Auckland Harbour Bridge: Meeting environmental challenges sustainably

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INTRODUCTION

The NZ Transport Agency (Transport Agency) has a statutory responsibility (NZ Government, 2003) to manage the operation of the nation's State highways, which includes the Auckland Harbour Bridge (AHB). Spanning the Waitemata Harbour the AHB ensures New Zealand's main State highway (State Highway 1) is continuous from Northland to south of Auckland. Because the AHB plays a pivotal role in maintaining the functionality and efficiency of the New Zealand's Upper North Island transport system it is regarded as a national asset and the most strategically important bridge in the country. The AHB is a significant contributor to sustaining and fostering national and regional economic growth.

In the regional context the AHB's role in transport is critical to the connectivity, growth and development of wider Auckland, primarily through maintaining the key conduit between central Auckland and the North Shore, which lies north of the Waitemata Harbour (See Figure 2 and Figure 3). In this capacity the AHB currently carries Average Annual Daily Traffic of over 170,000 vehicles. The AHB also provides a physical platform for key intra-regional utilities systems and lifelines such as potable water, electrical power, gas and telecommunications. These services rely on the AHB's functionality not only by providing a route for the infrastructure for normal supply needs but also in civil defence emergency situations.

Since 1998, the maintenance of the bridge has been undertaken by Total Bridge Services (TBS). TBS is a joint venture between TBS Farnsworth, Opus International Consultants Ltd and Fulton Hogan. Until 2012, works were undertaken under a performance specified maintenance contract (PSMC). In 2012 a maintenance alliance was formed, known as the AHB Alliance, between the Transport Agency as the owner, TBS and Beca. The structure of the AHB Alliance is shown in Figure 1 below.

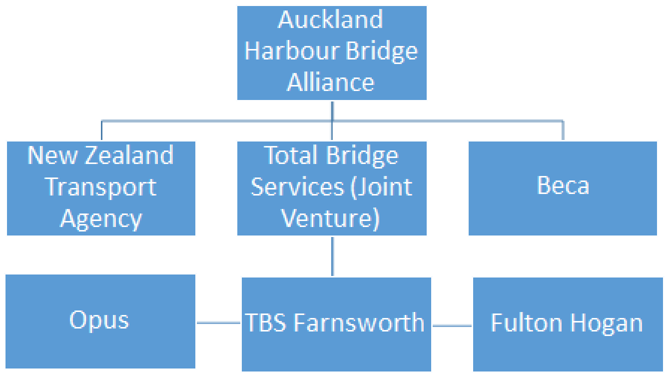

Figure 1: AHB Alliance – Participants Diagram

The establishment of an alliance model for bridge operation and maintenance has created a culture of collaboration. It brings together people with expert knowledge who work together to deliver excellent outcomes, foster innovation and provide best value for money solutions. Environmental management is supported by a core team of specialists across planning, marine, air and land disciplines collaborating together and working with key stakeholders.

Being a predominantly steel structure, the AHB requires continual maintenance over an area of 125,000m^2 which until recently has occurred at a rate of approximately ten percent of the surface area annually. Since opening in 1959, and the subsequent widening in 1969, the bridge has been maintained with a number of coatings systems using a "patch and recoat" philosophy. Maintenance activities include water jetting, wet and dry abrasive blasting, application of coatings (primers, rust inhibitors and paints) and minor structural works such as metal welding and concreting. Discharge of various contaminants from these maintenance activities occurs to air, marine waters and the surrounding land and requires resource consent under the New Zealand Government 1991, Resource Management Act (RMA).

In 2011 The Transport Agency renewed its resource consent to discharge contaminants to air and water arising from maintenance activities on the AHB. The application sought to progressively contain maintenance discharges (85% of dry discharges and paint overspray and 100% of washwater discharges). The consent was granted in 2012 on the basis of the continued use of the existing coatings system (zinc rich moisture cured urethane). While the outcomes sought by this approach were not unreasonable the implementation method for achieving this outcome was prescriptive, inflexible and costly. The cost for containment and associated strengthening was estimated at $65M over 10 years. The prescriptive nature of the consent resulted in a lack of flexibility constraining innovation and the ability to use more environmentally friendly solutions.

Since that time the AHB Alliance has reviewed their maintenance regime and identified alternative protective coating systems which will not only reduce maintenance requirements and costs, but also provide greater flexibility within the resource consent framework.

