing in the settlement. Low household incomes were identified as preventing many of the whānau from funding their own upgrades and therein future-proofing their homes from future extreme events.

In line with this, a number of participants discussed employment in Arowhenua, including the status of employment opportunities, the types of employment available, income levels and the sensitivity of these sectors to climatic related stresses, including extreme events. Many of the interviewees believe Ngāti Huirapa have been fortunate as Temuka has been able to sustain a certain level of employment for locals, which has been a crucial component in keeping *whānau* in the area. It was commonly held that agricultural sector based work had enabled a number of whānau to maintain a regular and tangible connection with their *marae*, as well as a physical relationship with their *tūrangawaewae* and surrounding natural resources. In maintaining this relationship mahinga kai traditions (within the bounds of the diminishing populations of *kai*) are able to be maintained and the knowledge kept alive. Whereas other surrounding *hapū* have had to move off their *tūrangawaewae* in order to find employment, moving from the surrounding small rural towns to cities such as Christchurch or Dunedin.

> *"Let's be perfectly honest about it. We're lucky in our hapū. We're close to work and we don't have to travel to Christchurch to get work. We've got the Meat Works, the Cheese factory, all sorts of work around us, so that's helped to hold us together here. If you go down the road to Waihou no one's down there. They're all in Christchurch. If you go down further to Moeraki there's very few people there. They're living in Christchurch or they're in Dunedin. So we're lucky in the fact that we're here, we're still able to stay on the land. A large percentage of us use the awa and the moana [sea/ocean], and get our kai the same as we always have. [We still] hold hui [meetings, gatherings] here and keep our system alive and that's for our following generations, but we've got to be realistic and say that if it wasn't for the industries that are here, maybe we wouldn't be here, maybe we'd have to move like everyone else" (8 December. 2010).*

Although participants recognised the value in having employment in the area, the climate sensitive nature of these industries was also noted. Many of the participants were employed in the primary sector including; farming, shearing, horticulture, and linked factory work. Thus, in the event of a drought or flood many of the *whānau* are affected by loss of work and associated reductions in income. One participant spoke of losing three months' work at the Freezing Works during a drought event, noting that the nature of employment and loss of income left his (and many other) *whānau* with little money to meet daily living needs, let alone afford preparatory measures such as regular house maintenance and/or insurance to help them deal with future climate related stresses.

> *"We have a higher number of our population in labour [occupations] rather than trained tertiary or professional areas of employment. There is a high number of Māori that are in labouring jobs such as the meat-works, fisheries, shearing gangs, working on dairy farms…those general labouring jobs. So when we have something like a drought or a flood, it does impact tremendously on the economy of our community - and, specifically on our Māori people" (8 December, 2010).*

Insurance was only mentioned by one person during the first round of group interviews where participants were asked to identify the *"Top 5 ways people are affected by a hazard event".* Therefore, participants in the second round of interviews were asked to elaborate on whether or not it was a priority for them, and whether they thought it was for others in the community. In response most participants believed that being insured was an important factor in being able to deal effectively with climate related stresses. Although the majority of those interviewed agreed that insurance *should* be a priority for everyone in the community, they were unsure how many whānau members across Arowhenua actually held insurance. Some believed it was simply too expensive to be a priority for families on low incomes, while two interviewees questioned whether some fully understood the idea of insurance and thereby considered education and perception to be a bigger barrier. The criteria required to gain household insurance was also viewed as a significant barrier for most *whānau*. Subsequently, it was assumed by interviewees, that many whānau had not, and would not prioritise it in the future. A few participants also commented on the age of many of the homes in the area and expected this (along with issues surrounding unconsented building) would affect the eligibility of some *whānau*. One participant even speculated that damage caused to property by a future climate related hazard event would only result in uninsured *whānau* facing increased financial stress as many are already under some degree of financial strain.

> *"[Whānau could be affected] emotionally, financially…. For those that have insurance that's fine, but for those who don't, it could be quite devastating. It puts more financial burden on a family" (8 December, 2010).*

In addition to these comments on insurance, a handful of participants rejected the idea of insurance all together. Their rejection was based on a lack of trust of not only the companies that provide insurance, but the fundamental premise of insurance being provided by people outside of the community who would likely not even recognise the person(s) actually being insured. One participant argued that traditional values such as *whanaungatanga*, *manākitanga, kotahitanga* and *tautokotanga* would be more responsive and reliable than any insurance policy.

> *"Insurance is a Pākehā kaupapa... If we were to work as whānau-whānau, whānau-katoa [whole family, extended family], and not whānau-iti [small family, immediate family]…insurance wouldn't be an issue. Because if you lost your house, you would be brought immediately to my house and set up and fed and looked after. So that's what I believe… that is the true insurance, whanaungatanga… If you've got whanaungatanga, if you've got kai, if you've got shelter, if you've got the ability to still go out there and mahi – that's about gathering kai…what else do you need in this world?" (23 September, 2011).*

Ideas such as these demonstrate the interconnectedness of these themes and reflect the importance of relationships within Arowhenua. Finally, while the challenge of community capacity was raised in the previous sub-section, there was also recognition given to the financial cost carried by *whānau* members that represent the Marae in *hapū* and wider tribal matters. Improved financial support was identified as critical to lifting the capacity of the *hapū* to develop expertise, participate in council and wider community processes as well as drive their own planning objectives and requirements – which includes management of climate related hazards and stresses.

6.2.4 Institutions, governance and policy

Discussion of the factors that influence the way people are affected by, and deal with, climate hazards and related stresses, led a handful of interviewees to question and comment upon the role of institutions (both Māori and non-Māori political and administrative institutions), governance structures (rules, regimes, procedures, administration and decision-making) and policy (plans, strategies and regulatory directions). Institutional structures and arrangements (across a range of Government authorities and agencies) were identified as having a determining role/ influence/impact on Māori life-ways and aspirations. Many of the participant's spoke of the role that local councils and government departments play in providing reliable infrastructure and resources for those most in need, setting resource use regimes and rules which often conflict with traditional approaches and practices, reducing community risk through policy and natural hazards strategies. The role of these institutions in facilitating equitable political participation and representation for the community was perhaps the most commonly referred barrier when participants considered processes such as local planning and decision-making systems and structures. In particular, concerns were raised about past water management and land-planning decisions made by local authorities; with a number of participants commenting that such development and treatment of natural systems/resources were often poorly informed and short sighted. Criticism was especially apparent when *hapū* members considered the number of consents which had been granted for activities that they saw as unsustainable and in conflict with the natural order of 'things'. Linked to these concerns, an overwhelming majority of participants believed the impact of human activities and the increasing pressures being placed on the ecological system actually raised the level of risk associated with climate induced hazards. Furthermore, often the details of these discussions led on to a recognition of competing world views and values, as participants questioned the motivation behind past environmental management decisions, especially when economic values override values of ecological integrity.

> *"I reckon we've put the cart before the horse. But it's like most societies our society is driven by the economics of capitalism, it actually defines western culture, but we've gone too far… I think the whakaaro is if it's of value we'll find a way of saving it, but it's how they value it. It's for gain it's not for a balance and I think at the moment that's where the whole of western society has gone" (10 December, 2010).*

> *"…what I'm finding is the dollar is over-ruling [everything]. These guys are there purely for financial gain" (8 December, 2010).*

> *"I think every marae has this [issue]. We battle with ECan (Environment Canterbury), we battle with Timaru District Council, we battle with Genesis and all the electricity outfits. Simply because they have a differing value for what the resource is used for, like the water and the land around the water and things like that, the mixing of waters. There's a whole heap of things that they have different values on and we're constantly fighting them to try and keep our way of looking at it…and it doesn't always work out" (23 September, 2011).*

Several participants elaborated on this point, noting that recognition of the fundamental relationship between human and environmental systems (and processes) is critically important for well-being. For example,

> *"If you poison the waterways, you poison the people. That's how we feel" (8 December, 2010).*

> *"In my world, which I have grown up with, everything is connected. The environment is exactly the same. The air, the water, the earth is all inter-connected and if one is suffering, the other has to too" (10 December, 2010).*

In line with these concerns, almost all of the interviewees discussed the importance of Māori political representation and meaningful participation in regional planning and management of local resources. However, it was the nature of this representation and the level of participation held by Ngāti Huirapa (and Ngāi Tahu) representatives in local, regional and national decision-making bodies which were the focus of much of the discussions held with participants.

Participants were quick to note that while obligatory consultation with *tangata whenua* was a step in the right direction they felt the nature of this participation which often translated into a 'seat' on various management committees was generally a 'token' gesture. Further, consensus among the *hapū* was that allowing for an obligatory representative did not translate to equality or an equal voice in the decision making process. Thus, many participants maintain a level of scepticism regarding their ability to have effective influence over decisions that influence the treatment and management of local ecologies and natural resources, as demonstrated in the following comments:

> *"…we have iwi reps that are sitting on steering groups. However, that's only one voice and I think there are ten. So you're sitting there with hydrologists, with engineers, with ... people that are qualified up to the max… but you're just the Māori face at the table… the tick in the box" (9 December, 2010).*

> *"I can't remember one organisation where we're supposed to have a say [and] our say is heard. Like I said we get a voice, but it's a token voice" (8 December, 2010).*

> *"…what I find today is they set up these boards and they will put a couple of brown faces on them – national, regional or local – but you don't actually have a voice there because there are only two of you, and this is still happening…" (23 September, 2011).*

Notwithstanding these frustrations/disappointments, many of the *kaumātua* who were interviewed believed representation had improved in recent years. They spoke of generations before them being excluded from decision making processes completely, the gradual shift which has taken place with legislation now requiring local authorities to consult with *tangata whenua*, and the on-going need to be at the decision-making 'table' to influence change.

> *"Well we're always trying to do it, we're always trying to have a bigger say than what we've got. We're allowed so much of a say and then they kind of switch off; we don't get [completely] inside the door, but we do what we can…I'm not saying it has improved 100% but it has improved from what it was 40 years ago" (8 December, 2010).*

> *"We should really be moving toward having our own people in those areas, and advocating for them to be there. In order to do that we need to be lifting our profile as a hapū/iwi so we need to start smartening up our professional image…at all levels. Locally we should be at least thinking about having a candidate at the Timaru District Council. We probably need to be looking at getting [someone in as an] MP [Member of Parliament]… We have got some up-and-coming kids who have the potential to do that. And as far as I'm concerned we are ahi kā [burning fires of occupation – title to land through occupation] until those kids come along and we can hand the reins over to them" (23 September, 2011).*

> *"But you notice we're very optimistic, we have great hope in ourselves, in the community." (8 December, 2010).*

Importantly, many of the interviewees considered that future *iwi* development and management of social-ecological risk and (and by extension climate change) would come from not only greater Māori involvement in local, regional and central government institutions, but also from the strengthening of existing (as well as creation of new) tribal institutions and governance structures. Formal Māori institutions such as Te Rūnanga o Ngāi Tahu and Te Rūnanga Papatipu o Arowhenua were acknowledged as currently providing not only important formal structures for dialogue at the *whānau, hapū* and *iwi* level but also linkages with external organisations such as local and regional authorities. Such institutions have increased formal access for the *hapū* to high level regional management discussions and decision making processes, as well as provided the community with expertise and information which they hope will accelerate *iwi/hapū* development and capacity. Although, confusion by external authorities over which level of tribal authority to engage with still occurs:

> *"Probably politically the hardest aspect for us is that a lot of agencies see Ngāi Tahu as the governing body so that's where they go" (23 September, 2011).*

Other Māori institutions/or organisations were also identified. For instance, a collective of *hapū* members recently formed the 'Arowhenua Mātaitai Roopū'. The Mātaitai group conducts cultural and environmental assessments of the waterways across the Arowhenua area. They have also established a monitoring programme, for which the data collected has aided in setting hapū priorities for water management, and facilitated various adaptive responses, such as *wānanga* and *hīkoi* for *hapū* members who want to engage in traditional learnings and practices grounded in *mātauranga* Māori, which they hope will evolve into sustainable long term strategies. Another example is the Health Clinic which has been established on the Pā alongside the *marae*. The clinic contributes to the mental and physical health of *hapū* members, thus increasing the collective capacity of the community to cope during times of adversity often brought on by events or challenges beyond their control.

Incidentally, a couple of interviewees also commented upon the importance of leadership within Māori institutions and the on-going challenge for such expertise to make decisions that balance (where possible) traditional and modern values:

> *"When you're talking about our leaders on the marae there's one or two that I actually respect because they're doing it the right way. Also, there are whānau members I respect as whānau leaders… I'm talking about the Māori tikanga side of things, not the economics. That's my big fear is that we're thinking about the dollars and not the tikanga or with the heart" (8 December, 2010).*

Meanwhile another participant discussed the fluidity required when defining the criteria for which a good leader should fit, noting that within Māori society as a whole people often hold preconceived idea as to what a leader should 'look like':

> *"Good leadership. We're going to need very good, strong leadership. Sometimes that's going to have to be ruthless. Male, female, tuakana, teina - I don't care. When the mauri calls it doesn't know tuakana / teina or gender issues. Our whakapapa is full of it, of tuakana doing great things but of teina doing just as many great things as well. Of wāhine doing brilliant things, of tāne doing brilliant things. It knows no real boundaries. It's just how we as people look at it and accept it, which is going to cause a major upheaval…" (10 December, 2010).*

Many of the participants discussed the central role that Māori institutions play in terms of supporting community well-being – such as local health care services and *Rūnanga* [tribal council] lobbying for more reliable infrastructure in areas of need. However, concerns surrounding the lack of formal hazard management systems and processes (as well as a lack of locally specific information) were raised by a number of interviewees as factors which influenced the way people in Arowhenua are impacted by climate induced hazards. In particular, a number of interviewees expressed concern for *kaumātua*, *tamariki* [children], the disabled and those of ill health. These community members were identified as being the most vulnerable and at risk in the event of a large flood event. Subsequently, a number of participants felt that a formal plan needed to stipulate clear lines of communication and clearly articulate people's roles and responsibilities, while also providing a pathway for information to filter out to each *whānau* to ensure they were as well informed and equipped as possible.

