Appendix 23: Hydro Dams

1. Introduction

The eight hydro dams along the Waikato, from Aratiatia to Karaapiro (Table 1), have drowned important cultural and geothermal sites, altered fisheries, changed the river's ecology, hydrology, sedimentology, morphology, water clarity and quality, temperature regime, and recreational uses. These changes have impacted on the relationship of iwi with the river. However the dams have also contributed significantly to the development of the Waikato and national economies, supplying about 13 percent of the electricity and providing important system flexibility to meet daily variations in energy needs. Furthermore, they contribute to flood control and support fisheries and recreational amenities, including an international rowing facility. This appendix summarises key issues related to the Waikato hydro dams and their operation, as identified at the consultation hui and in available literature.

Table 1: Waikato hydro dams and their significance amongst moderate-large (> 10 MW) stations for NZ hydro-electric generation (Young et al., 2004).

Name	First operated	Installed capacity (MW)	%mod-large dam capacity
Karaapiro	1947	90	1.76
Arapuni	1929–46	197	3.86
Waipapa	1961	51	1.00
Maraetai	1953–62	360	7.05
Whakamaru	1956	100	1.96
Atiamuri	1958	84	1.65
Ohakurii	1961	112	2.19
Aratiatia	1964	84	1.65
All Waikato	–	994	21

1.1 Sediment and channel morphology

The dams act as sediment traps, storing on average 280,000 tonnes of sediment per year (167,000 t/yr is sand and gravel that previously would have nourished the bed of the lower Waikato and 112, 000 t/yr is silt and clay that would previously have been transported along the lower Waikato as suspended load) while 37,000 tonnes per year of fine suspended load pass downstream from Karaapiro (Hicks and Hill, 2010). Lake Ohakurii makes the greatest single contribution to this sediment storage, at about 125,000 t/yr, followed by Maraetai, Karaapiro and Whakamaru, at about 40,000 t/yr each. The reservoir lifetimes before being completely in-filled with sediment have been estimated to be in the range one thousand to several thousand years (Hicks et al., 2001). The interception of the bed-material load upstream is a major cause of falling riverbed levels downstream of Karaapiro in recent decades. The reduction in suspended sediment as water passes through the hydro dams would have increased water clarity, however, increased water residence time within the reservoirs allows more time for growth of algal phytoplankton that reduce water clarity (particularly during summer).

The accumulation of sediment within the hydro dams has important implications for restoration options involving removal of the dams or opening the dam outlets to create a non-impounded flow regime. It was estimated in 2001 that it would take at least 35 years for the stored sediment to move past Ngaaruawaahia if the river reverted to a natural flow without dams scenario (McConchie, 2001) – resulting in a corresponding period of very high turbidity, particularly during floods. This would also cause bed aggradation in the lower river, flooding, and reduced drainage of the lower river land, reducing production and increasing drainage costs. Sediment scour would also release stored arsenic.

The reduction in downstream sediment transport below Karaapiro Dam also results in downcutting of the riverbed at least as far downstream as Ngaaruawaahia. Since Karaapiro dam was built in 1947, riverbed surveys have shown that the downcutting has advanced downstream as a wave. Initially, the downcutting was focused upstream from Hamilton and the bed-material scoured from there served to replace that trapped in the reservoirs upstream. However, with time a cobbly 'armour' has formed on the riverbed between Karaapiro and Cambridge, and by the 1960s the downcutting had advanced past Hamilton. Over recent decades, at Hamilton, the downcutting rate has averaged 25-35 mm/y; some sections have deepened more while others have been more stable, apparently in response to at least partial armour development. The downcutting wave now extends past Ngaaruawaahia, although downcutting there proceeds at a lesser average rate owing to restoration of the bed-material load from the sediment scoured from upstream and from fresh inputs from the Waipa River. Further downstream, river-bed downcutting has for the most part coincided with sand extraction; when this has ceased, riverbed levels have generally recovered.

This riverbed downcutting issue was reviewed at the time of the Mighty River Power Ltd (MRP) consent hearings in 2003. Potential issues due to downcutting include erosion around engineered structures, such as bridge supports, long-term erosion of streambanks along the mainstem and in tributaries as they adjust to the lower river bed levels and perched infrastructure associated with falling water levels. It was concluded (Rogen, 2001) that the downcutting had no significant effects on the structural performance of the bridges, and that any future issues relating to pile exposure could be managed with engineering solutions. Studies of riverbank erosion then (McConchie, 2001), and since (Fellows et al., 2007) have shown no clear evidence of increased bank erosion associated with hydro-power effects. However, geomorphic responses typically take decades to develop, and since the degradation is expected to continue for the foreseeable future, continued monitoring of bank stability appears to be prudent (Hicks and Hill, 2010). As water levels have fallen with the lower bed through the Hamilton area, facilities such as water intakes, drains, boat ramps, and jetties have been perched higher than their functional levels and some have required maintenance/repair.

1.2 Arsenic

The dams also store about 7-8 percent (15 t/yr) of the total input of arsenic to the river (c. 204 t/yr) (Kim, 2010). As with sediment, arsenic storage is greatest in Lake Ohakurii (c. 8t/yr, Aggett and Aspell, 1980), where the bed may have accumulated up to 380 tonnes of arsenic since the lake was formed in 1961 (Kim, 2010). Low oxygen conditions at the lakebed during summer stratification of the hydro lakes can result in arsenic release back to the water column and summer increases in arsenic have been observed at Hamilton (see Appendix 21: Toxic Contaminants).

1.3 Power supply

MRP operates the Waikato River hydro system (installed capacity 994 MW) according to resource consents granted for 35 years in May 2006. The eight dams and nine power stations (with two at Maraetai) provide 4200 GWH on average to the New Zealand electricity requirements, representing about 13 percent of the national electricity supply and up to 25 percent of daily peak supply[1], which is strategically located closer to the centres of peak electricity demand than other major hydro-electric power sources (located in the South Island). The Waikato hydro system also provides key ancillary services to the functioning of the New Zealand power supply, including frequency control, power reserves (to cover interruptions in supply elsewhere in the system), voltage support for the central and upper North Island and black start capacity.[1] This suggests that the Waikato River hydro-electric system is a keystone asset in the New Zealand economy.

1.4 Infrastructure built around the presence of dams

The hydro system has had a fundamental impact on the development of the Waikato region. Roads and towns developed as the dams and power stations were constructed, and the dams provided road access across the river. Many water supply intakes have been designed taking advantage of the hydro system and the dams play a role in moderating the effects of floods. The international rowing facilities rely on the Karaapiro dam and the control of water levels and flows that is now possible.

[1] T.J. Truesdale evidence, Mighty River Power Resource consent hearing

Housing has been built around the lakes and property values have risen as a result of lake views. These assets and the benefits they bring to the wider community would be severely affected if the Waikato River was to be managed in its 'more natural state' or if the dams were removed or operated as a 'run of river' system. The costs of mitigating such risks would be substantial, involving for example, flood protection works, re-engineering infrastructure, and compensation.

1.5 Water levels and flow peaking regimes:

The resource consent conditions under which MRP operates have set maximum and minimum levels at the Taupoo Gates (357.25 and 355.85 m ASL), minimum flows at Karaapiro outlet (>140 m^3/s as ½ h average and always >120 m^3/s, with some seasonal variations) and requirements to assist Environment Waikato in its role as flood manager. An example of the latter is condition 5.9 that requires that when the discharge from Karaapiro exceeds 500 m^3/s and/or the flow at Ngaaruawaahia exceeds 850 m^3/s Karaapiro hydro reservoir is operated so that flows downstream of Karaapiro are similar to or less than those that would have occurred without the hydro operations in place.

MRP's consents place no restrictions on rates of flow ramping (the rate at which flows are varied) to generate hydro-electric power to meet fluctuations in power demand. Ramping results in higher flows at Karaapiro outlet during the daylight hours that influence natural water levels downstream to about Ngaaruawaahia. Due to travel time over the 30 km to Hamilton, this results in typically highest flow in the city at midnight and lowest flows during the day. Since the mid-1990s the hydro-electric scheme has been run in a manner that has increased daily flow fluctuation and hydro lake water levels (Fig. 1). The magnitude of flow fluctuations at Hamilton increased between the mid-1990s and 2003. Between 1975 and 1997 median weekly flow fluctuations were 100 m^3s^{-1} or less. Since the beginning of 2000, the annual median flow fluctuation has been 135 and 160 m^3/s, about 50 percent higher than the 1975–1997 median (Figure 1).