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Figure 2: Location of AHB in relation to Auckland City

BACKGROUND

In December 1950 the Auckland Harbour Bridge Act (NZ Government 1950) established the Auckland Harbour Bridge Authority (Authority). The duties of the Authority were to construct, maintain, manage and operate a bridge across the Waitemata Harbour from Point Erin at the southern end and Te Onewa Point at the northern end (See Figure 2).

The Authority chose a steel structure for the bridge and construction began in 1956 with prefabricated sections being built on top of spans already in place and then floated into position in the harbour on barges. On the 30th May 1959 the bridge opened. Two extensions were put in place between 1968 and 1969 to address transport capacity needs.

The AHB has a total length of approximately 1600 meters with the span over water being approximately 1100 meters. Currently 8 lanes exist on the bridge, which operate in a tidal flow system during peak traffic periods.

The AHB is made of a number different structural components with the landward components consisting of three viaducts: two being steel and one concrete. The seaward components of the AHB include steel spans and trusses, box girders and the southern anchorage (See Figure 3).

The surface area of the AHB is approximately 125,000m², with an average paint thickness of 800µm (0.8 mm). The current paint system used on the AHB is a zinc rich moisture cured urethane which comprises one primer coat, one intermediate coat and one topcoat. The primer coat is made up of a zinc pigment suspended in a urethane binder, and the intermediate and topcoats comprise an iron oxide pigment in a urethane binder. Historical paint coatings *include zinc phosphate, zinc chromate and a lead primer paint, which has not been used on the bridge since the very limited applications in 1959.*

Being in a marine environment the AHB is vulnerable to paint deterioration and steel corrosion requiring continual maintenance to ensure it is structurally safe and fit for the required use. Routine works primarily involve surface preparation and cleaning, abrasive blasting and then coating by a specifically designed paint system. In addition, maintenance works such as welding and concrete works are intermittently undertaken to address minor strength issues.

A number of assessments of the historical paint systems on the AHB and performance of maintenance approaches have been made to develop a robust understanding about bridge characteristics and the potential environmental impacts of maintenance, and this is an ongoing process (Mandeno 2006, Mandeno and El Sarraf 2013).

South ***North***

Figure 3: Northward view of the AHB (Pt Erin to Te Onewa)

Figure 4: Typical spans over marine area requiring regular recoating maintenance

ENVIRONMENTAL CONTEXT

Discharges from maintenance activities on the AHB enter the air space surrounding the structure and deposit both on land and the marine area, the sea being the dominant receiving environment. The AHB spans the Waitemata Harbour between two land points, Pt Erin (South) and Te Onewa Point (North), that constrict ebb and flood tidal flows which move approximately 170,000,000 m^3, or 60% of the water in the Harbour during each six-hour tidal cycle. The channel below the AHB reaches 24 meters water depth at the northern end and shallows towards the southern side. Land discharges are limited in extent.

The Waitemata Harbour is a drowned-valley estuary, with a surface area of some 80 km^2 and a tidal prism of c. 216 million m^3. Numerous studies covering hydrology, water and sediment quality and biodiversity have been completed on all parts of the harbour (upper, central and outer). The Auckland Council reports the characteristics of the Harbour and research findings from these studies through its State of the Environment function. For the area directly below and adjacent to the AHB the July 2013 State of the Environment Marine Report Card (Auckland Council July 2013) identified the following environmental qualities:

- *WATER QUALITY: The water quality of the Central Waitemata Harbour has been ranked as 'fair' but closer to the bridge as 'poor'.*
- *CONTAMINANTS IN SEDIMENT: The Central Waitemata Harbour is widely contaminated with the worst areas nearer muddy estuarine zones receiving runoff from older urban and industrial catchments. The main contaminants being copper, zinc and lead, with some PAHs.*
- *ECOLOGICAL HEALTH: Ecological health varies greatly across the Central Waitemata Harbour with some sites ranked as good; but the majority of sites are moderate, poor or unhealthy.*

Adjacent to the AHB are zones described within Auckland Council planning documents (Auckland Council 2004, 2013 and September 2013) as having high natural character values. Descriptions include "an intertidal area which is an important wading bird feeding ground. Saltmarsh and mangrove communities grow on the margins of this area, protected by the shell banks nearer the mouths of the bays. These areas of saline vegetation offer a good habitat to secretive coastal fringe birds."

The main contaminant being discharged from AHB maintenance activities is Zinc and concentrations in sediments nearby (2 – 3km) are rising towards levels of concern. While assessments suggest Zinc impacts are less than minor, accumulative impacts remain difficult to clarify particularly in terms of provenance.