> *"Whether [a formal plan is] going to save us - we won't ever know until it happens, but we need to have something set up" (8 December, 2010).*

> *"Don't leave it to the last minute to make your plan because you don't have any control when a hazard is going to happen at all, so you have to pre-plan it" (10 December, 2010).*

> *"Well the nearest Civil Defence [Response Team] is [in] Timaru and that's 12 miles away and I suppose you could say we're out here on our own. If anything happens we have to assess the situation ourselves..." (9 December, 2010).*

One participant also stressed the importance of raising community awareness as well as providing access to information that is presented in a way that all people are able to understand.

> *"Documentary evenings at the Marae [would be a good start to getting information out there]. They had a big meeting after the earthquake at Christchurch. The first one got 500 people and the next one had something like 2,500 people… because it was information about how to handle the situation [in the event of an earthquake]. [For example] What you need - batteries, water, canned food, [and] stuff like that" (10 December, 2010).*

Importantly, these discussions occurred in the context of the importance of social networks and *whānau* relationships (as reported in Section 6.2.1). That is, hazard management in the past has largely been handled on a case by case basis, whereby systems and processes have been informal, with roles and responsibilities loosely defined within and between *whānau*. Yet, while these informal systems based on traditional values such as *kotahitanga*, *manākitanga*, *aroha* and *tautoko* have guided *whānau*, the regular occurrences of flooding and the changing character of the community have prompted discussions among a number of *whānau* members about the need for a formal hazard management plan, which includes systems and processes which are specific to the needs of the community to help deal effectively with future hazard events.

An example of how these traditional practices and values are applied is evident in the way the marae has been utilised as a shelter for both Māori and non-Māori during major hazard events. Climate (and non-climate) related hazard events which occurred in the area since the 1945 flood have seen the Arowhenua Pā used as a 'safe zone', including; the 1986 flood;

2002 and 2006 snow storms; and the 2010 and 2011 Christchurch earthquakes. These events saw many residents (both *whānau* and non-*whānau*) flee their homes and take up short term residency at Arowhenua Pā, where the *hau kainga* were able to ensure peoples safety while accessing necessities (such as large quantities of food) through informal relationships and traditional practices (such as *mahinga kai* knowledge and techniques).

> *"Like all marae, your mana is based on how well you look after your manuhiri. And we…have a real good reputation for looking after our manuhiri…so yeah its part of the kawa and tikanga of this Marae [to ensure that we maintain our traditional values and practices relating to looking after people]" (23 September, 2011).*

Ngāti Huirapa representatives are currently working alongside the regions Civil Defence Coordinator in Timaru and are working through developing a formal hazard management plan. Some of the participants were unaware of this current development and were anxious to see a formal plan in place. The formalisation of a marae based hazard management and emergency response system is considered by many of those interviewed to be a high priority.

> *"By having a formal plan and process in place means whānau are not relying on one person, if that person leaves the processes are still in place" (23 September, 2011).*

7 Projected river flooding and coastal inundation

This section presents the mapping results from our assessment of projected river flooding at Arowhenua Pā and coastal inundation due to climate change-induced sea-level rise at the mouth of the Opihi River. First-order interpretation of the maps is provided based on the insights derived from our analysis of community exposure to climate hazards and change in Section 6.1. Cautionary remarks and clarifications which explain the uncertainties inherent in presenting future climate projections are also provided.

7.1 River flooding scenarios

The flood extents for the modelled 1986 flood and the average inundation extent for a corresponding event by the 2040s under the A2 climate change scenario are shown in Figure 18. The 2040 inundation projection represents the average of the rainfall projections from the twelve global climate models used. Figure 19 shows the corresponding inundation extent for the A2 scenario for 2090. A cross-section of the river, showing flood levels between Temuka Township and the Marae at Arowhenua Pā, is shown in Figure 20, with the cross-section displayed as a dotted line in Figures 18 and 19. The 2040 and 2090 inundation extents under the less extreme A1B scenario are shown in Appendix C.

The A2 scenario results show that projected inundation extents for the equivalent of an extreme flood event with an average recurrence interval >500 years are unlikely to differ markedly from the inundation extents measured from a ~100-150 year extreme flood event that occurred on the Temuka River in 1986. This outcome is due in large part to the relatively steep elevation of local terrain around the flood extent where the water level can change substantially without much corresponding change in the extent of flooding. That is, in spite of the most extreme modelled estimate of future peak flood levels being more than 30% greater than the levels recorded for the 1986 flood event, there is very little additional surface area being flooded. To a lesser extent, the scale of the map is also a factor that influences the differences shown between the projected inundation and the observed 1986 flood extent. For example, where the land is flatter there can be larger differences in extent between floods of different size such as the area to the south of State Highway One (shown by the areas in yellow in Figures 18 and 19). It is evident from the cross-section that the Marae is elevated about 2m above Temuka Township so it is unlikely that the Marae would be flooded before the Township. However, this does not preclude the occurrence of flooding from local runoff, or from the unnamed Temuka River tributary flowing eastwards and just north of Huirapa Street.

The modelling for both 2040 and 2090 suggests that the ridges of the Pā site have been well chosen for community land-use and residential occupation, as they are elevated above the surrounding flood plain. More specifically, the modelling indicates that the Marae and school buildings would remain free from inundation for an event equivalent to the 13 March 1986 flood in the Temuka River under the climate change scenarios assessed. However, the results also show that lower lying properties and infrastructure (includes some occupied and unoccupied *whānau* homes, storage buildings, fencing and sections of Station Road and Huirapa Road) are at greater risk of inundation and resulting flood damage under a A2 Emissions Scenario in 2040 and 2090 given the expectations for higher peak flood levels. These heightened risks also extend to farm-stock (sheep and cattle) that sometimes graze the lower plains of the Arowhenua Pā. Less is known is about the direct and indirect impacts of such physical changes on local ecosystem services and related wild-food availability. Importantly, the occurrence of even higher flood levels on the Temuka River, flooding from other tributaries, or even failure of existing flood protection measures on the Opihi River, could result in quite different outcomes.

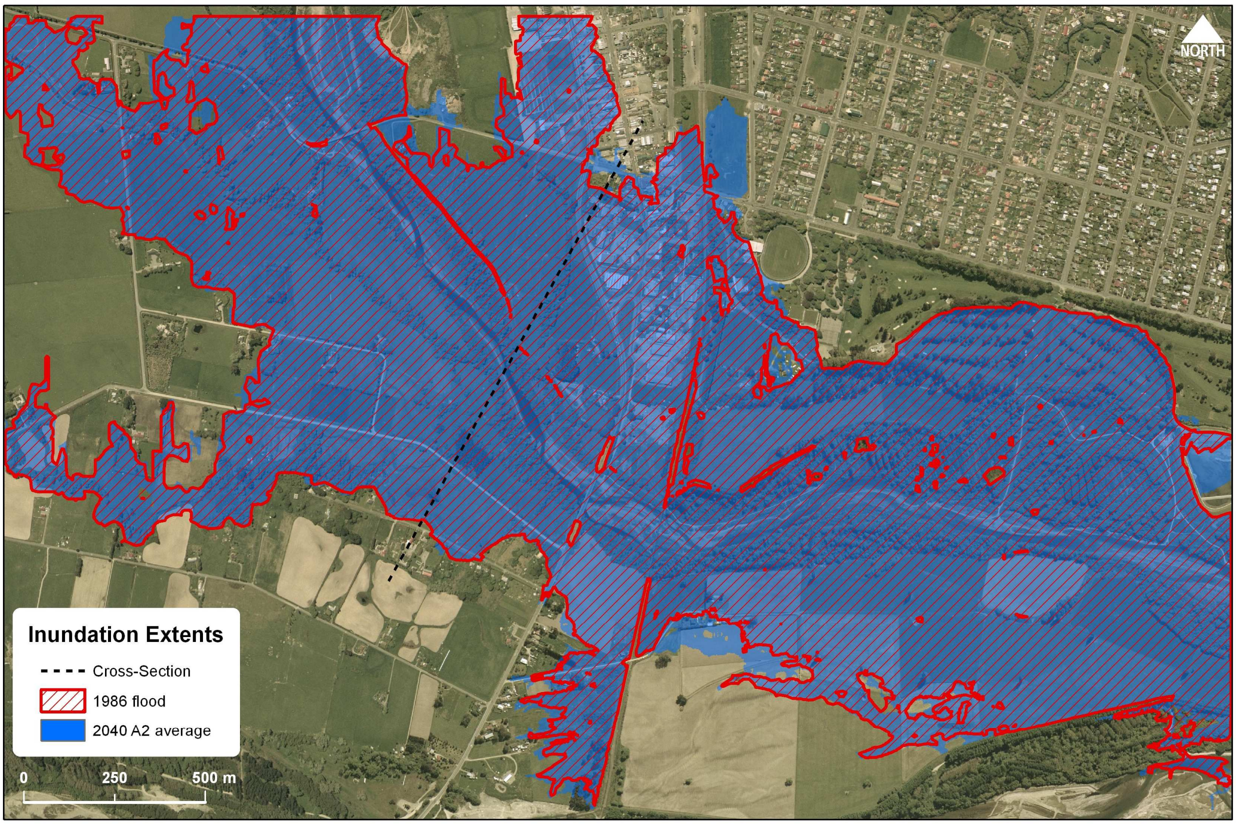

Figure 18: Inundation extents of the modelled 1986 flood and the 2040 A2 average flood.

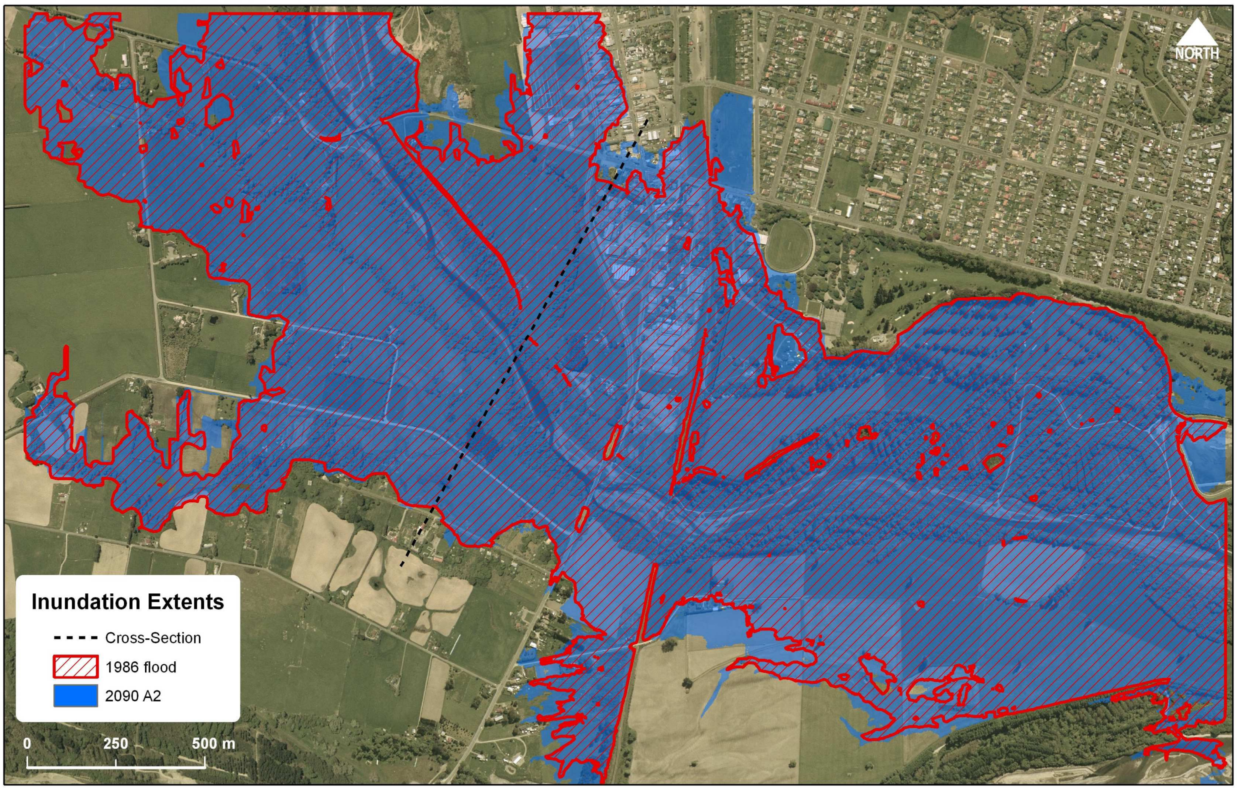

Figure 19: Inundation extents of the modelled 1986 flood and the 2090 A2 average flood.

