# The Quantification of Heavy Metal Sedimentation from Stormwater flowing onto Ōkahu Bay and the Potential for Pollutant Mitigation from a Mussel Shell Filter

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**Abstract:**

It has been assumed that a stormwater pipe above Ōkahu Bay deposits harmful pollutants such as copper and zinc onto the beach and into the water during storm events. Accumulation of these pollutants can harm the mana whenua of the bay, which is why the local iwi, the Ngāti Whātua o Orakei, have drafted a plan to reduce the flow of toxins entering the bay from the stormwater. Contaminated stormwater can have several negative effects on coastal marine environments, such as reducing the health wildlife populations, decreasing biodiversity, exposing humans to harmful toxins, and creating an environment which is not conducive to recreation, business, and healthy living. It has been envisioned that a mussel shell filter will be installed at the effluent end of the storm pipe, which will remove harmful particulates from the stormwater, and is inline with the Mauri Model which the community is using to frame their restoration project. Once the pollutant load of the stormwater is accurately determined through lab analysis, a filter can be crafted to the specifics of the stormwater in order to be most effective.

**Introduction:**

In 2014, The State of the Hauraki Gulf Environment Report identified sediment runoff as the most serious current environmental contaminant issue along New Zealand's Hauraki coastline (State of our Gulf, 2014). Stormwater is the main vector of pollutants into the coastal marine ecosystem in the urban environment, therefore it should be a primary concern of those seeking to reduce toxic sediment accumulation (Auckland Unitary Plan, 2013). Stormwater runoff onto Ōkahu Bay presents a series of negative repercussions to the Auckland community, the mana whenua of the Ngāti Whātua o Orakei, and the communities of wildlife that inhabit Ōkahu Bay. Currently, a stormwater pipe deposits rainwater from Tamaki Drive onto a stretch of

beach on Ōkahu Bay, where it then flows into the ocean. The stormwater is assumed to be polluted, as is most New Zealand urban stormwater, with high quantities of copper from vehicle brake linings and zinc from vehicle tires and roofing materials (Craggs, 2010). The stormwater may also contain arsenic and other harmful chemicals from a cemetery located across the street from the storm pipe. If the heavy metals such as copper and zinc make it to the coastal environment of Ōkahu Bay, it might render the area unhealthy for human activity and coastal flora and fauna.

Ōkahu Bay is of cultural, social, environmental, and economic significance to the Ngāti Whātua o Orakei. The Bay is associated with historic landings, is the site of significant fishing grounds, the former site of the main settlement of the hapu on Waitemata Harbor, and is adjacent to urupa (cemetery) remains at the Orakei Domain (Ōkahu Bay Tidal Creek Reinstatement, 2013). The Ngāti Whātua o Orakei have drafted a plan to restore the mauri of Ōkahu Bay, part of which includes addressing the polluted stormwater entering the bay (The Orakei Catchment Ecological Restoration Plan, 2012). With a mindset framed around the Mauri Model and minimal ecological impact, a mussel shell filter is envisioned by the community to remove harmful contaminants from the stormwater and restore the mauri to the bay. Mussel shell filters have been shown to be very successful at removing copper and zinc from lab controlled stormwater, however they have seen limited use in public and private enterprise (Vigar, 2012).

As the Ngāti Whātua restore the mauri of their lands, they are keeping the most up to date technology in mind which includes looking at alternatives to standard stormwater filters. In order for a successful mussel shell filter to be crafted and installed, the pollutant load of the bay must first be quantified. This will be done by collecting water samples from the storm pipe

during storm events. Once the water is collected and lab tested, a filter can be constructed to the specifics of the stormwater to best remove its pollutants. It may take many years for Ōkahu Bay to be free of harmful pollutants and its mauri restored, but when this feat is accomplished, the Ngāti Whātua, the Auckland community, and the flora and fuana of the region will be in a better state of health.

**Background:**

The Ngāti Whātua o Orakei, who have strong historical links to Ōkahu Bay, are trying to promote, develop and enhance Ōkahu Bay as the public gateway to the Whenua Rangatira while respecting its existing cultural and spiritual value to the Tangata Whenua and enhancing its relationship with the Waitemata (The Orakei Catchment Ecological Restoration Plan, 2012). Ōkahu Bay was formerly the site of a large Maori community and marae until 1952 when the land was confiscated and the Maori community displaced by the New Zealand government (The Loss of the Orakei Block). In recent years, the iwi has regained some sovereignty rights over the land and it's vision is that the bay's water will be fit for swimming, support a thriving marine ecosystem, and Ngāti Whātua o Orakei will have a strong presence in the area as users and kaitiaki (The Orakei Catchment Ecological Restoration Plan, 2012). Ōkahu Bay is currently a sink for the disposal of urban stormwater and associated contaminants for are large stretch of urban area above the bay (Figure 1). Ngāti Whātua o Orakei wish to restore the bay according to their way of viewing and understanding the world. Specifically, they wish to restore the mauri to Ōkahu Bay and their wider lands, Te Whenua Rangatira. The framework by which they will design, implement, manage and evaluate the restoration of mauri is the Mauri Model (Morgan, 2006). This tool is used to incorporate maximum opportunities in restoration concepts because it