REGULATORY ENVIRONMENT

The principle legislation in New Zealand for managing impacts to the environment is RMA which sets out key principles and requirements to manage impacts to natural and physical resources such as land, air and water.

To give effect to the principles and objectives of the RMA local city and district councils, and regional councils, develop regulatory plans which set out specific criteria to avoid, remedy or mitigate impacts to the environment.

Alongside the RMA and relevant planning documents are a number of National Policy Statements and Standards which provide objectives and policies for matters of national significance.

The AHB was required to seek consent under a number of Auckland Council Regional Plans for the discharge of contaminants to air, land and the coast.

The consents needed included:

- *Discharge of contaminants to the Coastal Marine Area*
- *Discharge of contaminants into air from dust generating activities*
- *Discharge of wash water, wastewater and dry wastes to land.*

Consents generally are very prescriptive to gain certainty in terms of environmental outcomes, and reduce risk for consenting authorities. Applications based on management plans with limited specific information and details that seek flexibility are generally not acceptable.

The consenting strategy adopted by the AHB Alliance focussed on quantifying the 'existing environment' to set a baseline for the effects assessment and to identify contaminant discharge thresholds. The discharge thresholds ensured that the environmental outcomes sought by Auckland Council could be met. An "effects" based Adaptive Management Framework (AMF) and Operational Model, underpinned by robust science and good planning, gave confidence to Auckland Council that these thresholds would not be exceeded while maintaining flexibility for bridge maintenance contractors.

The integrated planning approach required Auckland Council 'buy in' to be successful. The Alliance openly collaborated and communicated with Auckland Council throughout the resource consent process. An effective partnership was developed which ensured appropriate consent conditions could be developed that linked to the AMF purpose, processes and outcomes rather than prescribing methods and activities.

This approach is not restricted to the AHB. It is equally applicable to all infrastructure providers and other operators who undertake maintenance activities. This approach is truly effects based planning. The approach could equally apply to Australia.

MAINTENANCE APPROACH

The approach for managing discharges from AHB maintenance activities, outlined as part of the 2011 resource consent applications, focused on reducing discharges by progressively implementing containment. This approach was adopted based on international best practice and preliminary cost estimates for the containment structure. It was proposed that 85% of dry discharges and paint overspray and 100% of washwater discharges could be contained.

Key timing requirements for containment were as follows:

- *Pre-containment (30 Aug 2011 to 30 Aug 2014) – Containment required over land only;*

- *Partial-containment (31 Aug 2014 to 30 August 2021) – Containment required out to Piers 1 and 5 including spans 1, 6 and 7; and*

- *Full containment (post 30 Aug 2021) – Containment required over all areas of the bridge including spans 1-7 but excluding the lower overarch.*

The outcome sought from containment was to reduce annual discharge volumes of contaminants from approximately 92 tonnes of garnet and 1.4 tonnes of Zinc to approximately 17 tonnes of garnet and 250kg of zinc over a 10 year period.

In granting resource consents to the Transport Agency the Auckland Council considered the reduction of discharges by approximately 85% in volume a significant improvement in environmental outcomes. The impact of the 15% continued discharge was assessed as no more than minor. In this way the Auckland Council set the expected environmental outcomes.

Changes in the Transport Agency priorities for new and existing roading asset maintenance, and funding availability placed a requirement on the Alliance to look towards reducing long-term costs. The costs associated with containment became prohibitive when it was acknowledged that significant strengthening works would be required to construct the system. Consequently, the Alliance investigated alternative methods and products which could provide a more cost effective solution for environmental mitigation but that would still meet or exceed the outcomes achieved under the 2011 resource consent.

After extensive research, and on site trials the Alliance were able to determine that High Ratio Calcium Sulfonate Alkyd (HRCSA) coating products provided a beneficial alternative to the zinc-rich system currently in use, for much of the bridge.

One of the benefits of HRCSA coatings is that they significantly reduce the amount of zinc and abrasive agent entering the harbour and being discharged to air. Unlike the existing zinc-rich system, HRSCA coatings do not require the surface to be prepared by abrasive blasting, reducing the amount of dust, particulate and historic coatings (metals) being discharged. Further the actual products are relatively inert in the environment once cured, and doesn't contain zinc. HRSCA products can also encapsulate historic layers of paint which will further reduce discharges of contaminants such as zinc, chromate and lead, further minimising the environmental impact.