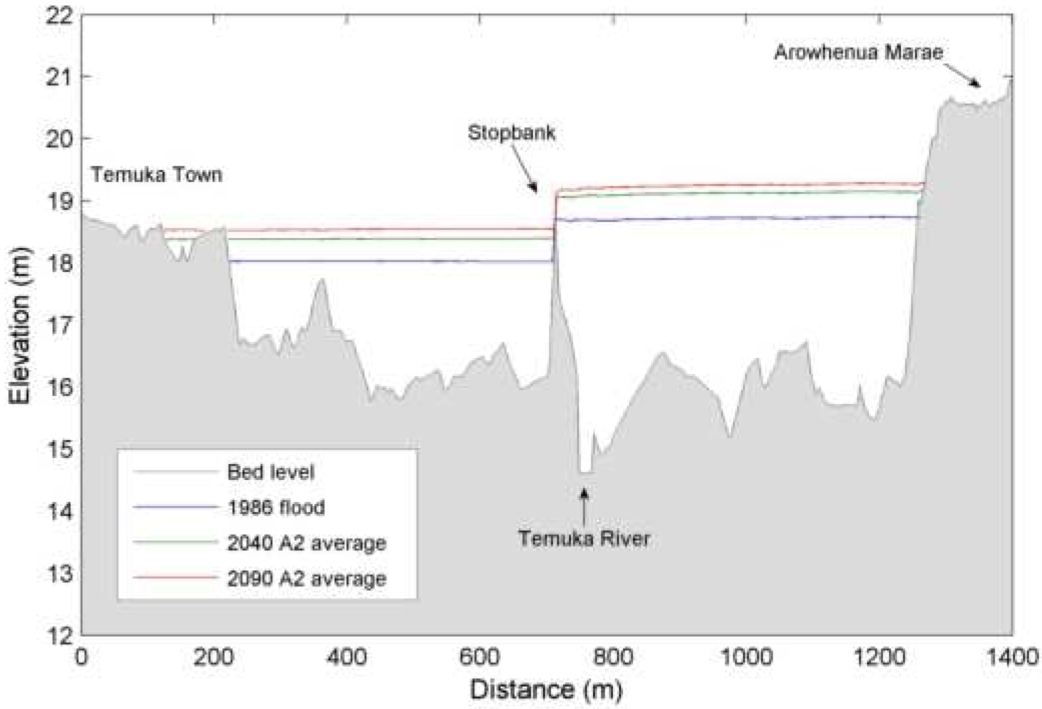

Figure 20: Cross-section of the Temuka River showing flood levels under the A2 climate change scenario for 2040 and 2090 AD between Temuka Township and the Marae at Arowhenua Pā.

Cautionary notes

(1) The flood model is only of flooding from the Temuka River and does not incorporate flood waters from the Opihi River or from local flooding such as waters identified at the 'Front-step' point which seem to have been caused by surface flooding from rainfall on the surrounding land.

(2) There could be larger events than those modelled. The modelled A2 2090 average flood peak has an estimated present-day ARI of greater than 500 years (Griffiths *et al*., 2011). If the flood peak was more extreme then the flooding might overwhelm the highest land elevations that exist in the Pā area.

(3) Flood peaks are very sensitive to the rainfall intensity pattern during the storm. Even if the storm rainfall total was the same as for the 13 March 1986 storm but the rain was more intense, then the flood peak could be larger.

(4) Flood size is partly affected by the antecedent soil conditions. That is, if the soil is very wet before a large storm then the flood may be much larger than expected for a given rainfall duration and intensity.

(5) To some extent the elevated areas of the Pā are less vulnerable to large floods than they might otherwise be by the standard of stop banking along the river and the relative level of the river bed and flood plain upstream. There is a history both ancient (Lynne *et al.,* 1997) and modern (Scarf *et al*., 1987) of overflows to the east from the river during large floods. Thus, if the Temuka River was subject to larger floods than those modelled, for whatever reason, bank overflows to the east upstream of, and through Temuka township, might reduce the extent of flooding that would otherwise be expected in the Pā area.

(6) A further factor affecting flooding of the Pā area is the build-up of debris on the SH1 and railway bridges. Severe build-up of debris has the potential to raise water levels adjacent to the Pā and these would not be relieved by over bank spills further upstream.

7.2 Sea-level rise scenarios

Coastal inundation extents surrounding the Opihi River mouth under current high tide levels (defined as the level exceeded by 10% of all high tides - MHWS10) as well as the corresponding sea levels for 2040 AD and 2090 AD with an assumed 40 cm and 80 cm sea-level rise respectively, are shown in Figure 21. As detailed in Section 5.4, these adjusted water levels have been projected onto the coastal plains. The **red line** shows how far landward the current MHWS10 extends under present day conditions (i.e. the high tide as it is experienced today). The **blue shaded area** depicts the extent of coastal inundation in 2040 for MHWS10 conditions, if sea-level rose by 40cm. Finally, the **yellow shaded area** depicts the expected extent of coastal inundation in 2090 for MHWS10 conditions, if sea-level rose by 80cm. Most notable is the considerable change in inundation of farm land on the northern side of the Opihi River (see top right hand corner of the mapped area). This inundation is possible due to the presence of a culvert that permits water to enter and exit through a stop-bank built following major flooding in 1945 (See: Section 2.3). However, no account is taken of the potential volume of water that could flow through the culvert over the high part of the tidal cycle. This may result in an over-estimate of the potential extent of area inundated.

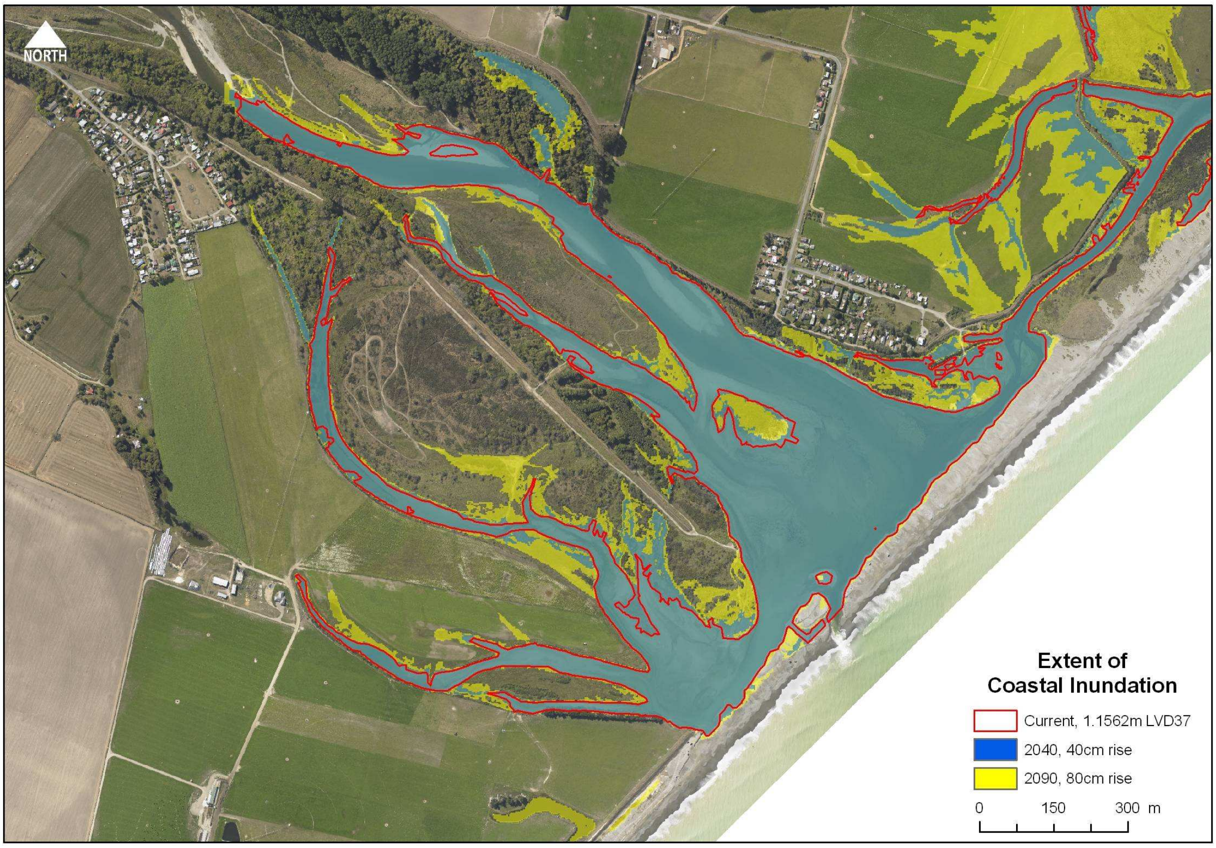

Figure 21: Extent of coastal inundation for current high-tide conditions (MHWS10) and for climate change-adjusted sea-levels for 2040 AD and 2090 AD.

Coastal inundation surrounding the Opihi River mouth was also mapped for an extreme (1% AEP) storm-tide level, which includes the combined effect of storm surge coinciding with a high astronomical tide. Climate change-adjusted sea-levels for 2040 AD and 2090 AD were superimposed on this storm level (Figure 22). It is important to recognise that because there was no Opihi River flow information available, the mapped inundation only includes sea-level effects; it does not include the combined effects of a flooding river plus a storm-tide. The **red line** shows the area of land below the level of the present day 1% AEP level, the **blue shaded area**, the area of land below the 1% AEP level with a 40 cm rise in sea level (2040), and the **yellow shaded area**, the area of land below 1% AEP level with a 80 cm rise in sea level (2090).

The most notable feature from this scenario is the widespread flooding on the northern side of the Opihi River and the added inundation under 2090 AD conditions that covers much of the Milford Huts coastal settlement. As mentioned above, the water levels depicted beyond the stop-bank are dependent on water entering through a culvert in the coastal stop-bank. It was assumed that levels reached equilibrium on both sides of the stop-bank, which might not eventuate due to flow limitations imposed by the culvert diameter and duration of the high tide. However, it is also important to recognise that these projections do not include contributions from wave over-topping or the coupled effect of backed-up river flows due to rainfall in association with a storm event.

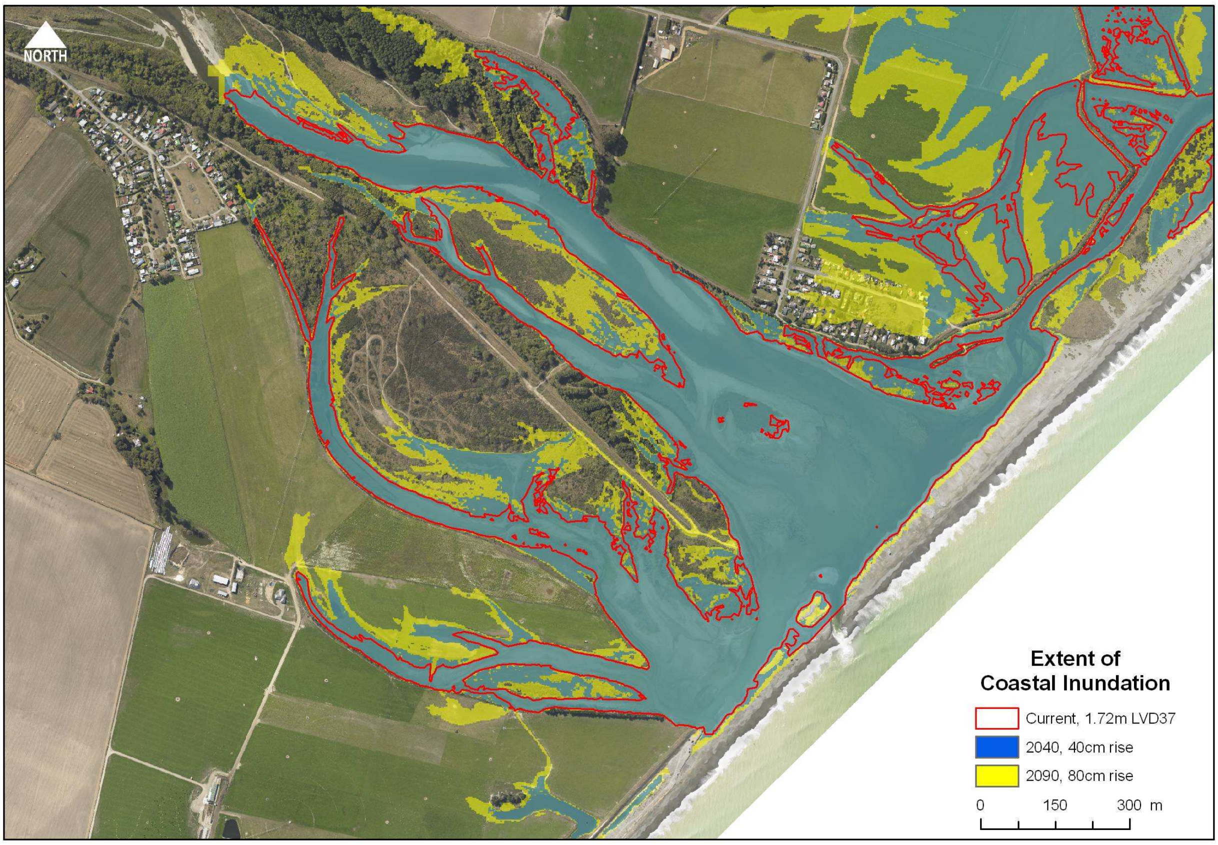

Figure 22: Extent of coastal inundation for current extreme storm-tide conditions (1% AEP) and for climate change-adjusted sea-levels for 2040 AD and 2090 AD.

Cautionary notes

1) Figures 21 and 22 show indicative coastal-related inundation. They do not account for potentially greater inundation due to high river flood flows combining with high tides.

2) It is expected that the beach barrier will adjust its height and move landwards to compensate for increased sea-levels due to long-term sea-level rise. It is also assumed that wave over-topping characteristics or breaching potential will not change significantly.

3) Due to the resulting reduced slope in the lower reaches of the Opihi River, aggradation of the bed is expected in the lagoon and coastal reaches of the Opihi River to adjust the river's slope. Over time aggradation will likely lead to increased flooding in the lower reaches of the river and areas surrounding the lagoon.

4) Any increase in the frequency of floods also increases the chance of floods occurring during adverse tidal conditions. These effects are complex, but the consequences can be calculated using hydrodynamic models. Further work is required to investigate the coupling of these two forces.

5) No account has been taken of the effect of likely coastal erosion over the next 80 years. Leckie (2003) estimates erosion rates of 0.63 m/y.

8 Synthesis and discussion

This section synthesises the results from individual, paired- and group interviews with Arowhenua Pā community members, and discusses the existing as well as emerging vulnerability (and resilience) of the community to climate variability and change. The aim here is to work through the implications of future risks and impacts associated with climate change induced river flooding and sea-level rise; and to consider how the changing nature of climate risks and challenges might be managed by the Arowhenua Pā community in the future. Entry points for reducing vulnerability and enhancing future adaptability are subsequently identified; and thereafter a range of selected coping (tactical) and adaptation (strategic) measures that might assist the community to manage the risks associated with future climate hazards and stresses are offered. Note it is important to recognise that many of the actions recommended are investments that will offer protection against risks from present day natural climate variations and extremes.