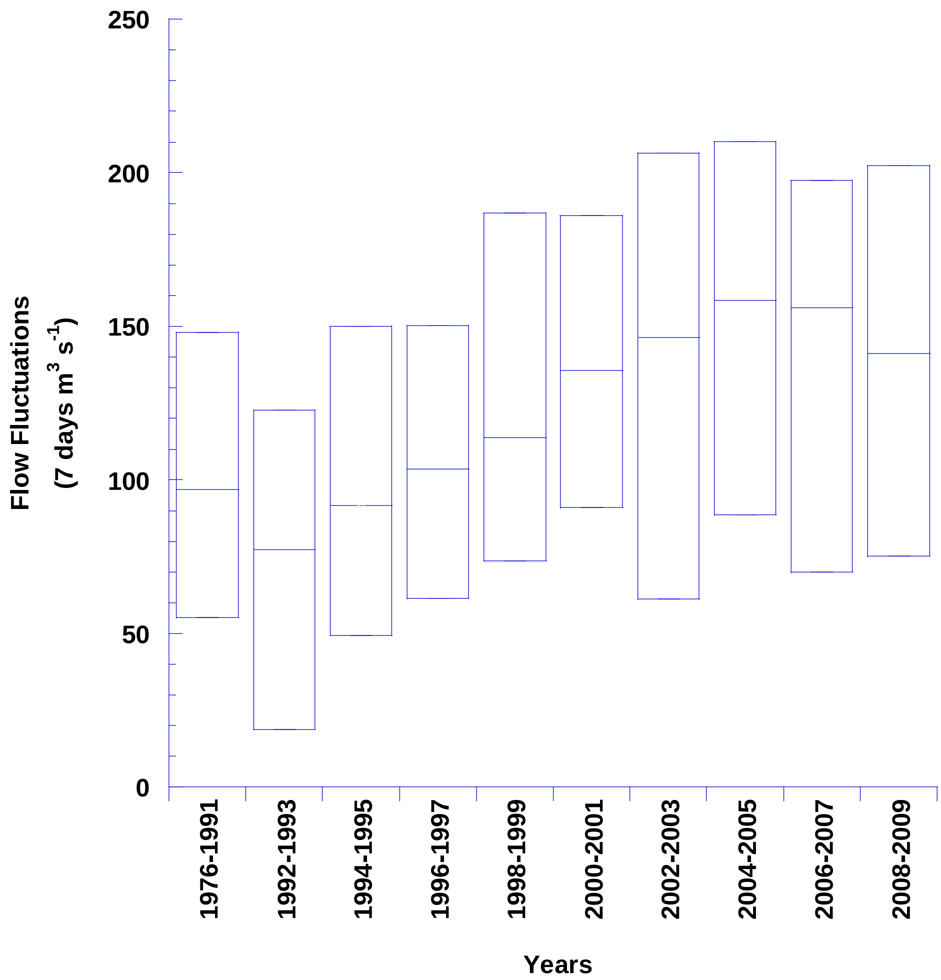

Figure 1: Box plot of weekly flow fluctuations in the Waikato River at Victoria Bridge 1976-2009. The box shows the magnitude of flow fluctuations that are exceeded 10 percent (top) and 90 percent (bottom) of the time and the bar indicates the median weekly flow fluctuation**.**

MRP argued at the 2003 hearing for renewal of its consents to operate the Waikato hydro system[2] that the ability to use hydro peaking freely is vital to the profitability of the company and important for efficiently managing the smooth supply of energy within the country and reduce the need to use greenhouse gas emitting energy sources. This need has likely increased with the increased use of wind power that fluctuates markedly in supply, requiring buffering by other sources.

Issues relating to the effects of increasing ramping that were raised in evidence to the MRP hearings and the consents Assessment of Environmental Effects (AEE) (NIWA, 1999) included:

- Potential effects on increased streambank and riverbed erosion (although this appears to be a minor issue (see Hicks and Hill, 2010)).

[2] Evidence of D. Heffernan and J Truesdale, Mighty River Power resources consents hearing.

- Reduced macrophyte abundance in lakes and the river between Karaapiro and Ngaaruawaahia (with flow on effects on invertebrate and fish habitat and food supply).

- Increased size of the varial zone on lake and river margins, where sediments are exposed to air for part of the day, with potential negative effects for sediment character, invertebrates (particularly non-mobile net-building caddis-flies at Aratiatia and Arapuni tailraces and snails), fish spawning (particularly smelt) and strandings, and aesthetics.

Table 2 shows the predicted effect that ramping has on the varial zone and river habitat.

Table 2: Predicted effects of Karaapiro flow regimes on width of varial (daily dewatered) zone through Hamilton city (Jowett, 2003).

Flow fluctuations (m^3s^{-1}) (Median, 10 and 90% Range)	Varial zone width (m)	Area of suitable macrophyte habitat (m^2/m)	Representing
100, 180–280	10	1.43	1975-95 average
140, 160–300	13	1.1	early 2000's
200, 140–340	17.5	0.56	max. allowed pre- consents

Anecdotal evidence on ramping effects presented at consultation hui identified additional impacts of low flow levels during the day and unpredictable changes in water level on waka ama (boat strandings/groundings), swimming, and potential effects on kooura that use river edge habitats in medium to large rivers (Hicks, 2003). The abundant common freshwater snail *Potamopyrgus antipodarum*, that was considered a core component of the Waikato River fauna but is vulnerable to ramping effects (due to its preference for macrophytes and slow velocity areas that occur along margins (Jowett et al., 1991)) has declined at the Hamilton Traffic Bridge over the period from 1991–2009 (National Rivers Water Quality Network, NIWA unpublished data).

The hearing commissioners to the MRP consents took the view that the potential impacts described were insufficient to out-weigh the overall benefits of the hydro-electric scheme and granted the consents with the level controls described above and requirements for ongoing monitoring the review impacts.[3]

[3] Mighty River Power Taupo-Waikato Consents Decision Report (2003) EW Document #: 852012.

1.6 Impact of hydro dams on fish movement

Prior to the construction of the hydro dams, the Horahora Falls (near the current Horahora Bridge, 15 km upstream of Karaapiro Dam) would have been a natural barrier to upstream movement by non-climbing fish (e.g., smelt and iinanga) whereas the Arapuni Falls (25 km upstream of Karaapiro Dam) were the likely barrier to most climbing fish (tuna, lamprey, climbing galaxiids), although kooaro appear to have been able to move throughout the river system. Thus the Karaapiro Dam has limited natural upstream fish movement by 15–25 km. However this is mitigated by the elver transfer programme that collects migrating elvers at the Karaapiro dam face in December to March each year and transfers them to each of the hydro dams except Ohakurii (avoided due to potential for geothermal-derived metal contamination of tuna).

Whilst the transfer programme has facilitated the tuna fisheries in impoundments above the lakes, it does not contribute to the spawning runs to the sea because most downstream migrating tuna are killed on passing through the power station turbines (see Appendix 5: Tuna).

1.7 Impact of impoundments on traditional features

The hydro dams have drowned many natural features (e.g., rapids, cliffs, geothermal features) and sites of cultural significance to Maaori.

1.8 Impact of impoundments on algal growth

The eight Waikato River hydro dams have the vast majority of the total storage within the Waikato catchment, totalling 570 million m^3 equivalent to 16.5 days of the average Waikato flow at Mercer (400 m^3/s). Impoundment increases the residence time of water flowing from the catchment to the sea, thus allowing more time for phytoplankton biomass to develop in response to light and nutrients, with associated changes in water colour and clarity (Rutherford et al., 2001).

The Waikato River Catchment Water Quality Model (WRWQM, Rutherford et al., 2001) has predicted the influence of the dams on factors including water travel times and water quality along the river mainstem. The WRWQM predicts that the dams increase the travel time between Taupoo and Karaapiro from 62 hours to 830 hours under summer low flow conditions and from 48 hours to 375 hours under winter high flow. These increases in residence time were predicted to result in 3-4-fold increases in suspended algal biomass (phytoplankton, measured as chlorophyll *a*) at Karaapiro and to reduce the water clarity at Karaapiro by 35 percent (2 m to 1.3 m) during summer low flows and 10 percent during winter high flows.

2. Actions

Possible actions raised during the consultation process and during the MRP consent hearings include the following:

1. Reducing the magnitude of flow peaking below Karaapiro Dam: Restricting the hydropeaking operation of Karaapiro Dam to the 1976-1991 level, whilst allowing the existing permitted operating regime of the dams upstream to continue.

2. Ceasing use of all the hydro dams for electricity generation and opening their sluice gates so that the river reverts to natural levels.

3. Removing all the hydro dams so that the river reverts to natural levels and natural longitudinal connectivity is restored.

These actions would be accompanied by complex resource consenting and other legal issues.

3. Costs

Direct costs to the Waikato River Authority would be relatively low (mainly legal) for the reduction in hydro peaking to 1976-1991 levels. However, there would be flow on costs to the economy from likely higher electricity prices, the difficulty finding a replacement system that can respond to hourly fluctuations in peak power demand, and to increased GHG emission taxes arising from the use of non-hydro electric generation.[4] Costs would be at least an order of magnitude higher for the options of returning the river to a natural level and flow regime and dam removal. This would create a need to replace 13 percent of the national electricity supply (up to 25 percent of daily peak supply) that is strategically located closer to the centres of peak electricity demand than other major hydro-electric power sources (located in the South Island). Evidence presented at the MRP hearings suggested that the cost of replacing the Waikato hydro system generating capacity would be in excess of $4 billion in 2003 dollars assessed over the next 35 years.