To support this coating system change associated environmental controls included:

- *Limiting spray painting during periods of high wind or when wind is blowing towards sensitive receptors.*
- *Applying protective coatings by hand to avoid over spray.*
- *Using wet abrasive blasting to avoid dust and air discharges where required.*
- *Containment of dry discharges and over sprays where practicable.*
- *Only undertaking identified maintenance requirements based on condition surveys, rather than sectional upgrades.*

Research continues to be undertaken by the Alliance into alternative coating systems. The investigations examine surface preparation and coating methods and products that avoid or limit abrasive blasting and are more *environmentally friendly. Studies of coating environmental toxicity have also been included as part of this research. (El Sarraf et al. 2014).*

The Transport Agency considers research and development a continuing practice as paint technology and maintenance systems improve. To address this, the Adaptive Management Framework (AMF), which supports the Environmental Management Plan, allows investigation into different products and methods to assess these against the environmental outcomes sought. The AMF provides a clear process for change when it is evident that environmental outcomes can still be achieved.

Embedding the AMF into the resource consent has been a change to normal statutory planning practices. The purpose is to allow maintenance activities to be changed without excessive statutory burden.

NEW RESOURCE CONSENTS

In 2014 the AHB Alliance sought new resource consents for AHB maintenance activities which adopted an innovative consenting approach focussed on environmental outcomes rather than relying on prescriptive methods and controls. The approach enables the Alliance to invest in new technologies and products as they became available so they can improve their environmental performance over time.

The approach represented a significant shift away from the solutions proposed as part of the 2011 consent therefore Council deemed that new consent applications were required. Further, the Council required that the new consent provided certainty that maintenance approaches would still be able to meet the environmental outcomes agreed as part of the 2011 consent process. The AHB Alliance and Council worked closely together to ensure the required applications provided for each other's needs in an integrated way.

The innovative approach relied on the integration of science, planning and operator knowledge to:

- *Develop a truly effects based regime using science to set thresholds that ensure good environmental outcomes are achieved.*
- *Deliver flexibility for operational methods, products and activities rather than prescription based on methods / products / activities.*
- *Develop a simple but effective monitoring programme that measures inputs and provides direct outputs for environmental reporting to show consent compliance.*
- *Produce an adaptive process that provides sufficient certainty for new products and methods to be used without needing to change or replace the consents*

An example of the AMF process is shown in Figure 5 below.

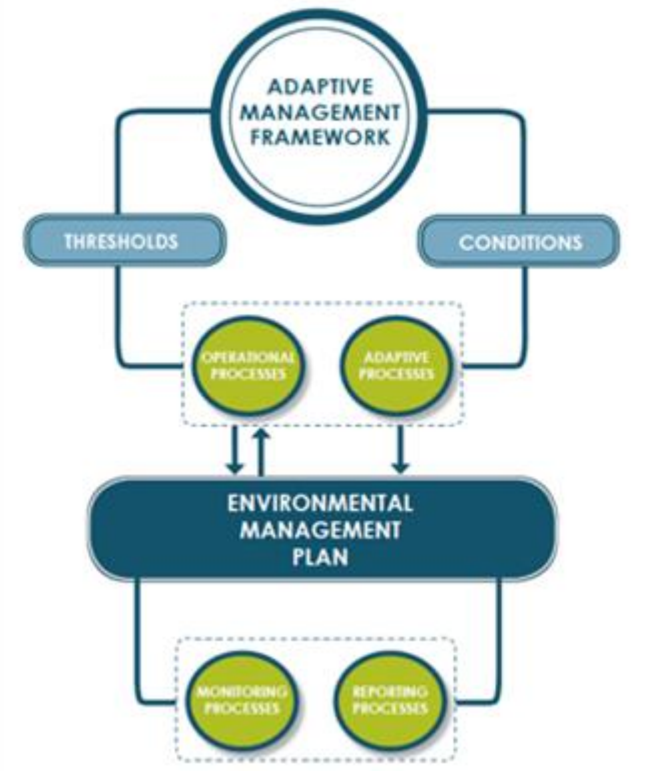

Figure 5: Adapative Management

Supporting the applications were assessments of the impacts from discharges of new products and their chemical natures. These assessments covered issues such as the effects of AHB discharges in relation to inputs from the wider catchment including storm water from urbanized areas, direct discharges from adjacent industrial and commercial activities, and rural catchments, particularly in the upper harbour.

Other issues the AHB Alliance addressed included Maori cultural values, the context of various land uses it traverses, land and sea scape values and the AHB's engineering history. While these were addressed to some extent in the previous resource consent, recent regional planning documents required greater emphasis on these issues.