8.1 Community vulnerability and adaptation

What do the results tell us about the underlying (and emerging) vulnerability of the community at Arowhenua Pā to climate variability and change?

Social networks, conventions and transformation

The work in this study demonstrates that the community from Arowhenua Pā have always lived with and responded to climate variability and change; and therein collectively the community possesses considerable capacity to 'deal with' climate induced hazards, related stresses and risks. Much of this capacity is rooted in elemental cultural values and approaches such as *tikanga* and *kawa* and actioned through principles such as *whakapapa*, *whanaungatanga*, *manākitanga*, *tautakotanga* and *kotahitanga*. Closer human-environment relationships through *mahinga kai* and *kaitiakitanga* are also central to community resilience (well-being and endurance) and thereupon linked with being able to respond to both direct and indirect climate impacts. This experience is not dissimilar from that of Arctic peoples whose successful long-term habitation and management of risk associated with environmental change has been possible because of the capacity of their social, economic and cultural institutions and practices to adjust (Nuttall *et al*., 2005). Such conventions and values have previously been identified as central to the long-term health, well-being and resilience of Māori communities, families and relationships (Durie, 2005; Panelli and Tipa, 2007; Moewaka-Barnes, 2010; among others). Much of this work – particularly in the health sciences, points to feeling valued, safe and respected, having strong social supports and a positive sense of connection and belonging as important pathways for better health outcomes which promote values and behaviours that help deal with adversity and stress (Moewaka-Barnes, 2010). A number of international studies alongside other indigenous peoples have also emphasised the importance of cultural arrangements and social networks in responding to storm damage and community recovery (Adger, 2001; Barnett, 2001; Berkes and Jolly, 2001; Berkes *et al*., 2003; Smit and Pilifosova, 2003; Ford *et al*., 2010; Pearce *et al*., 2010; among others).

However, such capacities are not uniform across the community and some individuals are less well equipped to cope and adapt than others in the face of changing climate conditions. Differential vulnerabilities to climate variability and change are particularly evident among those members of the community who are less well-resourced at Arowhenua Pā. Although at the same time, the author team were reminded by a number of elders in the community that the increasing reliance by some of the *whānau* on technology can also lead to reduced self-sufficiency and less flexibility, which are regarded as crucial qualities for dealing with adverse environmental conditions. Rapid transformations in local community structure, widespread land-use change, conflicting resource management regimes, decline in traditional practices, individual property titles and concentration of resources in fewer hands, as well as *whānau* spending more time away from traditional areas for employment and education all contribute to the increasing sensitivity of the community to climatic risks while simultaneuosly inversely undermining aspects of adaptive capacity such as the 'sharing of risk' across *whānau*. Analogous challenges and transformations in social structure have been identified in place-based studies with Inuit communities where socio-ecological resilience and adaptive capacity have been weakened by changing relations of trust, reciprocity and exchange (Berkes and Jolly, 2002; Ford, 2009). Such conditions highlight the dynamic linkages between human-environment interactions, and further underscore that the implications of future climate change cannot be given serious attention by focussing on the physical dimensions of change alone. Rather it is the connectedness and interactions between biophysical and societal processes that operate within and across local, regional, and global scales that must be recognised and carefully considered if meaningful responses are to be developed.

Deep social-cultural tensions and challenges surrounding greatly altered relationships between people and the environment were regularly reflected upon in this work. Such relationships have been undermined through land-use change and engineering of the physical environment, new resource management regimes and rules, increasing competition for environmental resources, as well as pollution from point and diffuse sources. Traditional fisheries have also declined, food sources have been lost and wetland habitats have been significantly degraded or changed beyond recognition (Tipa *et al*., 2010). These changes have thereupon affected the way the community can engage with traditional lands, waters and resources and have in-turn contributed to the decline of wild-*kai* knowledge, practice and consumption; as well as perhaps more fundamentally a weakening of the human-environment relationship which is central to community well-being and endurance, now and in the future[30]. Such challenges are not dissimilar from those reported by Chapin *et al*. (2005) and Nuttall *et al*. (2005) who concluded that the deterioration of cultural ties to traditional and subsistence activities, and all they represent, is the most serious cause of decline in well-being among Aboriginal people in circumpolar Arctic regions today. It is not surprising therefore that a chorus of Māori voices at the 2nd Māori Climate Forum in 2006 indicated that climate adaptation should focus on *kaitiakitanga* – that is, individuals, families, and communities being involved in the sustainable management (includes monitoring, protection and use) of environmental resources and habitats (King and Penny, 2006).

Knowledge, skills and expertise

A great deal of consideration has been given to the loss of indigenous knowledge and associated skill-sets, practices and beliefs that underpin the resilience of different indigenous peoples to social-ecological stresses and risks (Berkes and Jolly, 2001; Kral, 2003; Nuttall *et al*., 2005; Durie, 2005; Ford *et al*., 2006; King *et al*., 2008; among others). Recognition of such challenges among community members from Arowhenua Pā centred principally on the declining command of traditional skills relating to *mahinga kai* and the subsequent recognition

[30] This heart of this point is echoed in the following words: *"Those theories about kai and environment come down from our tūpuna [ancestors]. We have to be really careful how we handle that kind of stuff if we want to grow a future for generations to come. We need to care for what we've got now"* (10 December, 2010).

that such changes have implications for not only the supplementing of household food supplies and linked self-reliance but also tribal identity and custom. Explanations for these changes are not entirely different from those offered by other groups and commentators; and range (in varying degrees) from increasing constraints in accessing traditional *mahinga kai*; diminishing supplies and availability of customary *kai* species; fewer *whānau* remaining active on local river-ways (as well as public and private lands); and, more time spent away from the area by many *whānau* (particularly younger members of the 'community'). Such changes have thereby minimised practical learning opportunities, as well as face to face contact between younger and older generations which is crucial for effective transfer of traditional knowledge, skills and expertise; and thereby such changes are recognised as part of the "endurance" (i.e. resilience) challenge for some community members in dealing with future extremes in weather and climate. As articulated by one of the few remaining *kaumātua* on the Pā, the intermittent return home of young people wanting to learn is fine but it is also unrealistic to "*learn a life-time in a week*".

In spite of such commentaries of loss and deficit, some of the participant's simultaneously spoke of the importance of local knowledge and experience with local hazards and environmental processes. High risk areas and traditional safety zones were identified (See: Figure 17) as were abilities to ready and prepare the *whānau* for hazardous conditions by maintaining awareness of environmental signs that indicate when extreme weather/climate conditions and associated impacts are imminent and most likely to occur. In combination with collective-based values and conventions, these insights and skills were recognised by many in the community as the 'Māori-way' of managing risks and thereby mitigating harms. Similar conclusions have been reached by King *et al*., (2005) and King *et al*., (2007) who argued that Māori knowledge, practice and belief offer a range of learning opportunities that can contribute to not only detecting changes taking place in the environment and managing extreme events and related risks but also appreciating fundamental ecological principles about environmental constraints, among other contributions. For the Inuit community of Igloolik, similar issues have led to the organisation of 'Land Camps,' whereby elders take young Inuit on the land for weeks at a time throughout the year and teach hunting skills, and these have been purportedly successful in developing essential survival skills and strengthening inter-generational relationships (Wachowich, 2001; Takano, 2004). New strategies that can assist the maintenance, transfer and revitalisation of such knowledge (and linked cultural values) to the next generation are regarded as central to ensuring that Māori lifeways continue and that *whānau* are in turn able to minimise risk and sustain themselves in the future.

New interactions and the development of new skills and expertise by *whānau* (particularly younger people) spending more time away from the Arowhenua area for work and education were also commonly identified. Many of the *kaumātua* spoke of a marked change in skill-sets and knowledge held by the younger members of their *whānau* and the positive contributions these young people were making (and would make) to the community. These new skill sets held by the younger generation are expected to become more important as the emerging demands of complex social, economic, political and bio-physical system issues facing the community increase. Although, most interviewees consider that there is a strong need to find ways to benefit from the strengths that come from both *Mātauranga Māori* as well as advancements in modern science and technology. Subsequently, the 'right' decisions regarding future community well-being will require drawing upon a range of skills and expertise that cross a number of disciplines including science, law, *tikanga* and language (among others). Such strategies have been identified by a range of indigenous and non-indigenous commentators as critical to meeting the complex challenges facing diverse social-ecological systems on a range of scales (Furgal *et al*., 2006; Gearheard *et al*., 2006).

A growing body of research also highlights the importance of effective communication of climate change information to increase awareness and understanding, facilitate constructive engagements, and thereupon promote strategic planning and action (Moser and Dilling, 2007; Kahan, 2010). The need for people with expertise that can 'walk between worlds' was identified as a major obstacle at present, as too was the lack of timley and authoritative information on climate change to make informed decisions. Although, one participant astutely commented: *"You can't just fire the pamphlet out at them…you've got to talk about it, they've got to see something visually. It's good to get a presenter along so that they can see, and it's better if they're Māori".* Hui are recognised as effective fora for giving *whānau* (especially with *kaumātua* and *kuia*) access to the right people and the right information that is specific to them (Harmsworth, 2005). Furthermore, having someone Māori within 'outside' organisations can also assist in removing such barriers so that *whānau* can get the information they need in a format that they understand. Conversely, misunderstood information and/or unintended interpretation can severely obstruct interactions and will likely lead to inaction and possibly maladaptation. Notwithstanding the importance of such reflections, one elder argued that enough is already known to make informed decisions about future climate risks and the associated challenges of more sustainable life-ways.

Resourcing and finance

Perhaps the least surprising of the determinants identified through our analysis, 'Resourcing and finance' feature repeatedly in domestic and international studies of drivers of social/indigenous vulnerability to climate hazards and stresses (Cooper and Brooking, 2001; King *et al*., 2008; Tribbia and Moser, 2008; Matunga, 2006; Moser and Ekstrom, 2010; among others). Resourcing includes financial means but also information, technology, staff expertise, and time; and together these determinants are widely recognised as critical determinants that can either facilitate or constrain effective and enduring management of climate related community risks – for Māori and/or other groups in society (Adger *et al*., 2007; Smit and Wandell, 2006; Ford *et al*., 2008; among others). The work in this study indicates that the financial capacity of many *whānau* within (and connected to) the community at Arowhenua Pā is constrained; and subsequently, many activities or actions (particularly structural or engineering based adaptations – but not limited to these) that might reduce risks associated with adverse climatic conditions are limited at best. Housing affordability and lack of standards on rental properties as well as limited finances to undertake house maintenance tasks and upgrades such as structural repairs and insulation to combat winter coldness and dampness compromise not only existing *whānau* health and well-being to deal with everyday challenges, but can also preclude eligibility for insurance cover. Together these issues increase the risks associated with dealing effectively with future extreme climatic events and related stresses. According to Waldegrave *et al*. (2006) the quality and affordability of housing in New Zealand (including lack of standards on rental properties) are faced by disproportionate numbers of Māori across New Zealand and this compounds challenges for those *whānau* who are highly exposed to climate hazards. Potential effects may even be compounded by the cost of (and hence access to) appropriate health-care services in remote areas (Woodward *et al*., 2001).

Future changes in climate conditions have economic implications also for individuals and households in terms of damage to equipment as well as adverse implications for ecological conditions (not explored in the work) that are expected to exacerbate existing pressures on *kai* species and supplementary food gathering. Subsequently, economic hardship and resource limitations mean that for many *whānau* actions and plans that would minimise sensitivities and enhance capacities to respond with adverse climate challenges must often be met on the "back foot" because everyday issues effectively take precedence over possible future outcomes and preparing for such risks. Also connected to these issues is the shortage of community members who have the time (and relevant expertise) to represent and take responsibility (as well as provide leadership) for community related affairs – such as legislative demands that require local authorities, council boards and committees "consult" and "engage" with Māori (but not necessarily pay for such services) on resource management issues. This situation is simply explained in the following statement and was echoed by many interviewees:

> *"…we haven't got the resources and the capacity to be able to deal with all of the organisations that want to 'have a relationship with us" (9 December, 2010).*

Notwithstanding these barriers, a number of commentators have pointed out that it is important to not equate vulnerability to climate change with poverty and inequality. Such thinking can result in the assumption that reducing poverty will automatically reduce vulnerability to climate change. However, vulnerability is not the equivalent of poverty or inequality (Wisner, Blaikie *et al*., 2004; Schipper and Pelling, 2006) but rather both critically threaten sustainable development; and focusing on such determinants may not actually treat the root causes of vulnerability to current and/or future climate change risks (McEntire, 2000). While there is a valuable point being made here, about the complexity of forces that drive vulnerability, there is simultaneously an unintended position of privilege in such arguments that does not acknowledge strongly enough the role of existing inequalities and the subsequent need for financial assistance to improve access to the most fundamental needs such as healthy homes and affordable health care services. If some of the *whānau* who face significant financial constraints were able to eliminate or at least minimise such hurdles it would contribute enormously to the capacity of many *whānau* to better respond and plan for adverse climate consequences and related stresses when they arise. To extend this discussion slightly further, often commentators will argue that unique opportunities to address the impacts of climate change and plan for the future are available to those whose infrastructure is in need of renewal or upgrade, and that such actions will make infrastructure both more resilient to our current hazards and less vulnerable to the impacts of climate change in New Zealand (Hennessy *et al*., 2007). While there is value in such actions – particularly from the point of view of setting objectives, the reality as described above for some of the *whānau* is that financial stresses are actually preventing maintenance of the most basic infrastructural standards and thereby added improvements that take into account changing risks are beyond priorities of many of the *whānau* at present. Where infrastructural co-benefits can be found they should be promoted and adopted but such considerations are currently "pipe-dreams" for many of the *whānau*. Alternative mechanisms and more equitable policy interventions that can provide resource assistance through subsidies and technical support to *whānau* to help launch and finance their own strategies for climate risk reduction, readiness, response and recovery would contribute considerably to ensuring safety and quality of life, as well as reducing long-term costs.