Dam removal or natural flow options would require substantial expenditure to rehabilitate the exposed areas of dam bed and the dam removal option would involve further engineering expenses for dismantling and disposing of the dams. These options would also have substantial lost opportunity costs due to the loss of utility of amenities that have developed around the hydro dams, including cycleways, outdoor education and boating facilities, and the international rowing facility at Karaapiro. Furthermore, they would also incur costs downstream to deal with the

[4] T.J. Truesdale evidence to Mighty River Power Resource Consent Hearings.

increased flood risk due to downstream movement of sediment stored in the dams and to manage and compensate for effects on infrastructure built around the presence of dams.

4. Timing

Alteration of the hydro-peaking regime would require variation to MRP's existing resource consents. This would almost certainly be appealed, delaying its implementation. There would also be considerable delays before alternative power supply arrangements could be made.

Restoration of natural river levels would also involve considerable legal complexities If these could be resolved it would take two years before a new flow regime was stabilised, but it would take decades before fine sediments were flushed from the system and upstream fish access would still be restricted at Karaapiro Dam. It would likely take decades before alternative electricity generation capacity could be developed. If it was decided to wait until the dams had reached the end of their existing operational life, the removals would likely be staggered over the next century.

5. Outcomes

Reducing the magnitude of flow peaking below Karaapiro would reduce the size of the marginal band of the river that is regularly dewatered (the varial zone) in Hamilton city by about 30 percent and increase the area of suitable habitat for macrophytes by about a similar amount. This is likely to benefit river ecology by reducing the stranding of invertebrates and increasing the macrophyte habitat for them to colonise. However it would also result in the spread of and increased growth of aquatic weed beds which will affect swimming access and boating and other recreational activities.

The options to reduce the hydro-peaking or remove the hydro-electric function of the dams would have substantial negative impacts on the regional and national economy. The reliability and cost of electricity supply would be affected and if fossil fuels had to be used to replace the lost generation New Zealand's green house gas emissions would increase.

Returning the river to a natural level would reduce the residence time of water in the river (and hence algal growth and biomass). However, the net effect is likely to be further reductions in water clarity throughout the river system for a period of decades as sediment stored within the hydro reservoirs was eroded and transported downstream. The deposition of this large amount of sediment in the lower river would increase flooding and navigation hazards and require considerable additional expenditure on dredging and flood protection.

Other impacts would include:

- Dam removal would remove the ability to control flooding through reservoir manipulation and storage.
- Upstream fish passage would not improve, unless the dams were removed, because the outflow through the dams' sluice gates would likely present a velocity barrier.
- Dam removal would change opportunities for recreation and fishing. The loss of the international rowing facility on Karaapiro would be of particular significance.

6. Uncertainties and information gaps

There is uncertainty about the environmental impacts of the increase in flow variability due to increased hydro peaking since the 1990s. Monitoring required under MRP's consents will help to establish the nature and extent of possible effects.

The effects on the regional and national economy of altering the operation of the Waikato hydro scheme to reduce flow fluctuations below Karaapiro or removing the dams and returning the river to a natural flow regime are believed to be prohibitively large, based on general information presented to the MRP consent hearings. A more accurate costing of these effects would require a major economic study, but the preliminary cost estimates presented in the MRP consent evidence are sufficient for an initial assessment of these options.

7. Recommendations

It is concluded that the keystone nature of the Waikato hydro system to the prosperity of the Waikato region and New Zealand means that placing significant restrictions on the system's operation beyond those decided in the 2003 MRP resource consent process is not warranted. The MRP consent conditions include monitoring requirements for specific issues where potential for environmental impacts exist, a review clause if blue-green algal blooms are detected, and requirements for consultation and accommodation with river users around flow management to fit in with specific events. These existing conditions appear sufficient to manage issues resulting from the scheme's operation, without need for the Waikato River Authority's involvement. Similarly dam removal would not restore the Waikato River to its original state and there would be considerable negative effects as sediment and contaminants were flushed from the system. Also, the benefits that the hydro system provides in terms of flood storage and flood management would be lost. For these reasons, dam removal is not recommended either.

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Appendix 24: Flow effects

1. Introduction

Flow is a fundamental intrinsic factor affecting aquatic ecosystems. This appendix provides a summary of the various processes that can affect flow as well as the effect that management intervention and potential restoration actions might have on flow regimes. This information has been used in many sections of the main report.

The flow regimes of streams and rivers can be altered by changes in their catchment landuse (e.g., when forestry is replaced by pasture), riparian management, wetland restoration, dams and sand mining. This occurs because of the influences of vegetation type on evaporation and interception losses of incident rainfall and on soil moisture that influences runoff (Duncan and Woods, 2004; Scotter and Kelliher, 2004), water storage within dams, and dampening of flood flow velocities by rough riparian vegetation. Estimates of these effects are summarised in Table 1.

Table 1: Predicted effects on flows of land use change, riparian buffers and wetland restoration – rational for these provided in review below:

Action	**Low flow**	**Estimates annual runoff reduction**	**Maximum flood flows < 100 km^2 catchments**
Pine afforestation of pasture	minus 50%	minus 300-400 mm, 35-45%	minus 30% (5-50%)
Native restoration of pasture	plus 10%	minus 70 mm, 7%	minus 20%
15 m native riparian buffers	minus 3%	minus 30 mm, 3%	minus 10%[1]
5 m riparian buffers	minus 1%	minus 10 mm, 1%	minus 3%
Wetland restoration effect per 1% increase in catchment area as wetland	plus 8%[2]	nil	minus 4%[1]

[1] The actual effects on downstream flooding will be influenced by how reducing the speed of the flood wave affects the phasing of flood waves between major tributaries – in the Waikato the phasing between the mainstem and the Waipa is critical for flood effects in Hamilton (water can back up from the Waipa) and lower river. Understanding this will require careful hydraulic modelling at a later stage.
[2] Based on studies in Illinois (Demissie and Khan, 1993) so moderate level of uncertainty.

These effects have implications for sediment and nutrient yields, water quality, flooding, instream habitat, and availability of water for irrigation and hydropower generation.

Reduction in river bed levels due to sand mining may also reduce flood levels and lower groundwater levels (influencing wetlands). The effect of riverbed lowering on ameliorating flood risk along the lower Waikato was reported by Freestone (2003), while it remains the policy of the Environment Waikato Asset Management Group to control riverbed levels through targeted commercial extraction or maintenance dredging. Downstream from about Huntly, falling riverbed levels, in conjunction with land drainage works and pumping, have drawn down the water table in the peaty wetlands adjacent to the river. As these dry out, the peat under the wetlands shrinks and the land surface subsides – a process that displaces ecological boundaries and re-elevates the flood risk on the floodplain. For example, subsidence rates averaging 65-170 mm/yr from 1967-81 have been reported from Motukaraka Swamp (Freestone, 2003).

Dams also store sediment, and alter downstream water quality and channel morphology (Young et al., 2004). The performance of dams is dealt with in more detail below (see Section 3).

2. Land use and riparian management

2.1 Water yields and low flows

Pasture land use has lower evaporation than native forest or pine forest and hence has greater annual runoff (Fahey et al., 2004). However, because quickflow runoff (i.e., that during rain events) is greater under pasture, subsequent low flows can be lower under pasture than native forest land cover. Changes in annual runoff after whole catchment pine afforestation of grassland in New Zealand range from 30% to 81% (Fahey et al., 2004), in line with the average 44% reduction in streamflow from analysis of many international paired catchment studies of the effects of pine afforestation of grasslands (Farley et al., 2005). Eucalypt plantations had greater runoff reduction effects (average 75%) than pines (average 40%) in Farley et al.'s (2005) comparison.

Flow effects vary during the typical 27-30 year rotation of pine forest planting, growth, harvest and replanting, with these variations most apparent at small catchment scales (<300 ha) where most of the catchment may be logged over two-three years. However, at medium to large scales (>5000 ha in forest), effects of forestry on water yield are normally averaged out because different parts of the area in planted production forest are typically in different phases of the rotation at any one time (in order to provide a sustainable flow of work and product from the forest).

2.2 Annual runoff

The average annual runoff of the Waikato River at Mercer is 900 mm (or 400 m^3/s, based on data in (EW, 2008). This varies within sub-catchments in relation to rainfall (c. 1200 mm in lowlands, c.1700 mm on hills and up to 3200 mm on upper slopes of Ruapehu), vegetation and geology.

2.3 Pine afforestation effects on runoff

At Whatawhata, annual water yield from a pasture catchment (970 mm) decreased 29% (285 mm) by year 6 after planting (mainly pine) 62% of the catchment and averaged 19% (158 mm) less than the adjacent fully native forest catchment (Quinn et al., 2009); similar changes were observed in year 8 after planting (Quinn unpublished data). This indicates a 47% (450 mm) reduction on pasture water yield would have occurred if the whole catchment were afforested, assuming a linear relationship between area afforested and water yield. Annual flow from pasture at Whatawhata was 7% (115 mm) higher than from native forest.