adheres to a quadruple bottom line assessing social, economic, environmental, and cultural indicators. A number of Mauri Models for the bay have already been created by the community, many of which address the polluted stormwater by suggesting filtration or diversion of the water (Ōkahu Bay Tidal Creek Reinstatement, 2013). While diversion of the stormwater would simple move the problem elsewhere, a mussel shell filtration system would clean stormwater entering the bay in a cost effective and environmentally sound strategy, ultimately increasing the mauri of Ōkahu Bay. The filtration system would be an unobtrusive part of the coastal environment, which is respectful of the site's cultural significance, and would clean the beach for the benefit of the entire community.

Existing stormwater treatment devices typically use peat mixed with sand to provide adsorption of dissolved metals and filtration of particulate metals. The disadvantages of peat is that it degrades over time, it is relatively expensive, and it is a non-renewable resource (Vigar, 2012). Mussel shell is a waste product from the shellfish industry that is currently discarded or given away by mussel farmers and has none of the disadvantages of peat. Large amounts of mussel shells can be acquired for a very low cost, and with minimal effort they can be crushed and graded to be put into use as a filtration device. Various mechanisms for how mussel shells remove heavy metals and other toxins have been postulated, including: adsorption to the chitin polysaccharide component of the shell, ion-exchange with calcium ion from the sparingly soluble calcium carbonate component of the shell, or non-specific adsorption associated with the high surface area of the shell (Craggs, 2010). Whatever the mechanism, the results of several experiments clearly demonstrate that the crushed shell of the New Zealand green-lipped mussel,

*Perna canaliculus*, is very effective at capturing zinc and copper from solutions at relatively low concentrations such as those found in urban storm water (Vigar, 2012).

The removal harmful stormwater pollutants from the coastal ecosystem is very necessary if the Ngāti Whātua are going to restore the mauri of their land. Undiluted urban stormwater can be acutely lethal to fish and aquatic invertebrates within a few hours, and as it degrades the water quality of the wider ecosystem, aquatic biodiversity is lost and the ecological resistance of the community is reduced (McIntyre, 2016). Because stormwater is composed of several heavy metals and a variety of other industrial pollutants from unknown sources, it is impossible to create a specific threshold where exposures proves detrimental to human health (Yukun, 2016). In small concentrations, copper and zinc have to the potential to cause stomach pain and headaches, while small concentrations of lead and arsenic, which may be present in the stormwater, have the potential to cause serious illnesses such as seizures, liver failure, and irregular heart beat (Heavy Metal Poisoning). While the specific human health and ecological effects on of the stormwater flowing onto Ōkahu Bay cannot be known for certain, it is recognized that the contents of the stormwater are toxic and the removal of these pollutants would without a doubt increase the mauri of the ecosystem.

**Methods:**

In order for a mussel shell filter to be built for the Ōkahu Bay stormwater pipe, the pollutants in the stormwater must first be quantified. The pollutant load needs to be quantified because mussel shell stormwater filters are a new form of engineering whose specifics are not yet completely understood. Their is no consensus on the correct size of crushed shell to be used in the filter, or if any certain parts of the shell or design of filter is superior at sequestering

pollutants. Once the exact nature of the Ōkahu Bay stormwater is calculated, it can be recreated in a lab setting by adding identical concentrations of copper, zinc, and other measured pollutants. This solution can be tested in several different filter designs to see which is most effective at removing the specific heavy metals and other dissolved solids from the water. Once a filter has been created to remove the pollutants to a satisfactory level, then it can be installed at the effluent end of stormwater pipe which flows onto the beach. The basic design of the filter will be based on current models used to treat stormwater, with some modifications made in order for it to be adapted to mussel shell.

In order to quantify the pollutant load of the stormwater, several samples must be collected and analyzed. An auto-sampler will be installed at the effluent end of the storm pipe which will collect water samples every time a storm event flushes water through the pipe. Since every rain event is different in its intensity, length, and time of occurrence, a number of samples from different rain events must be taken in order to create accurate image of what an average storm event will look like. Once the auto-sampler collects a sample of water, it will be taken to a laboratory at the University of Auckland and analyzed with a Ion Chromatograph Coupled with Mass Spectrometry, which will be able to determine the concentrations of various heavy metals and dissolved solids within each sample. Once the data from several storm events is recorded and analyzed, one can deduce the pollutant load that an average storm event would produce. It is from this average storm event that the stormwater will be recreated in a lab. In order to ensure that the average pollutant load calculated is truly indicative of an average storm event, at least ten samples must be collected from the storm pipe to confirm accuracy.