Institutions, governance and policy

The identification of institutions (formal and informal), governance and policy (across a range of scales), and their influence on *whānau/hapū/iwi* development, well-being and resilience is attracting increasing attention across a number of research disciplines (e.g. economics, political science, energy, health, law, among others) (Dodd, 2002). But, few grounded studies have explored the dynamics and context of social-political structures, frameworks and rules; as well as their influence on Māori vulnerability and resilience to climate variability (including extreme events) and longer-term change. Whether we are talking about different levels of government and/or social mechanisms and customs that regulate behaviour and social actions, 'institutions' (and the governance that occurs within) are widely recognized as critical agents of influence that either enable or constrain the sensitivities and adaptive capacities of different populations to deal with social-ecological changes, stresses and risks (Berkes *et al*., 2005). It is not surprising therefore that some Māori communities and populations have already identified the importance of such factors in facilitating or 'standing-in-the-way' of better outcomes for Māori including the management of risk associated with climatic hazards and change (King *et al*., 2008).

The issue of Māori participation in local government and political decision-making in the context of climate change (which necessarily includes regional planning and management of local resources and the environment) is being increasingly recognised as crucial to the realisation of Māori community aspirations and goals (King and Penny, 2006). For Ngāti Huirapa, this recognition includes a general frustration over the level of their participation in local and regional political arrangements as well as the nature of that representation by *hapū* representatives. Obligatory consultation with *tangata-whenua* might be a step in the right direction but it can, and does, result in "token" participation – and in consequence, common feelings of no more than a "seat" within external organisations of authority. Unsurprisingly perhaps, there are many studies that recognise the value of greater participatory involvement in local and regional planning – particularly from the point of view of permitting people to articulate their views and concerns which can imbue a sense of contributing to solutions to problems (Adger, 2003; Berkes *et al*., 2005). Specific Māori participation in climate adaptation planning and action is likely to ensure that the setting of priorities for Māori is actually grounded in Māori realities. Given that decision-making institutions in the regions and sectors affected by climate change will play an important role in determining climate change adaptation strategies, it is crucial that Māori are represented and participate in such structures – both as citizens and *tangata-whenua* through observance of Treaty of Waitangi obligations.

Future iwi development and management of social-ecological risk (and by extension climate change) will not only come from greater Māori involvement in local, regional and central government institutions, but will also demand the strengthening of existing (as well as the creation of new) tribal institutions and governance structures. Formal Māori institutions such as Te Rūnanga o Ngāi Tahu and Te Rūnanga Papatipu o Arowhenua currently provide not only important formal structures for dialogue at the *hapū* and *iwi* level, but also linkages with external organisations such as local and regional authorities. Such institutions are considered to have increased formal access for the *hapū* to high level regional management discussions and decision making processes, as well as provided the community with expertise and information that contributes to *hapū* development and capacity. Notwithstanding this, a number of interviewees mentioned that confusion by external authorities over which level of tribal authority to engage still occurs. It is hoped that such grounded institutions will contribute to longer-term sustainable development and behaviours – both within and outside of the community. Although, it is important to emphasise that such formal institutions do not influence populations in isolation; but rather informal institutions through local traditions and practice can be equally powerful agents of change, support and action – as elaborated upon in previous sections[31].

A further institutional challenge for many of those interviewed related to traditional Māori views about the interdependence of the human-environment relationship and the competition of values and ethics that is occurring due to conflicting government policy directions, development paths and linked regulatory regimes. Concerns were raised about the lack of reverence for *Papatuānuku* [Mother-Earth, the ecological system] and the lack of recognition of her intrinsic value and integrity. According to some of the participants this was evident in the number of resource consents that had been granted for activities that they saw as in conflict with the 'natural order of things' and 'responsibilities of care' for *Papatuānuku*[32]. According to one participant one of the results of this competition of values is that far less than ideal natural resource conditions are now accepted as normal. Further, the overwhelming majority of participants believed the impact of human activities and the resulting pressures being placed on *Papatuānuku* actually raised the level of risk associated with climate induced hazards. Given such contexts, *whānau* and the *hapū* can only make changes if the wider institutional, governance and policy settings in which they act also change such as shaping what is legal or politically feasible, which decision protocols and values should be observed, or more simply being involved in the setting of budgets and infrastructure development. The idea that culture matters' in development processes is not a new one, but the central role it plays in achieving sustainable development has only recently been recognised by development planners and incorporated into development policy (SPC, 2010).

Another significant governance and policy issue is that climate change is still thought of as a separate issue from development. If climate change continues to be seen as a process that is separate from development itself, then the types of adaptation that are carried out, together with the types of development that are prioritized or promoted, are unlikely to be critically questioned and may well lead to mal-adaptation. Climate change policy moving forward will require new approaches that comprehensively address the interrelationships between the things that affect change and the things that magnify or dampen the drivers. This necessarily includes understanding local livelihood strategies and vulnerabilities; recognizing that a diversity of knowledge systems can contribute to solutions; and, identifying and addressing barriers to change (at all levels). Reducing sensitivities and enhancing adaptive capacity will only be successful therefore when they are integrated with other policies such as land-use planning, environmental conservation, coastal planning, disaster preparedness and national plans for sustainable development and human security. Such development and implementation of such policies will require institutional awareness, vision and perhaps the creation of new institutional arrangements. The institutions that facilitate adaptation need to also adapt themselves to changing contexts and challenges through an on-going process of social learning - so that climate change adaptation can be dynamic, goal focused and accommodate changing socio-ecological contexts rather than process constrained and

[31] While informal systems based on traditional values such as *kotahitanga*, *manākitanga*, *aroha* and *tautoko* have successfully guided whanau in the past, the regular occurrences of flooding and the changing character of the community have prompted discussions among a number of whānau members about the need for a 'back-up plan' that is formal and includes systems and processes that are specific to the needs of the most vulnerable in the community. Ngāti Huirapa representatives are currently working alongside the regions Civil Defence Coordinator in Timaru and are developing a formal hazard management plan.

[32] Such views are broadly shared by other groups and commentators and are being articulated through documents such as the 'Right relationship - building a whole earth economy' and 'Strong sustainability for New Zealand: Principles and scenarios' (Howell, 2010)

restricted by outdated institutional structures. Notwithstanding this need, the authors of this report acknowledge that it can be difficult for councils to achieve coordinated planning for climate change when functions and strategies operate under different legislation, at different time scales, and within different levels for government. As the 1996 IPCC Working Group III report stated, "The challenge is not to find the best policy today for the next 100 years, but to select a prudent strategy and to adjust it over time in the light of new information."

8.2 Projected climate change impacts and risks

Climate change considerations often focus on gradual, long-term changes in average conditions. However, the most immediate and more significant risks are likely to arise from changes in the nature of climate variability and extreme events. This sub-section considers the potential impacts and associated risks for the Ngāti Huirapa community at Arowhenua Pā arising from our climate change scenarios of Temuka River flooding and inundation of the coastal zone around the Opihi River mouth due to sea-level rise. These considerations are based upon the grounded analysis of the author team as well as the direct feedback on the scenario maps produced in this study given by community members during follow-up interviews in September 2011.

River flooding from climate-induced changes in hydrology

The scenario results produced from our examination of future extreme peak flood levels for the Temuka River in 2040 AD and 2090 AD showed that in a high emissions world (i.e. the A2 Emissions Scenario – See: Section 5.1 for details) local inundation extents for the equivalent of an extreme flood event with an average recurrence interval of >500 years are unlikely to differ markedly from the inundation extents measured from a comparable extreme flood that occurred on the Temuka River in 1986. The most extreme modelled estimate of future peak flood levels in this study was more than 30% greater than those recorded for the 1986 flood event - but the relatively steep elevation of local terrain resulted in very little additional surface area being flooded. While these results are favourable in terms of the higher ground occupied by the Marae, school buildings and many *whānau* homes, they also demonstrate that lower lying properties and infrastructure (includes some occupied and unoccupied *whānau* homes, storage buildings, fencing and sections of local roads) are at greater risk of inundation and flood damage under a A2 Emissions Scenario in 2040 and 2090.

In view of the scenario results, interviewees were quick to identify damages to lifeline infrastructure – with particular concern centred on the potential failure of sewerage systems and the risks that such impacts could pose for local ecology and *whānau* health. The costs of household maintenance, repairs in the aftermath of extreme floods and longer-term recovery were also identified – especially for those *whānau* with no existing insurance cover. Any increase in the frequency of extreme flood events would likely lead to higher insurance premiums which in turn would place additional burdens on dealing with future flood risk. A couple of interviewees also commented that projected future impacts and community risks might be aggravated by the return of city *whānau* as well as the arrival of new members to the community wanting to build in flood-prone areas – in spite of the wider community understanding of areas of high risk. Given that modelled peak flood levels in 2040 AD and 2090 AD are projected to reach heights greater than those measured in 1986, risks are also likely to increase for specific members of the community. Foremost in the minds of those questioned over future impacts and risks were deep concerns about the endangerment and welfare of elderly *whānau* living alone on the Pā and the high numbers of children who attend

Tarahaoa School during the week. Central to such concerns were issues related to the hazards caused by higher flow volumes in flood waters and road access being impeded into, and out from, the Pā. Challenges for *whānau* in need of medical care, dangers associated with crossing flooded road and access ways, as well as concerns for stock (sheep and cattle) that sometimes graze the lower plains of the Arowhenua Pā were also identified. Notwithstanding these insights, few of the elderly members of the community interviewed actually considered themselves at risk – but rather were more concerned about others on the Pā who they regarded as less self-sufficient and lacking in experience to deal with the impacts and risks associated with large floods. The potential risks and impacts associated with projected peak river flows for the Ngāti Huirapa community at Arowhenua Pā are summarised in Box 2.

Coastal inundation from sea-level rise

The scenario results produced from our examination of projected high tide levels (MHWS10) indicate by 2040AD that some areas of farm-land on the northern side of the Opihi River as well as some seaward located bach's and homes at the Milford Huts settlement, are at risk of inundation. Further inundation of coastal land to the north and south of this area is also likely – but the extent of such inundation along the coastal margin will depend upon relative land elevations, the presence of stop-banks, openings/culverts in the shore parallel gravel barrier that lines the coast, possible wave over-topping, aggradation of the river bed in the lower reaches, existing lagoon levels as well as the coupled effect of higher river flows due to coincidence of high rainfall and storm tides. In addition, the current shoreline is already retreating and this natural process is expected to continue leading to further loss of land through erosion and landward migration of the barrier. If not constrained by coastal protection works, these low-lying areas will likely transform into coastal marsh and eventually become a permanent part of the coastal or estuarine system. By 2090 AD, an 80cm increase in sea-level would produce even greater high tide extents and resulting inundation on the northern and southern side of the Opihi River.

The extent of inundation caused by extreme storm tide levels, which incorporates the combined effect of storm surge coinciding with a high astronomical tide, shows that most of the Milford Huts settlement would be under water as well as extensive farm-lands that stretch along the coast. Recognising that many members of the community from Arowhenua Pā have varying interests in the lands, infrastructure and natural features that are part of the landscape immediately surrounding the mouth of the Opihi River as well as along the coastal margin there are a number of risks facing the Ngāti Huirapa community at Arowhenua Pā. Notable concern centred upon the periodic and permanent loss of *hapū*-owned lands and reserves that are currently managed through long-term leases for a range of agricultural activities. Such land-uses are likely to be impacted and disrupted more frequently under the scenarios assessed, and the gradual loss of such 'generational' assets through inundation and erosion is expected to adversely impact financial returns and future economic opportunities. Relocation and sale of coastal lands and infrastructure were raised as options by a number of those interviewed, citing the previous migrations of *tūpuna* [ancestors, forbears] as examples of such actions having occurred in the past; however, others were more determined to see these 'generational' assets held in Māori ownership, regardless of the possibility of such lands being eventually 'gifted' to the sea.

Box 2: Potential impacts and risks caused by climate induced river flooding

- Danger to life in the case of extreme flood events - particularly for elderly residents living alone and school children on the Pā;
- Damage or destruction of lifeline infrastructure such as roads, water, gas, sewerage, power, communications;
- Costs from service disruption to water, power, gas, communications;
- Road access is likely to be impeded for certain whānau/households living on Huirapa Street and Station Road;
- Damage to homes, machinery and equipment as well as community buildings such as the marae, school, health clinic;
- Loss of household contents and family records/heirlooms;
- Costs of clean-up, construction and maintenance of protection structures;
- Households may find it more difficult to access adequate insurance cover in the face of increased flood risk;
- Loss of land-holdings and farm-stock as well as related economic opportunity/income;
- Destabilisation of properties and surrounding lands;
- Adverse health impacts: injury, stress, trauma and sickness;
- Damage and loss of sacred sites/places resulting in loss of identity and whakapapa;
- Adverse impacts on ecology from erosion, sedimentation and pollution from destruction of septic tanks and sewer lines;
- Future development in low-lying areas of the flood plain by returning *whānau*.

What is also apparent from the maps of future extreme storm-tide levels is the extent of inundation further upstream of the Opihi River extending towards the Waipopo Huts settlement. While the results are more favourable for the Waipopo area when compared with Milford Huts – it must be recognised that the extent of inundation does not take into account the coupling effect of elevated river levels during flood events. Given a number of the community from the Pā actually live at Waipopo and have investments in privately owned land and buildings, there is an increasing likelihood of flood damage as higher sea-levels penetrate further in-land raising upstream river levels. Adverse impacts on coastal sacred sites such as traditional Pa and burial grounds are also likely and this is of deep concern to many of those interviewed - particularly from the point of view maintaining cultural heritage, *hapū*-identity and *whakapapa* to place. Less is known is about the direct and indirect impacts of such physical changes on local ecosystem services and related wild-food availability. Notwithstanding this, there existing concerns about the adverse impacts from pollution and destruction of septic tanks and sewer lines on *mahinga kai* and the maintenance of traditional knowledge are common. The potential risks and impacts associated with projected sea level rise for the Ngāti Huirapa community at Arowhenua Pā are summarised in Box 3.