Somewhat lower responses to pasture afforestation by pines were found at Pukukohukohu, in the upper Waikato catchment near Rotorua, where rainfall was similar to Whatawhata but geology differed (pumice soils over impermeable bedrock, c.f. yellow-brown earths over greywacke at Whatawhata). Beets and Oliver (2007) compared paired catchments in native forest and in transition from pasture to pine at Pukukohukohu and found annual water yield from pasture planted in pine decreased, in proportion to the change in leaf area index, by up to 400 mm when leaf area index peaked. They predicted the annual flow from a managed pine site of average-to-high productivity over a 30-year rotation will be 160-260 mm lower than from pasture (i.e., 21-35% lower than average annual runoff from pasture of 745 mm) and 100 mm (17%) lower than from native forest.

Based on these two Waikato studies, it is estimated that the average effect of complete pine afforestation of pasture over the forest rotation would be to reduce annual water yield by about 300 mm. The difference in effects between Whatawhata (c. 450 mm at year 6) and Purukohukohu (maximum 400 mm for mid-late rotation forest, average over 30 year rotation 160-260 mm) result in there being a high level of uncertainty around this estimate.

2.4 Riparian forest effects on runoff

Large riparian buffer forests can also influence streamflows. Evaporative losses from buffers are likely to be larger than for full forests because they have more edge, thus allowing greater wind-driven evaporation (Smith, 1992). In a study in Nelson

(Moutere, rainfall 1020 mm/y), wide riparian pine riparian plantings (25-35 m strip enclosing the stream, i.e., similar to 15 m buffers on each side as proposed for Kyoto compliant carbon forests) that occupied 20% of the total catchment area reduced the annual runoff by 68-104 mm (= 21-55%) when the stands were 8-10 years old. Native riparian plantings are expected to have lesser effects on flow than these pine plantings, based on comparisons of water yield from the native forest/pine at Whatawhata and Pukukohukohu, but we lack direct evidence of how much less. For the purposes of the scoping study, it is assumed that reduction in water yield relative to pasture of 15 m native buffers (total width 30 m, 20 m and 10 m) would be one third Smith's (1992) finding for 30 m wide pine plantings (i.e., mean 86 mm/3 = 30 mm or 3%). Similarly the effects of 10 m and 5 m native buffers (20 m and 10 m total widths) are estimated to be proportionately lower (i.e., 2% and 1%, respectively).

2.5 Low flows

At Whatawhata (Waipa hill country, annual rainfall 1650 mm, 3 km^2 catchments) the annual 7-day low-flow (a commonly used low flow index) was 11% lower in pasture than in an adjacent native forest catchment (Quinn et al., 2009). This suggests a 10% increase in baseflow is likely once pasture is restored to native forest, however regrowing native forest is likely to have greater water demand than old growth forest, so there may be little increase in low flow from conversion of pasture to native forest in the first 50-100 years.

Afforestation of 62% of a pasture catchment at Whatawhata (58% pines + 4% natives) reduced the 7-day low flow by 33% (Quinn et al., 2009). Scaling this to 100% afforestation, assuming that flow reduction is proportional to area afforested, indicates that complete afforestation would result in a low flow reduction of 55% (Quinn et al., 2009). This is greater than the 20% reduction in the 7-day mean low flow in Berwick forest in east Otago (Smith, 1987). In smaller catchments, pine afforestation near Rotorua (Dons, 1987) and Nelson (Duncan, 1995) extended the duration of periods of zero flow.

In contrast to riparian forests, riparian and other wetlands store water and enhance base/low flows (Mitsch, 1992). Hence, as well as reducing contaminant concentrations and loads (Tanner et al., 2005), restoration of wetlands on drainage systems can modify flood and baseflows.

Lowland agricultural areas of the Waikato have been drained extensively using under-field (mole-pipe) systems linked to open drains that typically lower the water table and bypass wetlands. Upland Waikato agricultural areas commonly have valley bottom wetlands at the head of stream channels and riparian wetlands occur where springs emerge. However these wetlands are commonly drained by digging a central channel that lowers the water table to provide more grazing land. Thus there is scope to restore the hydrological functions of wetlands in pasture by creation of artificial wetlands on tile drains and infilling/damming channels cut through wetlands and restoring wetland vegetation buy planting and livestock exclusion.

The relationships between wetland management and flow regimes have not been systematically addressed in the New Zealand context, so the estimates on wetland effects on flows in the predictions table are based on a study in the USA (Demissie and Khan, 1993). Some local evidence indicates that these predictions may be quite conservative for effects on low flow enhancement in lowland Waikato catchments: lowflow yield during the current Waikato drought (mid-march 2010) was >200% higher from a 10 ha catchment with a large wetland (2.3% of catchment area) at its outlet than from the larger total catchment that has low wetland cover (Dr R.J. Wilcock, NIWA, pers. comm.). This catchment, Toenepi near Morrinsville, has similar characteristics to many lowland Waikato streams. This compares with 18% increase (8% x 2.3) predicted based on Demissie and Khan (1993). Specific studies on low flow enhancement of wetlands are needed to better understand their effects in the Waikato.

2.6 Land use and mitigation effects on flood peaks

2.6.1 Afforestation of pasture

Afforestation of pasture is expected to reduce flood flow peaks (by increasing interception and infiltration of rainfall into soil), with benefits for flood hazard management throughout the catchment, particularly in lowland areas. Afforestation of pasture with pines and gorse reduced flood flows by 80% in a small catchment study in Nelson (Duncan and Woods, 2004) and pine afforestation reduced storm flows by about 50% in a small Rotorua catchment (Dons, 1987). There was an indication of reduced peak flows in the first 8 years after the 62% area afforestation at Whatawhata when the median ratio of annual maximum was 20% lower than in 7 years before changes. This suggests complete afforestation may reduce storm flows by about 30%.

Concerns about the hydrological effects of recent conversion of pine forest to pasture in the upper Waikato catchment led to Environment Waikato commissioning, in 2007, a modelling series of studies on potential effects on flooding throughout the downstream catchment of the potential pine-pasture land use change of 12% of the total land area of the Taupo to Karapiro catchment. Findings are summarised on the Environment Waikato website[1]. Although the Environment Waikato coordinated study addresses *deforestation* (pine-pasture land use change), it is useful for

[1] http://www.ew.govt.nz/Projects/landusechangeupperwaikato/

evaluating the level of benefit that would accrue if afforestation of pastures was adopted as a restoration action. Key predictions are summarised in Table 2.

Table 2: Changes in flood peaks predicted by Environment Waikato Technical Panel for a 12% change from pine forest to pasture land use in the upper Waikato River catchment[1].

Landscape scale	**Small flood (5-yr rainstorm)**	**Medium flood (20-y storm)**	**Large flood (100-yr rainstorm)**	**Extreme flood (500-yr storm)**
Local flooding within Upper Waikato 10–100 km^2 catchment area, 0–80% upstream land use conversion	Significant increase (5–50%) for streams where most of catchment has land use change	Significant increase (5–50%) for streams where most of catchment has land use change	Very significant increase (more than 50%) for streams where most of catchment has land use change	Very significant increase (more than doubled) for streams where most of catchment has land use change
Upper Waikato Taupoo-Karaapiro inflow 4,405 km^2 area, 542 km^2 land use conversion (12%)	Little or no change	Little or no change	From 2–9% increase in peak flow rate (average 4%) 3–5% increase in 72-h flow rate (average 2%)	From 3–16% increase in peak flow rate (average 7%) 2–9% increase in 72-h flow rate (average 4%)
Waikato River at Hamilton 8,230 km^2 area	Little or no change	Little or no change	40–110 mm water level increase 6–21 m^3/speak flow increase	280–530 mm water level increase 70–140 m^3/s peak flow increase

[1] http://www.ew.govt.nz/Projects/landusechangeupperwaikato/

The overall conclusions from the study, as agreed by the Technical Expert panel, are that the effect on flood flows and water levels from land use change in approximately 12% of the Upper Waikato catchment are likely to have:

- Significant to very significant increases in peak flow rate for local flooding in small catchments where full conversion is expected.
- At Hamilton, insignificant impacts during small to medium floods, increases of up to 40-110 mm in peak water level for large floods, and increases of 280-530 mm for extreme floods.
- From Ngaaruawaahia to Rangiriri, insignificant impacts during small to medium floods, increases in the peak flood water level of 20-40 mm during large floods, and increases of 170–270 mm in extreme floods.

Afforestation of pasture is likely to produce reductions on peak flows of similar magnitude to these predicted increases in response to deforestation.