**Discussion:**

Assuming that future data is produced which confirms that heavy metals and other harmful pollutants are being dumped onto Ōkahu Bay, it is of great importance that measures be taken to reduce there flow onto the bay. Not only are stormwater pollutants dangerous to human health and ecosystem stability, but they take a great deal of time to exit the ecosystem once they are deposited. Many heavy metals are assumed to be sequestered in the mud at the upper end of the beach, and they will remain their until they are leeched out of the soil by rain events or are potentially taken up by flora which can be planted in the area. Only when the flow of heavy metals into the ecosystem is stopped can the ecosystem and the mauri of the area begin to recover to a more prosperous state.

Mussel shell filters have the potential to increase the quality of life for people, plants, and animals along the Ōkahu Bay coastline and the greater Hauraki Gulf. Heavy metals can accumulate in the accumulate in the flesh of organisms and can be harmful to many trophic levels in the food chain. They are especially toxic to children, the most vulnerable members of our society, which is an added incentive to ensure that harmful levels are not present in our ecosystems. Beyond the regional implications, mussel shell filters have the potential to change the world by transforming a discarded waste material into something useful for urban areas everywhere. Urban areas aggregate an immersive amount of pollutants into a single location, and the water of these areas are often treated to a standard which is not the best interest of human and environmental health. Mussel shell filtration provides a relatively inexpensive water purification process which removes some of the most toxic substances out of urban stormwater. By raising awareness to the issue of polluted stormwater, perhaps people will change some of

their most destructive practices like removing copper from vehicle brake linings, just as lead was removed from paint years ago.

This research project has shown a light on a lack of information in a new and dynamic field of study, and has created a number of questions for future projects to attempt to answer. A lack of information on the specific processes which allow mussel shells to successful remove pollutants from a body of water hinders the potential effectiveness of the filter. If the exact process by which mussel shells filter out harmful pollutants is known, than a filter can be constructed to amplify the process in the most effective manner. A variety of promising filter designs should be tested in the lab and in the field to see which works best, and from there the designs could be refined and improved. Once a filter is installed on the effluent of the Ōkahu Bay storm pipe, follow up analysis should be conducted on the mud, sand, and water of the bay to see if pollution concentrations are decreasing. Additionally, further research should be conducted on whether the shells of green lipped mussels are the most effective at removing heavy metals from a column of water verse other shelled organisms such as clams, gastropods or paua.

It is great that the Ngāti Whātua have taken up the ambitious goal of restoring the mauri to their ancestral land, however there is a need for the city of Auckland and the government of New Zealand to recognize that they are largely responsible for decreased the mauri whenua and should play their part in its restoration. Pakeha of New Zealand forced the Ngāti Whātua o Orakei from their lands and pakeha are the ones who brought harmful industries and heavy metal pollution to New Zealand. If the restoration of Ōkahu Bay increases the health and prosperity of the region beyond the Ngāti Whātua community, then the Ngāti Whātua should not be the only

ones who bear the price to clean up and restore the land. If the pakeha of New Zealand accept their responsibility in the deterioration of the land's mauri, then there will be more attention, more resources, and more ideas for how to restore the mauri of the land in the most productive of ways.

**Conclusion:**

Ōkahu Bay is an area of land that is held dearly by many in the Ngāti Whātua community because of their long and proud history associated with the region. Their ancestors landed at this bay centuries ago and used it sustainably for hundreds of years and a fishing area and shipping lane. This land was unjustly confiscated and returned to them with the mauri diminished along with their sovereignty. The Ngāti Whātua have ambitiously taken on the initiative to restore the quality of their land in a manner which is inline with the quadruple bottom line of the mauri model. Their willingness to engage with an unconventional technology such as mussel shell filtration in order to restore their land is a story which should be shared and replicated in communities around the world. Once the mauri of Ōkahu Bay begins to be restored to a more prosperous state, the bay can serve as a place of business, recreation, and thriving coastal ecology for the enjoyment of the Ngāti Whātua and the greater Auckland community.

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**Appendix:**


**Figure 1** - Catchment Areas with Peak Flow and Runoff Volumes for a 10-yr Annual Recurrence Interval Rainfall Even (Ōkahu Bay Tidal Creek Reinstatement, 2013)