Box 3: Potential impacts and risks caused by climate induced sea-level rise

≡ Increased risk of flooding from rising sea-levels and extreme weather events;

≡ Loss of *hapū*-owned farm-land resulting in loss of economic opportunity;

≡ Degradation of sacred places and sites resulting in loss of identity and *whakapapa*;

≡ Permanent inundation of low-lying coastal areas including salinization of fresh water resources;

≡ Increased coastal erosion and destabilisation of coastal slopes from rising sea-levels and storms;

≡ Altered river flows in association with newly configured rivers and streams;

≡ Adverse impacts on ecology from erosion, sedimentation and pollution from destruction of septic tanks and sewer lines;

≡ Structural damage to privately owned buildings and infrastructure from storms;

≡ Danger to life in the case of extreme flooding events;

≡ Costs of maintaining protection structures and future-proofing households with raised foundations;

8.3 Managing future risk, vulnerability and adaptation

In this final section, selected coping and adaptation strategies and actions that will help (i) minimise (reduce) present and projected future community exposure to climate induced flood conditions and risks at Arowhenua Pā, and (ii) move towards eliminating (or at least minimising) community grounded sensitivities on the one hand and enhancing coping and adaptive capacities to deal more effectively with climate induced hazards and stresses, on the other, are identified. The benefits and co-benefits that might be realised from short and long-term strategies and actions are briefly considered including any risks or unintended consequences associated with implementation[33]. Such recommendations are based upon the synthesis of the qualitative and quantitative results (includes community considerations of projected climate change impacts and risks), as well as national and international assessments of adaptations practices and options.

Note it is important to acknowledge that the coping and adaptation strategies and actions identified below are based upon fundamental risk management principles which recognise that risks can be avoided (or mitigated) by modifying any of the elements of vulnerability. This

[33] Estimated costs associated with the options identified have not been quantified. Future work will be required to estimate such costs.

approach is consistent with the New Zealand Ministry of Civil Defence and Emergency Management which recognises four key components in managing societal risk from natural hazards: reduction, readiness, response and recovery. Together these four R's contribute to limiting impacts and supporting adaptation (MCDEM, 2004). Given the inherent complexities of the climate system, and the many social, economic, and technological factors that determine impacts, future adaptation will need to be iterative where risks and possible response options are revisited over time taking advantage of new knowledge, information, and technological capabilities.

Reducing exposure to river flooding and sea-level rise

In varying ways and degrees, future projections of river and coastal inundation coupled with transformations in living arrangements are likely to challenge how different groups and individuals within the community at Arowhenua Pā deal with climate extremes and variability over the next few decades. One way to minimise and avoid the negative impacts from such changes is to reduce the 'exposure' of the 'community'. Listed below are a series of actions (or entry points) to limit projected impacts, support coping strategies and facilitate adaptation decisions and activities. Note some of the following recommendations to deal with future risks associated with river and coastal flooding have been identified before. For example, CRC (1993) prepared a 'Flood Hazard Discussion Document' for the Orari, Waihi and Temuka Rivers (and their tributaries) which included a variety of options to cope with the flooding hazard. In addition, Johnson (2002) drafted the report 'Assessment of Options' which identified a range of engineering-based flood mitigation options that would potentially alleviate the degree of impacts caused by flooding across the Arowhenua Pā area.

(i) Future-proof existing infrastructure and buildings. This option might include raising the lowest lying section of Huirapa Street which when flooded can prevent access between State Highway One and the Arowhenua School and Marae, elevating existing homes, and raising minimum floor levels in areas close to rivers and sea. The raising of Huirapa Street is a Timaru District Council (TDC) issue and should be pursued further. Existing processes for periodic maintenance and renewal of some of these structures may lead to opportunities to make the appropriate improvements at minimal added cost.

(ii) Implement building restrictions in high risk areas. Set-back zones can reduce the effects of climate change through restoring and maintaining a protective natural buffer between coastal development and the sea. Milford Huts are in a particularly vulnerable location from land and sea flooding. It is therefore worth considering prevention of further development in this area. In short, plan infrastructure for what the locality will face over the next one to two generations, not what it needs today.

(iii) Retreat or relocate at-risk dwellings and other infrastructure away from flood-plains and coastal areas. Given the competition for land resources this option is likely to be very expensive and even if Māori reserve lands were made available. New lifeline services and infrastructure would also be costly. Aside from resourcing constraints, moving from some ancestral areas and sites is likely to be unacceptable to some of the *whānau*. On the other hand, a number of interviewees emphasised pragmatic decision-making and planning. There may be deep heartache involved, long-running debates and even people who will never agree to such a proposition, but moving from ancestral grounds is not unprecedented. It has happened before and it will happen again[34].

(iv) Remove debris and metal build-up along the river. This action is particularly important for debris caught under structures such as bridges which can result in flood-waters backing up and being dammed behind such obstructions. Such strategies are a part of many river management practices – which require regular work and maintenance to be carried out.

(v) Support integrated catchment management. This sustainable planning approach is based on a catchment perspective or *ki uta ki tai*, in contrast to a fragmentary approach that artificially separates land management from water management. Such an approach gives greater account of the complex role of ecosystems in supporting and regulating human-environment interactions and well-being.

(vi) Encourage sustainable infrastructural development. Major long-life infrastructures (such as roads and causeways) will likely need climate change factors incorporated into future design, planning and construction; while improvements in household water, energy and sewerage services (among others) would assist *whānau* to deal with adverse conditions caused by climate extremes and therein reduce the risks from climate impacts. Further, action across many of these sustainable development issues might also be expected to lead to employment creation for local people.

(vii) Protect and enhance wetland areas. This will enhance the ability of wetlands and watersheds to store water, and thereby reduce some of the potential impacts and risks caused through extreme flood flows. Note that steps have already been taken to enhance the area in the front of the marae with wetland plantings.

Importantly, sea-level is not expected to stop rising at 2100 AD but rather to continue rising for many centuries into the future. Decisions on how to manage climate-related coastal hazards therefore have to remain responsive not only to changing societal pressures but also to new information about future risks. Given the permanence of infrastructure and development of coastal settlements such as Milford and Waipopo Huts, consideration will need to be given to timeframes beyond 2100 to address sustainability issues. The Ministry for the Environment (2008) suggests using a risk-based approach to manage future sea-level rise and therein recommends considering the potential consequences of higher sea-levels. Consequently, for planning and decision timeframes beyond the end of this century, an additional allowance of 10 millimetres per year is recommended.

Minimising community sensitivity and enhancing adaptive capacity

As we have argued throughout this report, there are a range of existing community sensitivities and adaptive capacities that influence the vulnerability (and resilience) of the community to deal with climate risks and stresses. While structural/engineering solutions are expected help minimise risks associated with future changes in climatic regimes simultaneously a range of non-structural measures (i.e. social-cultural factors) will also be required to minimise climate vulnerability and related risks from adverse impacts. Listed below are a series of actions (or

[34] There are a number of cases in recent years around the country where Marae have been moved due to costly flood impacts and on-going risks – e.g. Hinemaurea Ki Mangatuna Marae, Te Tairawhiti.

entry points) to limit impacts, support coping strategies and facilitate adaptation decisions and activities.

(i) Raise *hapū* awareness of climate change and natural hazard preparedness. This might include promoting education programmes on mitigation and adaptation options, risk-wise behaviour such as avoiding crossing flooded road-ways, insurance among those who occupy flood plain areas (i.e. loss burden), and learning about what is happening now and what could happen in the future. Building capacity must include scientific and technical capacity so as to better understand the risks and evaluate options for responding.

(ii) Enhance social capacity and community cohesion. The concept of mutual support and collective action was identified as a traditional coping mechanism applied at the household and community level. Actions might include conducting marae-based language and *tikanga wānanga*, expanding the skills base of community leaders and representatives, lobbying Ministry of Science and Innovation to fund research, and working with other communities to share lessons and experience.

(iii) Promote and reaffirm old-ways of environmental knowledge and natural resource management. Together with learning new strategies and practices such actions can contribute to minimising damage to natural resources and thereupon strengthen underlying social-ecological systems. Key cultural challenges must be addressed including the loss of traditional *kai* species, *mahinga kai* areas and associated *whānau*/*hapū* knowledge; and the weakening human-environment relationship. Shared norms and clear vision provided by astute leaders are key based on a vision of inheritance for future generations.

(iv) Seek economic support and technological resources from internal and external sources. In most instances, economic support will be required to assist risk reduction, emergency preparedness and adaptation to new conditions. Fostering partnerships with government bodies, companies, community organisations, and neighbouring councils might yield funding opportunities or the ability to leverage existing resource allocations.

(v) Promote Civil Defence procedures and capability. This might include establishing safe assembly areas, access to emergency routes and services, undertaking emergency preparedness measures, creating a hazard emergency response plan, and participating in local governance and institutions that encourage disaster prevention and response. The formalisation of hazard management and emergency response systems was a priority identified by many of the interviewees – particularly given the widespread concerns about more vulnerable members of the community such as school children and elderly *whānau* living alone.

(vi) Engage with regional partners and other relevant organisations to collaborate on climate change-focused initiatives and programs to prepare for climate impacts. Managing risk will require co-operation with many groups. This might include building partnerships with local agencies and organisations that support climate change adaptation activities – such as resource management, sustainable infrastructural development, hazard management and health services. Partnerships with external institutions and authorities must be based on reciprocity, mutual respect and equality.

(vii) Support research, analysis, and evaluation of climate change and its evolving implications for the community. Scientific research and technology development can expand the range, and improve the effectiveness of, options to respond to climate change. Systems for collecting and sharing information can also help ensure that climate-related decisions are informed by the best available knowledge and analyses, and can help to evaluate the effectiveness of actions taken.

(viii) Consider climate change adaptation in all *hapū/iwi*-management planning efforts. This might include integrating disaster preparation, flexible resource management regimes, environmental conservation and plans for sustainable development. It might also include supporting the protection and enhancement of local ecology such as lakes, rivers and wetland areas. This can contribute to increasing the adaptive capacity of natural systems by reducing other environmental stresses.

In the context of climate change the Arowhenua Pā community's management of risk in the future will be about drawing upon the best available information to determine the likelihood of climate impacts and the secondary or flow-on effects of their consequences. This information will in turn be used to select and implement response options that will minimise climate risk and therein reduce potential harm or loss. Together these strategies will lead to greatly lessened community vulnerability to risks from climate variability and extremes. Importantly, many of the actions recommended here to reduce exposure and sensitivity and enhance adaptive capacity to deal with climate change impacts are investments that will offer protection against natural variations in climate such as extreme weather events.

9 Conclusions, lessons and future work

The aim of this study was to identify the character of local climate hazards and associated risks that face the community at Arowhenua Pā, and to thereafter explore how the community respond to these (including the factors and processes that constrain their choices and actions). Projections of future flood risk for the Temuka River and coastal inundation at the mouth of the Opihi River due to sea-level rise were simultaneously explored to consider future risks and identify entry points for future strategies and decisions making around adaptation action and planning. In this work, we have only begun to understand the detailed social, economic, cultural and physical relationships that link activities together, and how these are affected by changes in climate. However, we can readily identify key climate exposures as well as a handful of key community determinants that are influenced by climate and likely to be exacerbated by future changes in climate conditions.

Early dialogue with community members was dominated by references to local flooding and impacts on *whānau*; historical changes in river courses, flows and mahinga kai [species and techniques]; causes and amplification of flood risks due to human modification of the environment; as well as the important role of local planning in setting regulations and managing climate related hazards and risks. Grounded insights were offered also on the 'things' that contribute or influence the way people are affected by (and deal with) climate hazards and stresses. Not surprisingly, the matters discussed often intersected environmental, economic, social, political and cultural aspects of community life. However, what was not expected was that our attempts to analytically distinguish between community sensitivities and adaptive capacities led to the recognition that one could not be discussed without the other. Four principal determinants of community sensitivity and adaptive capacity were subsequently identified: (i) social networks, conventions and transformation; (ii) knowledge, skills and expertise; (iii) resourcing and finance; and (iv) institutions, governance and policy. While this analytical outcome is contrary on the one hand with a number of vulnerability-based studies conducted with other indigenous communities that commonly consider exposure-sensitivity jointly (rather than sensitivity-adaptive capacity) the interconnected nature of human-biophysical (social-ecological) interactions is not dissimilar.

Successive visits, interviews and on-land interactions with community members from Arowhenua Pā made evident the capacities held by the community to deal with climate hazards and related stresses. Much of this capacity is rooted in elemental cultural values and approaches such as *tikanga* [tribal rules and customs] and *kawa* [ceremonial rituals, protocol, etiquette, correct procedure] and actioned through *whanaungatanga*, *manākitanga* and *kotahitanga*. In addition to the importance of internal (as well as external) social networks and conventions, knowledge of place and closer human-environment relationships through *mahinga kai* were often expressed as central to community strengths and well-being (resilience) and thereafter being able to deal with environmental risks. However, such capacities are not uniform across the community and some individuals are less well equipped to cope and adapt than others. Rapid transformations in local community structure, decreases in Māori-owned land holdings, lack of financing for infrastructural maintenance and insurance, a growing reliance on modern services, land-use change, resource management regimes, and *whānau* spending more time away from traditional areas for employment and education (among other social and institutional changes) were readily identified as increasing the sensitivity of the community to climatic risks and inversely undermining certain aspects of adaptive capacity. Notwithstanding these insights, new interactions and the development of new skills and expertise were also identified as opportunities for helping to meet the emerging demands of increasingly complex social, economic, political and bio-physical system issues facing the community. Interestingly, In spite of all of these insights, few of the people interviewed actually regard themselves as vulnerable. And yet, agreed that new community driven strategies and actions would be needed to confront existing community challenges and those likely to be exacerbated by future changes in climatic conditions.