2.6.2 Riparian forest and wetland restoration/revegetation

Riparian forests and wetlands are also expected to attenuate the peak flow of runoff into the stream channel in small rainfall events (Smith, 1992). Furthermore, well-developed riparian vegetation, and particularly forests, has greater hydraulic roughness than short grass and hence retards the progress of flood flows that spill out into the riparian area (Coon, 1998). This may cause increased local flooding of the riparian area and adjacent land, but typically reduces the peak flow in downstream reaches (Anderson et al., 2006). Anderson et al., (2006) predict that 3 m high riparian vegetation in their 50 km long model channel would reduced the downstream flood peak by 10% for 2-year annual return period floods and 13% and 50-year annual return period floods, respectively. Factors expected to influence these effects are the likelihood of overbank flow events (less in deeply incised channels), the width of the riparian area and floodplain, the extent of wetlands, and the roughness (size/density in relation to the flow depth) of the riparian vegetation (Sholtes, 2009).

Demissie and Khan (1993) found 4% reduction in peak flows in relation to rainfall for every additional 1% of catchment area as wetland in their USA study of 30 watersheds, and we have used this relationship for estimating benefits of wetland restoration in this scoping study.

3. Dams and flows

3.1 Introduction

Dams affect the river flow regimes and, in some cases, provide opportunities to manage floods and low flows. Dams can reduce flooding, through storm flow storage (e.g., management of the Waikato hydro dams assist with flood control), and have variable effects on low flows depending on their design, location and operating regimes. Farm dams typically reduce low flows, particularly headwater dams that capture flows of headwater ephemeral streams. Dams can also reduce sediment loads, enhancing water clarity by reducing downstream suspended solids, but can also increase algal phytoplankton biomass (reduces water clarity) by increasing residence time of water in the river (Pridmore and McBride, 1984). Dams also influence downstream channel morphology, particularly by reducing peak flows and sediment supply (e.g., Young et al., 2004; McKerchar et al., 2005). The Waikato hydro dams produce daily fluctuations in lake and river water levels that affect the edge/littoral habitat available for macrophyte growth and habitat for macroinvertebrates and fish. This hydropeaking issue is discussed in more detail in the Appendix 23: Hydro Dams.

3.2 Farm dam rules

The Waikato Regional Plan has a permitted activity rule allowing (with conditions) creation of farm dams in the bed of ephemeral rivers or streams, where: the catchment area is less than one square kilometre (100 hectares), and the maximum water depth of the pond is less than three metres, and/or the dam retains not more than 20,000 cubic metres of water. Larger dams require resource consents.

3.3 Waikato Catchment study area dam numbers

There are 246 dams in the Waikato River catchment study area listed in NIWA’s database (McKerchar et al., 2005) developed during 2004–05 (Figure 1). This includes records provided by Environment Waikato and the territorial local authorities, and so appears not to include the numerous small dams created under Environment Waikato’s permitted activity rule - this accounts for only eight farm stock water dams being listed as ‘permitted activity’ dams that do not need to be notified. Average hydraulic residence time (HRT) was calculated for each of the 120 dams for which volume estimates are available, by dividing the volume by the mean inflow, calculated from the upstream catchment area and the average specific discharge of 28 $L/s/km^2$ (EW, 2008). Only three dams had ‘high’ HRT (after McKerchar et al., 2005; > 100 days). Twenty-three had ‘medium’ HRT (6–100 days), corresponding to interception of 1–25% of runoff, and the majority (91) had low HTS with little effect on flow regimes. Median HRT was greatest for silt detention dams and least in recreational/aesthetic and tailings/mining dams (Table 3). The Waikato hydro dams have HRTs between 1.5 days (Aratiatia) and 10.5 days (Ohakurii). Rural and urban water supply dams had the greatest range of HRT: this was greatest for the WaterCare dams in the Hunua Ranges. Rural and urban water supply dams had the greatest range of HRT: this was greatest in the Watercare dams in the Hunua Ranges that provide water supply to Auckland. A farm dam built within the permitted activity rule (i.e., 20,000 m^3 volume, mean depth 2 m, 50 ha catchment with 1,000 mm runoff) would occupy c. 2% of the catchment and have an HRT of 15 days.

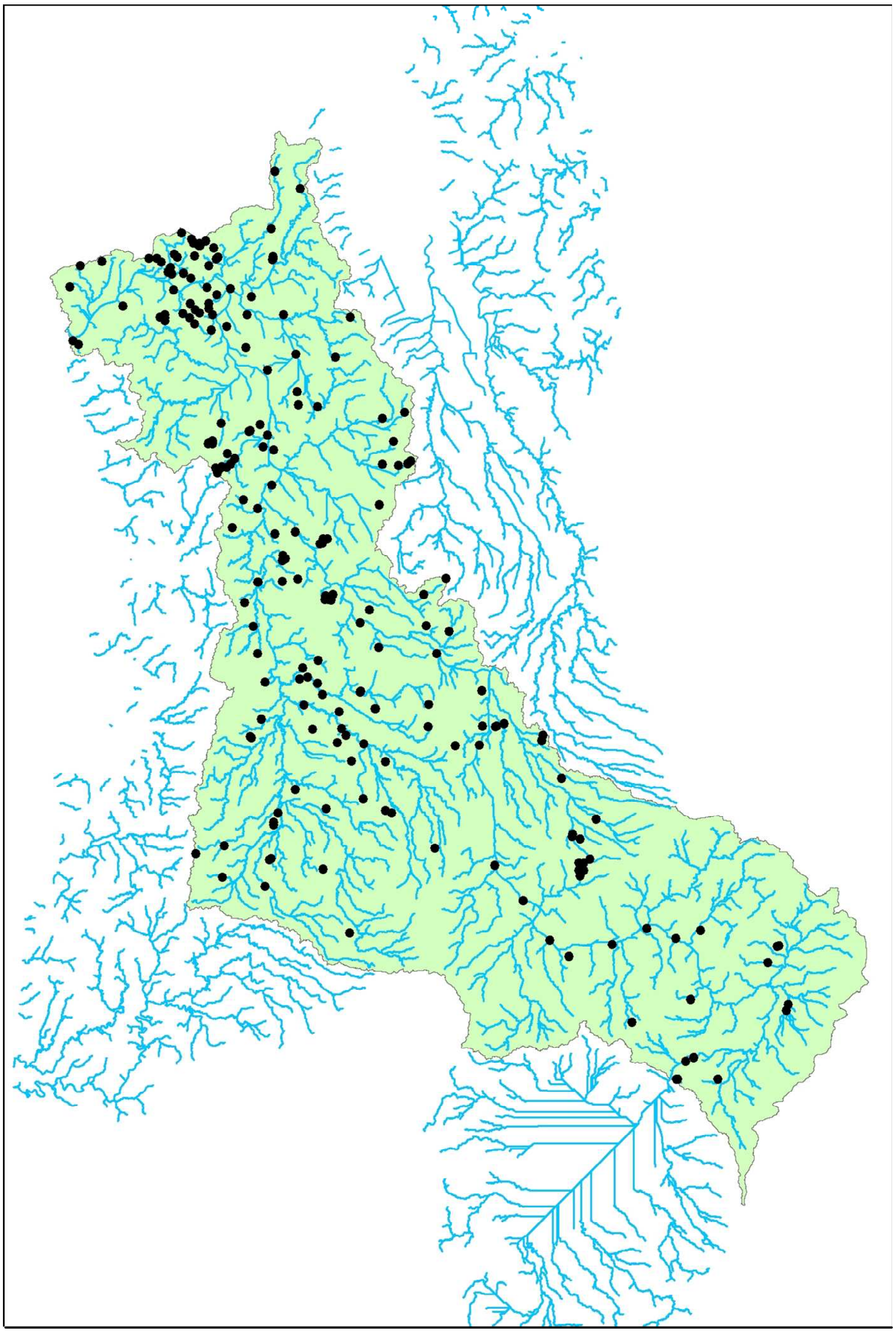

Figure 1: Location of dams listed in the NIWA database within the Waikato River catchment area (shaded in green) overlain on the River Environment Classification (REC) stream network showing ≥3rd order streams.

Table 3: Summary of dams within the Waikato River catchment study area in the NIWA database (McKerchar et al., 2005). Types ordered by median hydraulic residence time (HRT).

Dam type		HRT (days) median, range, n for which HRT calculated	Volume stored by type in dams for which estimates are available (Million m^3)
Silt detention	17	16, 7–27, n=17	0.1
Farm stock water	8	8.4, 0.6–10.5, n = 8	0.06
Flood control	62	6, 0.1–64, n=13	>1.5[1]
Waikato hydro dams	11	5, 1.5–10.5, n=8	570
Irrigation	45	3.5, 0.1–208, n = 45	0.8
Water supply (urban and rural)	18	0.9, 0.02–416, n=18	56
Recreational/aesthetic	70	0.7, 0.05–3.8, n=21	>0.26[2]
Tailings/mining	2	0.9, n=1	negligible

[1]Volumes available for only 20% of dams of this type, so actual storage may be c. 5x higher.
[2]Volumes available for only 37% of dams of this type, so actual storage may be c. 3x higher.

The eight Waikato River hydro dams have the vast majority of the total storage within the catchment totalling 570 million m^3, equivalent to 16.5 days of the average Waikato flow at Mercer (400 m^3/s) (Table 3). The next largest store of 56 million m^3 is in the water supply dams, while other dam types have estimated storages if less than 1.5 million m^3.