A number of operational tools were also developed as part of the consent process to ensure the Alliance could effectively monitor and comply with the conditions of consent. The AHB Operational Discharge Model is a database which monitors and reports the discharges of contaminants from maintenance activities (See Figure 6). Discharges are estimated based on information that is logged during works and entered into the database. The information includes where maintenance work is being carried out, what activities are being carried out, the scale and nature of the activity and any environmental controls put in place (such as containment). The discharges of key contaminants are then calculated based on key assumptions derived from sampling and analysis undertaken at the AHB to-date.

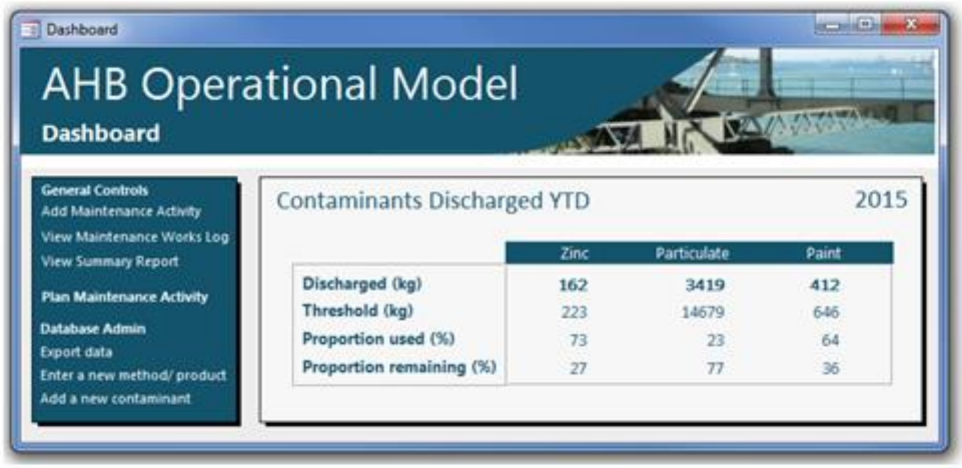

Figure 6: *Example output from Operational Model*

Under the previous maintenance resource consent the level of zinc authorised to be discharged to the harbour during the partial containment phase (i.e. from 2014 – 2021) was a total of approximately 7 tonnes (about 1 tonne of zinc per year). Using the alternative HSCRA product allows the AHB Alliance to reduce the amount of zinc being discharged to the level that was anticipated under the full containment phase of the previous consent – less than a quarter of a tonne per year. This means that over seven years a total of up to 1.6 tonnes of zinc can be discharged, representing a reduction of 5.4 tonnes of zinc being discharged into the harbour over this period (See Figure 7).

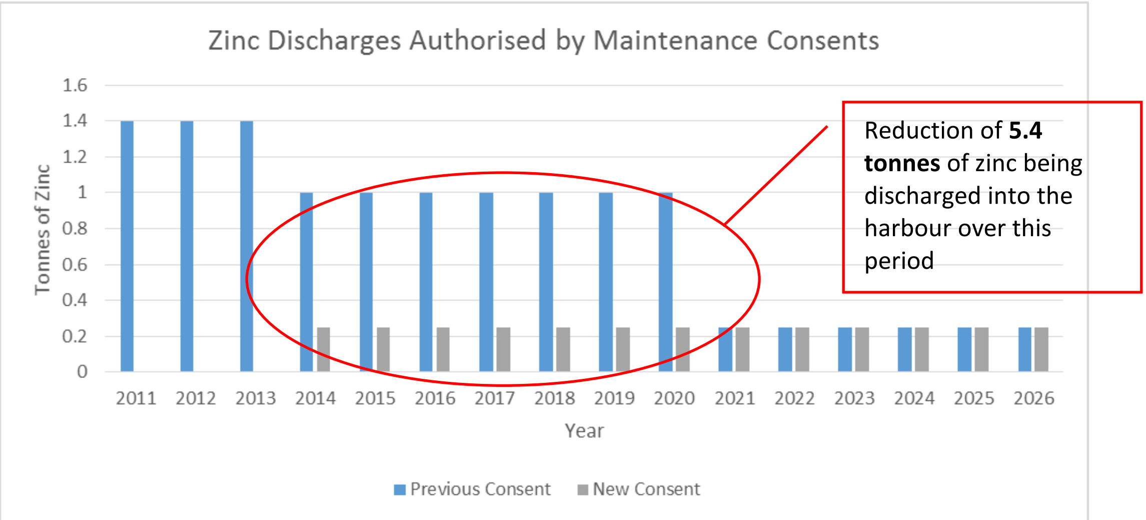

Figure 7: *Example of reporting*

In late 2104 the Council granted new resource consents for the AHB maintenance activities that achieved significant environmental benefits for the Waitemata Harbour and allowed efficient changes to the management approach to reflect developing knowledge and practices. This is a significant departure from normal statutory planning authorisation which seeks to define controls and bind parties to these, and provides opportunities and guidance for other large infrastructure organisations to work together with statutory organisations to achieve shared outcomes.