The scenario results produced from our examination of future extreme peak flood levels for the Temuka River in 2040 AD and 2090 AD showed that in a high emissions world (i.e. the A2 Emissions Scenario) local inundation extents for the equivalent of an extreme flood event with a current average recurrence interval >500 years are unlikely to differ markedly from the inundation extents measured from a ~100-150 year extreme flood event that occurred on the Temuka River in 1986. That is, the most extreme modelled estimate of future peak flood levels in this study was more than 30% greater than those recorded for the 1986 flood event - but the relatively steep elevation of local terrain resulted in very little additional surface area being flooded. While these results are favourable in terms of the higher ground occupied by the Marae, school buildings and many *whānau* homes, they also demonstrate that lower lying properties and infrastructure (includes some occupied and unoccupied *whānau* homes, storage buildings, fencing and sections of local roads) are at greater risk of flood damage. Heightened flood peak levels also raise the likelihood of harm for farm-stock (sheep and cattle) that sometimes graze the lower plains of the Arowhenua Pā. Less is known is about the direct and indirect impacts of such physical changes on local ecosystem services; however, concerns about potential adverse impacts from pollution and destruction of septic tanks and sewer lines were common. Note the occurrence of higher flood levels on the Temuka River, flooding from other tributaries, or even failure of existing flood protection measures on the Opihi River, could result in quite different outcomes.

Coastal inundation extents surrounding the Opihi River mouth under current high tide levels, extreme storm-tide levels and sea-levels for 2040 AD and 2090 AD with an assumed 40 cm and 80 cm sea-level rises respectively were also investigated. The most notable change for the area under projected high-tide levels was increasing flood extents over time on the northern side of the Opihi River. Currently, this area is partially occupied by a mix of leasehold bach's and a small number of permanent residents (commonly referred to as the Milford Huts) as well as extensive dairying operations that stretch along the coast. Blocks of this coastal land remain in communal and private Māori ownership and are for the most part are managed through long-term leases. Such land-uses are likely to be impacted and disrupted more frequently under such scenarios, and therein the on-going value of such leases (and investment returns) are likely to decline, particularly as permanent inundation occurs. Analysis of an extreme storm-tide level, which incorporates the combined effect of storm surge coinciding with a high astronomical tide, and climate change-adjusted sea-levels for 2040 AD and 2090 AD showed even greater flooding extents on the northern side of the Opihi River are evident – especially under 2090 AD conditions when much of the Milford Huts coastal settlement is projected to be inundated. A further risk (and adaptation option) identified by interviewees was the sale of coastal lands and the relocation of infrastructure. Previous migrations of *tūpuna* [ancestors, forbears] were cited as examples of such actions having occurred in the past; however, others were more motivated to see these traditional assets held in Māori ownership, regardless of the possibility of such lands being eventually 'gifted' to the sea. Note that the inundation maps produced through this analysis only include sea-level effects; they does not include the combined effects of river flooding plus a storm-tide which are likely to produce more extreme inundation results.

What is clear from these results is that considerations of vulnerability and adaptation to climate change are inseparable from issues linked to natural hazards management and sustainable development. Even without climate change and on-going climate variability and extremes, Māori from Arowhenua Pā remain affected by social-economic and political processes that influence their capacity to cope with challenges in the short-term and adapt in the longer-term. This point is critically important for leaders and decision makers across a range of scales and institutions, as well as *te hau kainga* [home-people] on the ground who often indicated either how overwhelming and contentious the climate change issue can be or how unimportant it was as an issue when compared with other challenges currently confronting the community. In spite of these perceptions, many of those community members interviewed acknowledged the need to strengthen their social, cultural and institutional capacities to assess, plan, and respond to the direct and indirect challenges brought on by changing climate regimes and conditions.

It is also evident (as in other studies of vulnerability to climate stress) that the constraints and strengths identified represent important points of entry for strategic community, *iwi* and government level planning and policy development that can contribute to addressing the adaptation needs of the community now and into the future. As expressed above, such points of entry are deeply connected with existing social-economic-political and environmental conditions; and therein the capacity of the community to deal with future climate change risks, such heightened river flood peaks and loss coastal lands due to sea-level rise, rests upon responding to existing issues linked to resourcing, political participation, community governance, *whānau* health and education, cultural capital and management of risk associated with natural hazards. There are of course numerous complexities and uncertainties that will affect the management of future climate risks facing the community – including, among others, the capacity and willingness to create management practices that can accommodate changing risk and social-ecological conditions. As pointed out by a number of *whānau* however, this is not unusual, but rather a process that has always been followed based on resourcefulness, partnerships and learning from experience which all help to improve manage risk over time.

In spite of the range of matters explored in this study, much more remains to be done. Deeper analysis of the extent to which projected impacts can be dealt with in the future is required; as too is the need to improve the integration of information from other scientists, policy analysts, and decision-makers to strengthen the conclusions reached, and to help facilitate actual plans and actions that respond to existing vulnerabilities, and that support different adaptation options. Again, such actions will certainly need to include consideration of investment requirements, the availability of technology, societal responses, inter-generational equity, planning frameworks, as well as the possibility of absolute limits to adaptation. Analysis of the comparative climate change risks facing different Māori communities is also required to ground-truth diverse exposures, sensitivities and adaptive capacities. We strongly recommend that such research be conducted in co-operation with communities, in order to include grounded understanding and knowledge of local conditions. The benefit of such work would permit insight into the diversity and range of influences which shape attitudes and perceptions by focusing on the specificities and uniqueness of people and place. Such work would also help to avoid the danger of generalisation while teasing out the shared concerns and challenges of Māori in different places.

A further issue that remains to be addressed is how to engage with the most vulnerable groups within the community – and, how to reaffirm traditional ways as well as increase the ability of different stakeholders to use scientific knowledge for adaptation. Communicating the complexity of risks surrounding potential climate change is also challenging. Few people have the expertise/skills (or time) to understand the underlying science and thereafter to evaluate climate-related proposals and controversies. Public educational initiatives such as short video clips to raise awareness about climate change and key concepts (that can be confusing amidst the flood of information now available) would therefore be valuable. Further, given that perceptions of risks are known to be important in influencing communities' actions, tailored information as well as the 'right people' would greatly assist effective communication in the future.

The authors would like to end this report by emphasising two points. First, climate variability and climate change are part of the same continuum of issues and should not be treated as distinct and separate issues in developing methods for climate adaptation. Regardless of the science of climate change, there will be advantages for Māori with an interest in climate adaptation because of the variability that is inherent within the climate system. In short, weather extremes such as storms and floods, and climate anomalies such as droughts will continue to occur. Second, for other Māori communities interested in examining their own climate change challenges it is important to know that consideration of community vulnerability does not require location-specific climate information and nor does it require the science of climate "prediction" to be more developed. Rather, first-order climate change projections are readily available and these can be used to enhance awareness about potential impacts and associated risks. Perhaps more importantly, strategies and policies to tackle vulnerability and enhance adaptability to climate variability and future change can be developed in spite of the uncertainties, because most of the factors and processes that constrain choices and actions intersect existing issues of *whānau/hapū* development and social-ecological well-being.

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11 Mihimihi

Tuia te raki e tū iho nei, tuia te papa e takoto ake nei, ki kā manu tīoriori o kā pari kārakaraka, ki kā pūwānaka o te kī, otiiā ki kā whakamīreirei o te marae o Kāti Huirapa, tātu atu ki Te Rūnaka o Arowhenua – tēnā koutou, tēnā koutou, tēnā rā koutou katoa!

Me mihi ka tika ki a tātau tini mate, nō reira e te toka tū moana e Haki moe mai, moe mai, moe mai rā e te rakatira. Haere ki ō tupuna e tauwhaka ana mōhou. Rātau te huka wairua ki a rātau, ā, tātau kā kanohi ora o rātau mā kua karo ki te kore. Nā koutou katoa rā, i tū rakatira ai tā tātau kaupapa whakaharahara. Heoi anō rā koutou, he maha tonu kā kākano i ruia mai ki te hinekaro o tēnā takata, o tēnā takata o mātau, ā, ka puta, ka pihi, ka pūāwai hei kā wā e haere ake nei. Heoi anō, me kī, me kore ake rā koutou, kua kore tēnei kaupapa e whai take, kia puta i te whei ao, ki te ao Mārama.

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12 Glossary: Māori language

A	
Āe	Yes, I agree
Ahi kā	Burning fires of occupation – title to land through occupation
Aroha	Sincerity, mutual-respect, love
Aruhe	Edible rhizome of bracken-fern, fern root
Awa	River
H	
Hapū	Sub-tribal kin group
Hau-kainga	Home-people
Hīkoi	Land-walks, to step, stride, march, walk
Hōhā	Be fed up with
Hui	Assemble, meeting, gathering
Hui ā-tau	Annual Ngāi Tahu meeting
Hura kōhatu	Unveiling – a ceremony at the graveside to unveil the headstone
I	
Īnanga	Whitebait – *common Galaxias*
Iwi	Tribal kin group
K	
Kāika / Kāinga	Home, village, settlement, habitation
Kai	Food, to eat, consume
Kaitiaki	Trustee, minder, guardian, custodian, keeper
Kaitiakitanga	Stewardship, respect, identity, guardian
Kanakana	Lamprey – *Geotria australis*
Kanohi kitea	Seen face, in person, literally means 'face to face'
Kawa	Ceremonial rituals, protocol, etiquette, correct procedure
Kaumātua	Elders (plural) – not gender specific
Kaupapa	Topic, policy, matter for discussion, plan, scheme, agenda, subject, programme, theme
Kāuru	Edible stem of the cabbage tree. *(See also Tī and Whanake)*
Kōkopu	*Galaxiids*

Kōrero	Discussion, account, narrative, to speak
Kōura	Freshwater crayfish - *Paranephrops*
Koha	Gift, donation, contribution
Kotahitanga	Solidarity, unity, collective action
Ki uta ki tai	From the mountains to the sea – Ngāi Tahu paradigm and ethic regarding overall approach to natural resource management
Kuia	Elderly woman, grandmother
M	
Māhaki	Humility
Māori	Indigenous peoples of Aotearoa/New Zealand
Māra	Garden, cultivation
Mātauranga Māori	Māori knowledge – the body of knowledge origination from Māori ancestors, including the Māori world vies and perspectives, Māori creativity and cultural practices
Mahi	Work, employment, practice, activity, excercise
Mahinga kai	Food gathering, cultivation
Mana	Dignity, authority, control, prestige, power
Mana whenua	Territorial rights, power from the land - power and authority associated with possession and occupation of the tribal land.
Manāki	To support, take care of, give hospitality to visitors, protect, look out for
Manākitanga	Hospitality, kindness
Manuhiri	Guests, visitors
Marae	Meeting house and surrounding area
Mauri	Life principal, entity
Mihi whakatau	Formal welcome speech
Moana	Ocean, sea
Mokopuna	Grandchild
P	
Pā	Traditional settlement
Pākehā	New Zealander of European descent
Pakeke	Adult (plural)
Pāwhara	Process of preparing and drying fish
Papatipu Rūnanga	Sub-tribal council

Papatūānuku	Mother-Earth, the ecological system
Paru	Be dirty, muddy, soiled
Pōua	Grandfather
Puna	Spring (of water)
R	
Whakarāpopotonga	Executive summary
Rangatahi	Younger generation, youth
Rangi	Sky-Father
Raruraru	Problem, trouble, be in difficulty, perplexed
Reo	Voice, language
Rohe	Area, boundary, region, district
Rūnanga	Tribal council
T	
Tāne	Male, man, also name of Deity of the forest, trees and birds *Tāne Mahuta*
Taua	Grandmother
Tautoko	To support, care, prop up, advocate, verify
Tangaroa	Deity of the sea/oceans
Tangata whenua	Home people, people of the land, locals, residents, hosts
Tangi	Funeral, grieve, cry
Teina	Younger sibling or relative (of the same gender)
Tī	Cabbage trees of various species - in this case the *Cordyline australis*. A palm-like tree with stong leaves; the young inner leaves are eaten both raw and cooked. *(See also Whanake)*
Tikanga	Māori conventions, culture, custom, correct procedure, lore
Tiko	Excrement
Tuakana	Elder sibling or relative (of the same gender)
Tuna	Freshwater eel – *Shortfin eel (Anguilla dieffenbachia), longfin eel (Anguilla australis)*
Tūpatotanga	Caution
Tūpuna	Ancestors, forbears
Tūrangawaewae	A place to stand, home grounds through rights of kinship and *whakapapa*
U	

Umu	Earth oven
W	
Wāhine	Females, women
Wāhi tapu	Sanctuary, sacred area
Wānanga	Seminar, forum, to meet and discuss
Wairua	Spirit, soul, spiritual
WH	
Whānau	Extended family, born
Whānau-katoa	Whole family, extended family
Whānau-iti	Small family, immediate family
Whakāro	Thought, opinion, understanding, idea, plan
Whakapapa	Ancestral and kinship linkages to people and place, genealogy, literally means ‘to place in layers’
Whakapiki tangata	Empowerment
Whakatuia	Integration
Whakawhanaungatanga	Kinship, process of strengthening relationships
Whanake	Cabbage trees of various species - in this case the *Cordyline australis*. A palm-like tree with stong leaves; the young inner leaves are eaten both raw and cooked. *(See also Ti)*
Whanaungatanga	Relationships, interconnection, birth
Wharenui	Main meeting house at a marae

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Appendix A Photo Gallery

This appendix contains a selection of photos from the first phase of community interviews conducted with Ngati Huirapa the 8th - 12th December 2010.

Appendix B Rainfall statistics for climate change emission scenarios A1B and A2 (2040 and 2090 AD)

This appendix contains rolling average three monthly rainfalls over the Temuka catchment for the A1B and A2 emission scenario for 2040 AD and 2090 AD. A positive number indicates an increase in rainfall over the base period and a negative number indicates a reduction in rainfall over the base period.