3.4 Farm dams

3.4.1 Farm dam numbers

The actual number of farm dams in the study area is undoubtedly under-estimated in the NIWA database (Table 3). Some large areas of the Waikato are probably unsuitable for creation of small dams due to problems with sealing them in areas of peat and pumice soils. However, Fish & Game NZ staff spoken to considered that most hill-land farms have at least one or two dams for waterfowl or aesthetic purposes (pers. comm. Ben Wilson, Fish and Game NZ, Hamilton). A scan of 60 1 km^2 areas of hill farm around the Waikato catchment on Google Maps satellite images located 32 dams, confirming that these are under-represented in the NIWA database. Farm dam creation was subsidised by Acclimatisation Societies in the 1970–80's (pers. comm.). Currently, Fish and Game NZ is active in wetland restoration (particularly to enhance waterfowl) in the eastern part of Whangamarino wetland, where 25 ponds have been developed recently.

3.4.2 Farm dams as a water quality management tool

NIWA has included ponds on headwater/ephemeral streams as a mitigation tool for control of sediment and nutrients in NPLAS (Nitrogen and Phosphorus Load Assessment System). Pond performance was simulated by Rob Collins using BUCSHELL. Time series of sediment loads were generated for four soil drainage types and three rainfall records. The loads were passed through ponds of various sizes (pond volume in m^3 as a percentage of catchment area in m^2), assuming a single settling velocity of 0.000001 m/s, corresponding to a fine sediment (coarse clay). The model assumes that there is no infiltration through the base of the pond. The depth was 1.5 m, with vertical sides. A preliminary set of simulations showed that there was little effect of slope in terms of percentage removal of sediment, so slope was not included as a factor thereafter.

The results are shown in the Figure 2 and 3 below. As the rainfall increases, the pond performance deteriorates, as there are higher hydraulic loadings. As the soil drainage gets worse, the performance also deteriorates, for similar reasons. Also, as the pond size increases, the performance improves. Note that these results are for fine sediment only.

The performance decreases exponentially (1-E = exp(aS)) where S is the size and E is the efficiency (Figure 3). This will be useful for interpolation of results for different pond sizes.

Nitrogen and phosphorus removal efficiency are estimated to be c. 50% of that for fine sediment, due to dissolved fractions and particulate fractions associated with very fine sediment.

Colin Stace (soil conservationist, Environment BOP) commented that it is hard to get more than 0.3% storage in detention ponds in steeper areas. This is expected to increase in flatter areas.

Dams on perennial streams can have negative effects on some aspects of downstream water quality by increasing water temperature and reducing dissolved oxygen (Maxted et al., 2005). These can be avoided by locating dams off-channel and in ephemeral channels.

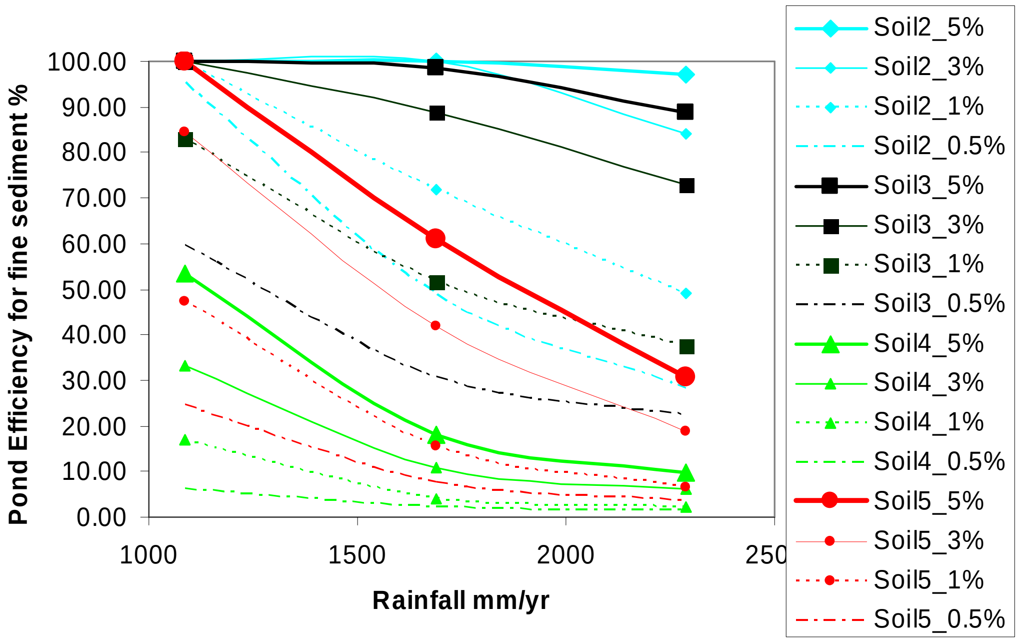

Figure 2: Simulation results for pond performance for fine sediment removal as a function of pond size (% of catchment area drained) and catchment soils. Soil 2=very well drained; 3 = well drained; 4 = poorly drained; 5 = average drainage.

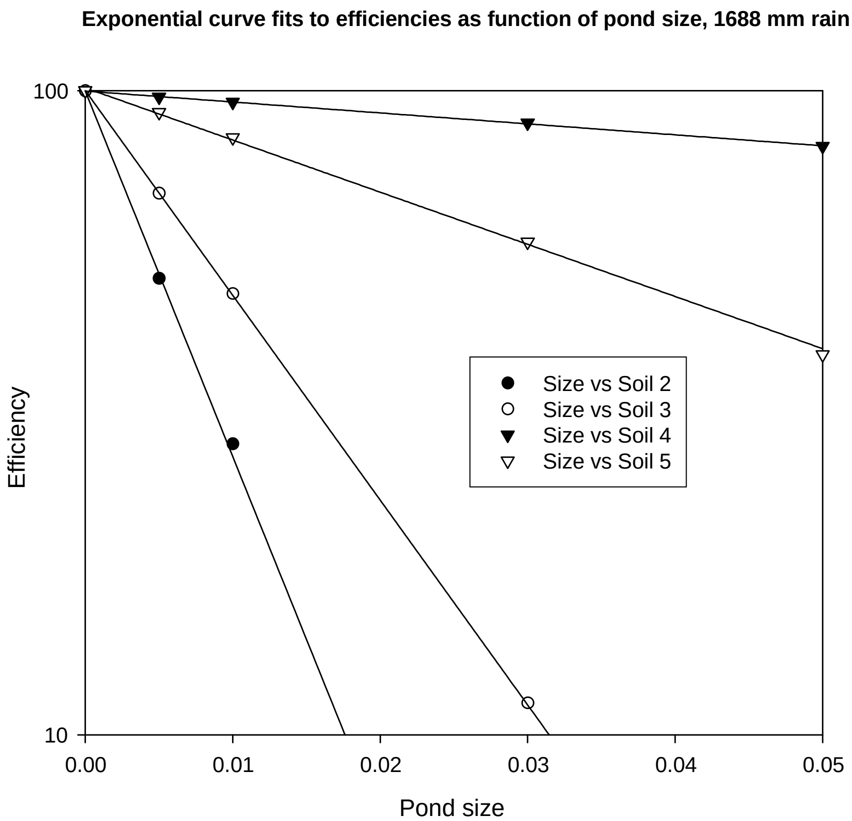

Figure 3: Fine sediment removal efficiency curves for a typical Waikato hill rainfall in relation to pond size and soil type.

This analysis suggests that there is scope for additional small dam development in ephemeral headwater areas for the purpose of controlling flood flows and trapping sediment and nutrients. Such dams could be designed to enhance benefits for fish (particularly eels), waterfowl and aesthetics (e.g., by incorporating requirements for eel access in the outlet design and slope of the downstream batter of the dam). These dams could also provide stock water by supplying troughs rather than by direct livestock access.

4. Sand mining

Sand and gravel extraction from the bed of the lower Waikato began in the 1940s, largely to service the construction industry. The overall rate of extraction increased up until the mid 1970s, with over 1 million m^3 extracted in 1974. Between 1953 and 2006, the extraction rate averaged 350,000 m^3/yr, which was more than three times the average rate of bed-material entrapment in the hydro-lakes. Most extraction has occurred in the Mercer area but over time the focus has shifted downstream. The historical extraction has created a long hole in the riverbed, lowering average bed levels by up to 2 m in the Mercer – Punihu area, and the extraction volumes between Rangiriri and the coast show a good overall match with surveyed riverbed volume changes. As discussed in Section 1, the lowered riverbed has reduced flooding in this area but it has also lowered the water table in the adjacent wetlands such as Whangamarino and Motukaraka, which in turn has led to subsidence of the wetland peat deposits.