The resource consent obtained through this process provides an environmental effects baseline which will also drive behaviour to reduce overall discharges by focussing on performance rather than compliance. The project was recently recognised as Best Practice at the 2015 New Zealand Planning Institute (NZPI) Awards in the category of Integrated Planning and Investigations and has also received the inaugural Environmental Protection Award at the Transport Agency's 'Going the Extra Mile' awards.

CONCLUSIONS

The previous resource consents for maintenance of the AHB were based on progressive containment and required significant resourcing and funding to be implemented – due predominantly to the hefty cost of strengthening the truss bridge element. The significant cost could not be justified by the Transport Agency.

Studies into other maintenance techniques and controls identified viable alternatives that led to the development of an innovative adaptive management framework that provides more flexibility for contractors and enhances environmental outcomes over the long term.

The AHB maintenance project has demonstrated that achieving excellent environmental outcomes doesn't have to come at a large financial cost. In the case of the AHB re-consenting process the collaborative nature of discussions drove innovative environmental management solutions which not only safeguarded the environment but also provided cost savings of $65M to the Transport Agency.

Starting with the end in mind and designing outcome-focussed solutions drives productivity and innovation within a project. It requires teams to take a backcasting approach which can be applied and adapted to suit any situation. Following an outcomes-driven process creates unique challenges. It often highlights barriers to change due to the development of new and untested solutions. To overcome this, it is crucial to collaborate and understand the needs of relevant stakeholders to ensure win-win solutions can be developed.

The AHB Alliance now have a clear adaptive management process enabling them to assess alternative methods and products as new technologies become available within the coatings industry, and to evolve their environmental management practices over time. This will ensure that AHB maintenance activities keep pace with industry changes and allow them to further reduce their environmental footprint over time.

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Kat Mac Donald

Kat is a Certified Environmental Practitioner with over 10 years' experience in environmental management, environmental science and sustainability. Kat joined Opus in 2010 as an Environmental and Sustainability Consultant in the Westhaven office and specialises in environmental impact assessment, environmental monitoring, preparation of environmental management plans/systems and sustainability projects. A large part of Kat's role involves leading teams of contractors and consultants on multi-disciplinary projects to achieve better environmental and sustainability outcomes. Kat achieved her accreditation as an Environmental Practitioner in 2012 and is a member of the Environmental Institute of Australia and New Zealand (MEIANZ). In 2013 she was appointed as Chair of the Opus Sustainability Professional Interest Network which is a role that oversees the technical wellbeing of over 200 professionals worldwide. In 2014 she was appointed as the Company Sustainability Leader, a global role carried out alongside her consulting work, with a strong strategic focus involving policy development, strategy and planning, and sustainability reporting.

Kat recently received the Association of Consulting Engineers NZ (ACENZ) 2015 Future Leader Award. Her involvement developing innovative environmental management solutions has also been recognised recently with the Auckland Harbour Bridge project winning 2015 New Zealand Planning Institute Award, Best Practice Award for Integrated Planning and Assessment.

David A Greig

David has a background in environmental science with over 30 years' experience in the resource management field. Working within regulatory, consulting and asset management fields David has focused on navigating the regulatory environment by ensuring comprehensive assessments are competed for projects. His background is in zoology and earth science with a Marine Geology Masters.

In the last eight years working with the transport field David has been lucky enough to be involved in nationally significant projects, but also locally important jobs. All his recent projects have covered typical water and soil issues and ecology, but also cultural and social aspects of road development and operation.

David works in the Highway and Network Operations National Office Environment and Urban Design Team, providing advice to the Transport Agency on managing effects on natural systems to ensure projects can meet statutory needs and also good practice. Working with a range of engineering teams, statutory planners and stakeholders, David is able to influence the Transport Agency towards meeting its environmental and statutory responsibilities, something he finds rewarding.