Table 7: Percentage change in rolling average three monthly rainfalls for the emission scenario A1B (2040 AD). The highest and lowest percentage increase and decrease are shaded.

Rainfall: A1B 2040 - 3 month averages

Monthly mean		M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11	M12
Jan	70.7	11.0	9.6	3.9	1.3	8.4	-1.2	-8.8	1.3	-3.7	22.0	-8.4	11.0
Feb	81.3	7.0	7.7	7.0	0.8	2.7	-5.3	-1.2	1.2	-2.8	22.3	-0.5	13.8
Mar	93.1	0.6	8.3	5.2	2.7	-1.2	-1.7	0.5	-0.5	-4.1	9.4	2.4	11.1
Apr	65.3	0.2	6.8	-1.2	1.8	-8.1	-5.0	-1.6	-2.2	-9.9	5.7	-1.6	15.8
May	52.9	-16.5	11.1	-12.0	-0.8	-10.7	-3.0	-9.3	-4.8	-12.8	2.7	0.8	13.2
Jun	58.3	-18.3	5.6	-14.2	-5.1	-11.5	-3.3	-8.1	-6.1	-8.3	0.6	-0.6	0.2
Jul	66.2	-19.7	1.6	-10.7	-7.9	-7.8	-0.8	-4.4	-6.4	-7.2	-5.5	-0.4	-2.8
Aug	55.4	-14.7	-6.7	-3.9	2.8	-5.5	5.5	-3.8	-1.6	-4.4	-1.7	1.9	-6.8
Sep	64.0	-1.9	-4.2	-1.8	2.7	-4.9	6.1	-1.3	-2.1	-2.6	1.0	-0.1	1.8
Oct	76.6	3.6	3.5	-2.2	4.8	0.5	4.4	-7.9	2.7	-1.6	7.9	-1.6	1.5
Nov	76.4	10.3	11.4	-3.6	1.1	1.1	1.6	-9.6	-0.1	-1.2	8.5	-5.2	6.7
Dec	85.3	8.9	7.7	1.1	0.6	1.7	2.9	-3.9	-2.5	-1.6	7.9	-6.2	5.8

Table 8: Percentage change in rolling average three monthly rainfalls for the emission scenario A1B (2090 AD). The highest and lowest percentage increase and decrease are shaded.

Rainfall: A1B 2090 - 3 month averages

Monthly mean		M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11	M12
Jan	70.7	12.3	9.6	4.4	-1.6	12.5	16.6	-2.0	7.0	3.7	25.3	-12.9	8.8
Feb	81.3	5.4	9.8	6.8	-4.3	12.8	10.9	7.3	3.0	5.9	23.2	-2.6	6.5
Mar	93.1	1.1	7.5	0.1	-5.8	5.7	8.1	3.6	-0.6	1.2	9.6	1.2	4.6
Apr	65.3	-5.6	13.0	-3.6	-6.6	-7.1	4.6	-5.4	-4.2	-1.4	6.2	-1.2	6.9
May	52.9	-13.8	13.3	-17.1	-2.2	-20.1	6.9	-10.3	-13.7	-7.6	4.4	-8.2	1.3
Jun	58.3	-21.7	8.7	-20.1	-3.0	-19.8	4.0	-6.0	-11.2	-6.2	5.6	-8.1	-2.5
Jul	66.2	-21.9	0.3	-17.8	-5.6	-9.0	6.9	-0.8	-6.0	-4.9	-0.5	-4.8	-4.0
Aug	55.4	-22.4	-6.1	-9.8	0.4	-5.3	17.8	0.0	-0.4	-2.1	-1.2	-1.3	-0.1
Sep	64.0	-5.9	-1.5	-1.6	2.6	-9.1	18.0	-6.1	-4.1	5.2	1.2	-1.3	-1.7
Oct	76.6	4.3	4.3	-4.3	1.8	-7.1	15.2	-10.9	-1.2	6.2	8.6	-4.4	3.2
Nov	76.4	11.2	11.9	-6.4	-2.8	-5.3	12.1	-14.4	-2.6	8.4	10.6	-6.6	2.9
Dec	85.3	10.0	7.3	-0.7	-2.5	0.0	12.6	-7.0	0.3	4.5	12.1	-7.5	2.4

Table 9: Percentage change in rolling average three monthly rainfalls for the emission scenario A2 (2040 AD). The highest and lowest percentage increase and decrease are shaded.

Rainfall: A2 2040 - 3 month averages													
Monthly mean		M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11	M12
Jan	70.7	13.3	11.6	4.6	1.6	10.1	-1.4	-10.6	1.5	-4.3	26.5	-10.2	13.4
Feb	81.3	8.5	9.3	8.2	0.9	3.3	-6.6	-1.4	1.5	-3.4	26.9	-0.6	16.7
Mar	93.1	0.7	10.0	6.1	3.3	-1.4	-2.0	0.6	-0.7	-4.8	11.4	2.9	13.5
Apr	65.3	0.2	8.2	-1.5	2.2	-9.8	-6.1	-1.9	-2.7	-11.8	6.8	-2.0	19.2
May	52.9	-20.0	13.4	-14.1	-1.0	-12.9	-3.6	-11.2	-5.8	-15.2	3.3	1.0	16.1
Jun	58.3	-22.2	6.7	-16.7	-6.2	-13.8	-4.1	-9.8	-7.4	-9.9	0.8	-0.7	0.3
Jul	66.2	-23.8	1.9	-12.6	-9.5	-9.4	-0.9	-5.3	-7.8	-8.6	-6.6	-0.4	-3.4
Aug	55.4	-17.8	-8.1	-4.6	3.3	-6.6	6.8	-4.6	-1.9	-5.3	-2.1	2.3	-8.2
Sep	64.0	-2.3	-5.1	-2.1	3.3	-5.9	7.5	-1.6	-2.6	-3.1	1.2	-0.2	2.2
Oct	76.6	4.4	4.2	-2.6	5.9	0.5	5.4	-9.6	3.3	-1.8	9.6	-1.9	1.9
Nov	76.4	12.5	13.7	-4.3	1.3	1.3	2.0	-11.6	-0.1	-1.4	10.3	-6.3	8.1
Dec	85.3	10.8	9.3	1.3	0.7	2.0	3.5	-4.7	-3.1	-1.9	9.5	-7.5	7.1

Table 10: Percentage change in rolling average three monthly rainfalls for the emission scenario A2 (2090 AD). The highest and lowest percentage increase and decrease are shaded.

Rainfall: A2 2090 - 3 month averages													
Monthly mean		M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11	M12
Jan	70.7	14.9	11.6	5.2	-1.9	15.1	20.4	-2.4	8.6	4.3	30.5	-15.6	10.6
Feb	81.3	6.5	11.8	8.0	-5.2	15.3	13.4	8.9	3.6	7.0	28.0	-3.1	7.9
Mar	93.1	1.3	9.0	0.1	-7.0	6.9	9.9	4.4	-0.8	1.5	11.6	1.5	5.6
Apr	65.3	-6.8	15.7	-4.2	-8.0	-8.6	5.6	-6.5	-5.2	-1.6	7.5	-1.5	8.3
May	52.9	-16.7	16.1	-20.2	-2.7	-24.1	8.5	-12.4	-16.7	-9.1	5.3	-9.9	1.6
Jun	58.3	-26.3	10.4	-23.7	-3.7	-23.7	5.0	-7.3	-13.7	-7.3	6.7	-9.8	-3.0
Jul	66.2	-26.6	0.4	-21.0	-6.8	-10.8	8.5	-1.0	-7.3	-5.8	-0.6	-5.9	-4.9
Aug	55.4	-27.1	-7.3	-11.6	0.5	-6.4	21.8	0.0	-0.5	-2.5	-1.4	-1.6	-0.1
Sep	64.0	-7.2	-1.9	-1.9	3.2	-10.9	22.2	-7.4	-5.0	6.2	1.5	-1.6	-2.0
Oct	76.6	5.2	5.2	-5.1	2.1	-8.5	18.7	-13.2	-1.5	7.4	10.3	-5.3	3.9
Nov	76.4	13.6	14.4	-7.5	-3.4	-6.4	14.9	-17.4	-3.1	10.0	12.8	-8.0	3.6
Dec	85.3	12.2	8.7	-0.8	-3.0	0.1	15.5	-8.5	0.3	5.4	14.6	-9.0	2.9

Appendix C Flood extents under the A1B climate change scenario 2040 AD and 2090 AD

This appendix contains flood extents for the modelled 1986 Temuka River flood and the inundation extent for a corresponding event by the 2040s (Figure 23) and 2090's (Figure 24) under the A1B climate change scenario. The inundation projections represent the average of the rainfall projections from the twelve global climate models used.

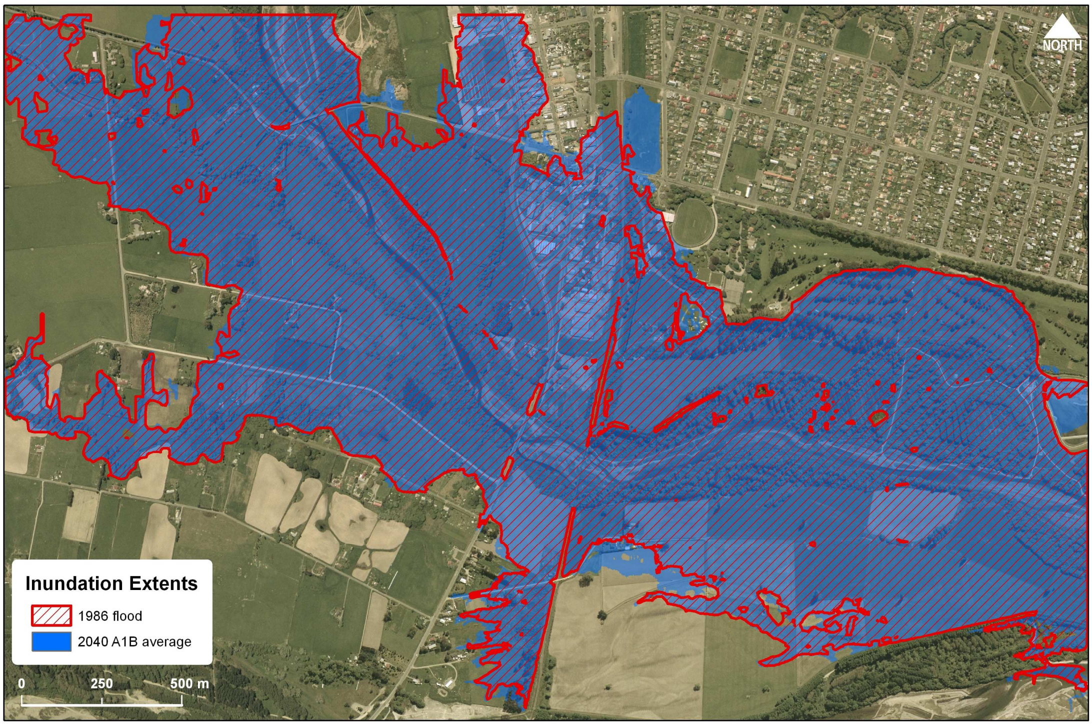

Figure 23: Inundation extents of the modelled 1986 flood and the 2040 A1B average flood.

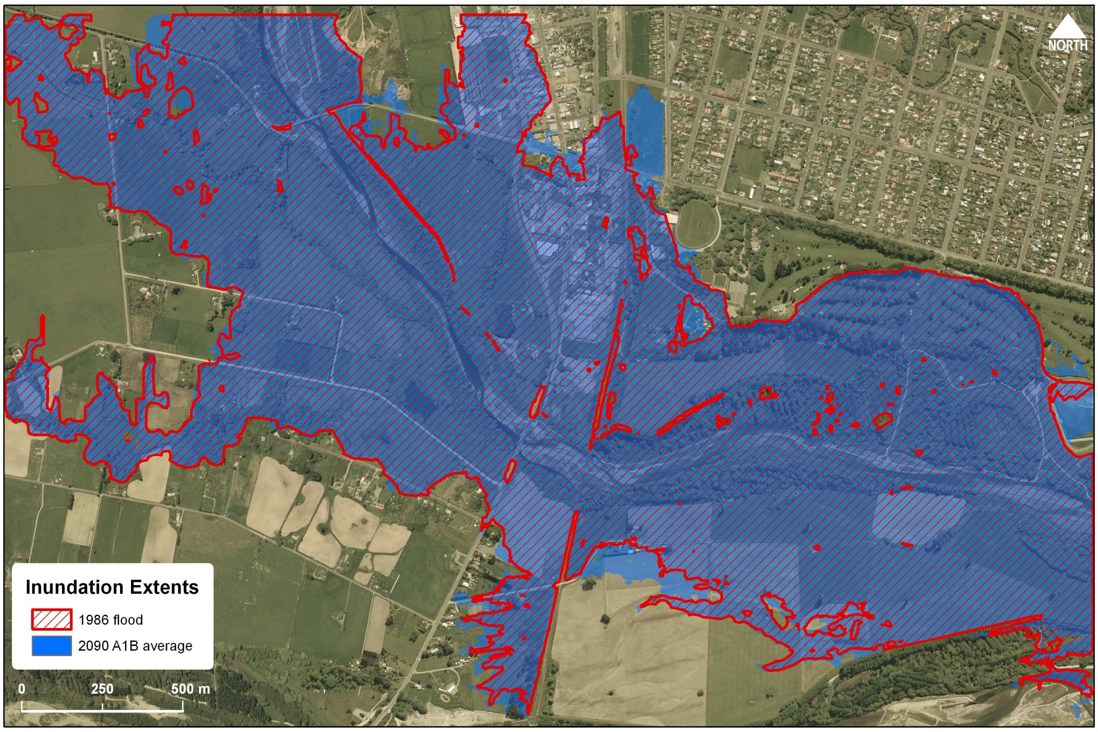

Figure 24: Inundation extents of the modelled 1986 flood and the 2090 A1B average flood.