Current sand extraction is confined to the Puni-Tuakau area and is approximately 160-180,000 m^3/yr. This accords with the strategy of the Lower Waikato and Waipa Control Scheme's Asset Management Plan (Environment Waikato, 1997), which sets a sustainable average extraction rate of 180,000 m^3/yr based on best estimates of the bed-material load entering the extraction reach. This management plan includes maintaining a target water-level profile at a reference discharge, thus the hole created by the current mining is expected to infill about as fast as it is dug-out.

Sand mining is being managed by Environment Waikato through resource consents. It is recommended that the WRA keeps a watching brief on the issue.

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Appendix 25: Boat Ramps

1. Introduction and methods

There are a number of ways that have been identified to improve access to the Waikato River, such as the provisions of boat ramps, creation of reserves adjacent to the river and creation of river walks. Which of these options is the most suitable will largely depend on the locations chosen at which to improve access.

For example, the Lower Waikato lakes are likely to require improved boat access, but in the Upper Waikato region, the existing boat access may suffice. Another consideration is that most locations on the Waipa River are unsuitable for installing a boat ramp, and in these areas they may choose to spend money on improving access in other ways such as creating reserves next to the river.

For the purposes of this Study it has been assumed that where providing a boat ramp is not possible, an equivalent amount will be spent on other measures to improve access to the river.

A generic boat ramp that is assumed to be suitable for use throughout the Waikato Region has been identified by the Study team. The dimensions and materials have been based on a number of existing boat ramps in and around Hamilton.

A typical boat ramp installation is shown below:

Figure 1: Roose Commence Boat Ramp (Hamilton) - BECA.

2. Goals

The purpose of this paper is to:

- Identify and cost a generic boat ramp that can be assumed to be suitable at a number of locations around the Waikato River catchment.
- By providing a cost for a boat ramp, estimate an equivalent cost for the creation of reserves and walkways adjacent to the river.

3. Actions

There are several existing boat ramps around Hamilton City. These have been used as a basis to determine the requirements of a generic boat ramp design and construction. The generic boat ramp chosen is made of concrete and is single width. An adjacent parking area or approximately 1,000 m^2 has been allowed for. No toilet or washdown facilities are allowed for.

No specific locations for the future construction of boat ramps have been determined at this stage. In lieu of this information, the Study team has assumed that four boat ramps (or equivalent access measures) will be constructed in each economic region of the Study area.

4. Desired outcome

There is improved access to the Waikato River for recreational and other users.

5. Risks and probability of success

Construction of boat ramps will improve access to the Waikato River. However, there are a number of reasons why a boat ramp at a specific location may deviate from the generic boat ramp chosen.

Construction of a boat ramp will need to be tailored to its specific location, and need to take into account a number of factors including:

- The degree of water level fluctuation.
- Direction of the current relative to the bank (i.e., position of eddy currents).
- Stability of adjacent riverbank and local soil conditions.
- The depth of water required to launch.

The location will also influence how frequently each ramp is used. More popular ramps may warrant double width construction, increased parking area and provision of toilet and washdown facilities.

Land purchase and resource consent costs have not been allowed for. These will be location dependent and will vary significantly throughout the Study area.

Where construction of boat ramps is not possible, but improved access to the river is still desired, it is assumed that the money for a boat ramp could be used on other measures to improve access. These measures have not been well identified, and any measure which requires substantial earthworks or construction is likely to exceed the cost to provide a boat ramp.

6. Costs and timelines

Since the locations of new ramps for boat access to the river have not been determined the Study team used generic costs based on figures provided by Hamilton City Council for a ramp that was designed to be installed at the Waipa Delta. Hamilton City Council advised us that their estimate for a replacement ramp at the Waipa Delta would cost between $300,000 and $400,000. The costs were developed in 2009 and are considered to be a reasonable estimate. The Study team therefore suggests using a cost of $400,000 per boat ramp to estimate total costs (Table 1).

Each ramp will require parking facilities. It is assumed that flat land is available adjacent to the boat ramp site. It is also assumed the car park requires negligible earthworks and will be constructed using a 200 mm sub base, 100mm base course and 25 mm asphalt seal. Asphalt seal has been selected as it is harder wearing and will withstand the effects of heavy turning vehicles better than either a chip seal or unsealed surface. Based on 1,000 m^2 parking area, including margins and fees the estimated cost of each car park would be in the vicinity of $60,000.

Therefore an estimated cost of $460,000 has been applied for each boat ramp and parking facility. This does not allow for the specific costs of road access, toilets, washwater or any other general amenities.

It is assumed, for the purposes of the Study, that new boat ramps would be owned by the local council. They would be responsible for the upkeep and maintenance of the ramp and any associated facilities. Operating costs have not been determined for a boat ramp at this time, but it is expected to require only minor repair work over a 30 year time frame.

It is expected that a single boat ramp would take 8–12 weeks to construct, assuming there are no site issues (e.g., adverse ground conditions, flooding etc.).

The following table summarises the cost estimates to install boat ramps in each of the four zones of the Waikato River catchment.

Table 1: Cost estimate for construction of new boat ramps.

Economic region	Number of Boat Ramps (or equivalent)	Total Capital Cost	Annual Operating Cost
Lower Waikato	4	$1,840,000	Minor
Waipa	4	$1,840,000	Minor
Middle Waikato	4	$1,840,000	Minor
Upper Waikato	4	$1,840,000	Minor
Total	16	$7,360,000	Minor

7. Mechanisms and statutory framework

Access to and along the Waikato River has been identified as a priority issue for recreational purposes such as boating and fishing, amenity, traditional cultural uses and spiritual reasons. There is increasing public demand and interest for access to the Waikato River, as illustrated by the Government's national cycle trail project which has identified a section of the trail, called the Waikato River Trail, to run alongside the River. Impediments to access are largely a result of land being in private ownership or private lease, where access is fenced off and/or denied. A range of methods are available to obtain and enhance access to the river and its margins, including:

- Designation process under the Resource Management Act (RMA).
- Esplanade reserves, esplanade strips, access strips.
- Marginal strips.
- Reserves.
- Non-statutory approaches to securing access e.g., Te Araroa Trust.

Appendix 26: Significant Sites

1. Introduction

The degradation of significant and historic sites within the Waikato River catchment was raised during the Waikato River Independent Scoping Study as an issue, particularly for the five river iwi. These sites are of special cultural significance to Maaori and their loss or degradation has a negative effect on spiritual and cultural relationships iwi have with the Waikato River. Historic sites also contribute to the wider Waikato community's cultural landscape and sense of local and regional cultural identity.

Many sites of significance to the five river iwi have been damaged or destroyed over the last 100 years in a variety of ways. These sites include waahi tapu, urupaa, historic access points and river crossings, kaainga, paa, gardens and named river features. The extent of the degradation described by iwi at the consultation hui ranged from total destruction and physical loss (e.g., paa, kaainga, marae and waahi tapu inundated all along the Waikato River), to irreversible damage (e.g., ngaawhaa and geysers being filled with concrete), restricted or denial of access (e.g., waahi tapu located on private land) and lack of respect (both knowingly and unknowingly) (e.g., http://www.ew.govt.nz; O'Sullivan and Te Hiko, 2010; Waitangi Tribunal, 1985 and 1993).

Vision and Strategy

The Vision and Strategy outlines the importance of initiating and promoting the protection, restoration and enhancement of significant sites throughout the Waikato River catchment, including those of the five river iwi (where they so decide). Strategies 6 and 7 set out tot:

- Recognise and protect waahi tapu and sites of significance to Waikato-Tainui and other river Iwi (where they so decide) to promote their cultural, spiritual and historic relationship with the Waikato River.
- Recognise and protect appropriate sites associated with the Waikato River that are of significance to the Waikato regional community.

The methods listed in the Vision and Strategy to implement Strategies 6 and 7 include (but are not limited to):

- Surveys of waahi tapu and other significant sites (where appropriate) within the Waikato region to protect and recognise their cultural and historic significance and importance.

Hydro power generation (both the construction of hydro dams and their continued operation) is viewed by iwi as the most dominant and pronounced cause and/or perceived cause of degraded or destroyed significant and historic sites in the Waikato River catchment (e.g., O'Sullivan and Te Hiko, 2010; Waitangi Tribunal, 1993). Land confiscation, development (including housing, roading, telecommunication and railway infrastructure), geothermal power generation, quarries, poor management and private land ownership were also raised as pressures impacting significant sites by the river iwi. Although these pressures have resulted in many significant sites being lost, knowledge of these sites and the spiritual connection iwi have with them remains though the physical connection has been damaged or destroyed.

The Maaori Heritage Council's vision statement *Tapuwae* is intended to guide the work of the New Zealand Historic Places Trust (NZHPT) in its activities in relation to Maaori heritage (NZHPT, 2009). This vision outlines the importance of Maaori heritage places and knowledge to New Zealand's cultural and social wellbeing and envisages a future in which Maaori heritage is recognised as an integral component of our national and cultural identity and a foundation of New Zealand's economic and environmental sustainability. Maaori heritage includes the knowledge, stories and experiences that people have when engaging with these places and therefore encompasses the experiences and consciousness that is created and maintained through people's interactions with these significant sites. The vision statement recognises:

1. That too often, Maaori heritage is undervalued at a national level and by non-Maaori communities.
2. That iwi and Maaori communities need assistance with understanding and protecting their heritage and how it can contribute to their health and wellbeing.
3. That many property owners and developers have a poor understanding of heritage generally, and of Maaori heritage specifically (NZHPT 2009).

Within the Waikato catchment a number of significant and historic sites are currently recognised and protected under the New Zealand Historic Places Trust (see Table 1). Further information regarding these sites can be accessed through the Historic Places Trust Register (http://www.historic.org.nz/TheRegister/). Waahi tapu are registered but this information is not available online.

Local authorities also have databases of sites in the Waikato region that are recognised as having archaeological significance. Local authorities may use this data for resource management purposes to carry out its functions for archaeological site management and protection under the Resource Management Act 1991.

Table 1: Number of historic sites that are currently recognised and protected under the New Zealand Historic Places Trust (excluding registered waahi tapu and waahi tapu areas).

Local authority	Total number of registered historic sites	Estimated number of registered historic sites in the Study area	Examples include
Taupo District Council	3	0	–
Rotorua District Council	14	0	–
South Waikato District Council	25	19[a]	• Arapuni Dam • Arapuni suspension bridge • Waotu-Puketurua Playcentre building
Otorohanga District Council	15	10	• Middens and Paa • Kiokio School • Otorohanga Railway Station
Waitomo District Council	16	16	• Paa • Waitomo Hotel (THC) • Courthouse (Te Kuiti)
Waipa District Council	66	66	• Paa • World War One memorials • Victoria Street Bridge (Leamington)
Hamilton City Council	40	40	• Pascoe building • Buffalo Hall • Fairfield Bridge
Waikato District Council	44	41	• Paa • Middens, Pits and Terraces • Turangawaewae House • Rotowaro Carbonisation Works
Franklin District Council	12	1	• 'Pioneer' Gun Turret and War Memorial

[a], This number includes sites registered in Lichfield and Putaruru, places that are on the boundary of the Study area.

2. A description of the prioritised action(s)

All river iwi, to various extents and in various documentation, have identified, catalogued and mapped sites of significance to them. In many cases this information has been submitted to and held in confidential files by local authorities and the Historic Places Trust, e.g., waahi tapu and archaeological sites. Local authorities use this data for resource management purposes to carry out functions for site management and protection under the Resource Management Act 1991.

The NZHPT (2009) outlines four key elements to be addressed in promoting the identification, protection, preservation and conservation of Maaori heritage, including:

- The identification and protection of existing Maaori heritage places. An awareness of these places amongst those who seek to develop land and/or make decisions about them is vital to prevent the further damage and destruction of significant sites.
- Maintenance, reconstruction and creation of appropriate knowledge about Maaori heritage.
- Creation of sustainable and meaningful experiences involving Maaori heritage.
- Creation of new interpretations and understanding of the significance of Maaori heritage to communities.

The five river iwi want to see expanding awareness within the wider Waikato region of the importance of significant sites by developing and improving the understanding, appreciation and recognition of these places. In order to maintain the integrity of significant sites it is vital that each river iwi (with input from whaanau and hapuu) or wider community organisation retain control over how their significant sites are identified, addressed and managed.

Action A. Development of significant site management plans by each river iwi covering, for example, identification, priorities for restoration, signage, publicity and education.

Knowledge about the physical environment was often committed by Maaori to memory using place names as a way to record and transfer information about local, social, cultural and environmental history from one generation to the next (Reed 2002, Orbell 1985, King et al., 2007 & 2008). Associated with the physical loss of some sites, there has also been a dislocation of many place names. This has heightened concerns that there has been a loss of knowledge pertaining to the original place names, locations and histories of some significant sites particularly amongst rangatahi. The NZHPT acknowledges that “through the actions of the ancestors, such places embody their mana, mauri and wairua, irrespective of the physical evidence which survives”. Therefore, it is important that the strategic plans developed by iwi are supported so that “knowledge of the whakapapa, kōrero, and matauranga Māori surrounding such places sits alongside scientific assessments when heritage management decisions are being made” (NZHPT 2009). The river iwi note that significant sites are not currently given enough recognition and protection, and said the use and integrity of Maaori place names should be better enabled and supported throughout the catchment.

Action B. Following completion of Action A:

- Development of signage.
- Encourage support for site restoration actions.
- Update significant sites management plan with place names to be appropriately documented and confirmed through New Zealand Geographic Board.

3. Action Report Card – Significant and historic sites

Action Report Cards summarise monitoring information that measures the success of a single action or a number of closely related actions. To enable stakeholders to track progress towards development and implementation of actions to restore significant and historic sites in the Waikato River catchmen, the following targets, indicators and scores are recommended.

Significant and historic sites				
Action	**Measure or indicator**	**Target**	**Current state**	**Score**
A	Significant site management plans have been developed by each Waikato River iwi	5	2	C
B	Appropriate signage and support of site restoration actions and update significant sites management plan is established, with place names to be appropriately documented and confirmed through NZ geographic board	To be determined	–	D
Outcome				
	Knowledge of historic and significant sites is incorporated into general and restoration planning and consent processes	–	–	C
	Knowledge on key historic and significant sites is passed on to rangitahi and the wider community in an appropriate form	–	–	D

3.1 Current state

In the table above the 'current state' of these actions have been preliminarily scored based on the information gathered as part of this Study:

- **Action A:** The current state of this action has been preliminarily scored by the Study team as a C (i.e., fair). This score reflects that all river iwi, to various extents, within various documents, have identified, catalogued and mapped many of their sites of significance. In many cases this information has been submitted to and held in confidential files by local authorities and the Historic Places Trust, e.g., waahi tapu and archaeological sites. Local authorities use this data for resource management purposes to carry out functions for site management and protection under the Resource Management Act 1991.

- **Action B:** The state of this action has been preliminarily scored by the Study team as a D (i.e., poor). This score reflects that some significant and historic sites are currently recognised and protected within the catchment, although not always to the level of satisfaction expressed by the river iwi during the consultation hui. For example, some significant sites have been destroyed and will never be able to be restored. The targets to measure restoration success and the satisfaction of the river iwi with the levels of recognition and protection of significant sites will need to be decided by iwi upon the completion of their strategic plans. The Study team considered it inappropriate to assign such targets on behalf of the iwi. This is their right.

4. How will the action(s) be accomplished?

The NZHPT's Māori Heritage Council recognises the complexities faced by iwi, hapuu and whaanau when identifying and establishing measures of protection, restoration and/or enhancement of significant sites. Thus, the Council is willing to support and assist tangata whenua in negotiating (where appropriate) the various measures and legislative channels necessary to undertake the actions listed above. That legislation includes (but is not limited to); the Historic Places Act 1993, Resource Management Act 1991 and Te Ture Whenua Māori Act 1993.

5. Where in the Waikato River catchment should the actions occur?

Significant and historic sites are located throughout the Waikato River catchment. However, it is envisaged that each of the five river iwi will determine where future restorative activities are focussed through their respective waahi tapu and significant site management plans. Some signage will be linked to river walkway and cycleway developments. The proposed visitor centres and Waikato Museum will be a key sources to impart information to the public on significant and historic sites.

6. What is the cost of the action(s)?

The estimated costs of the proposed significant and historic site actions include:

Action	Description	Set up costs	On-going costs (i.e., after set up)
A	Development of waahi tapu and significant site management plans by each river iwi.	$100k/iwi	__
B	Appropriate development of signage and support of site restoration actions and update significant sites management plan with place names to be appropriately documented and confirmed through NZ geographic board.	__	$300k/iwi

7. Who could do it and how long would it take?

The targets listed in the Vision and Strategy in regards to the timeframe for completion of this initiative is:

- Within 3 years: Waahi Tapu and Significant Sites Management Plans have been completed.

8. What are the interactions with other activities (co-benefits, drawbacks)?

The actions proposed here will increase the involvement and participation of Waikato River iwi and the wider Waikato community in restoring the health and wellbeing of the Waikato River. These outcomes will contribute to the restoration of Aspiration 4 – Significant and historic sites "*That significant and historic sites along the Waikato River and its lakes, wetlands and tributaries are restored and protected*", Aspiration 1 – Holism "*That the management of the Waikato River and its lakes, wetlands and tributaries to protect their health and wellbeing is conducted in a holistic, integrated way*" and Aspiration 2 – Engagement "*That people feel engaged with the Waikato River and its lakes, wetlands and tributaries, and processes, initiatives or actions to restore and protect their health and wellbeing*".

9. An analysis of uncertainties and information gaps

The Study team considered it inappropriate to assign restoration targets in relation to **Action B:** "*Appropriate development of signage and support of site restoration actions and update significant sites management plan with place names to be appropriately documented and confirmed through the New Zealand Geographic Board*" as this can only be appropriately completed by each individual river iwi. Although the Study team has tentatively scored this action as a D (i.e., poor) this is merely a preliminary score and will need to be revised once the river iwi determine their own target.

10. References

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