FIGHTING AN UPSTREAM BATTLE - THE BARRIERS TO IMPLEMENTING THE FISH PASSAGE GUIDELINES.

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ABSTRACT (500 WORDS MAXIMUM)

Implementing the New Zealand Fish Passage Guidelines on a road safety improvement project containing over 50 existing culverts has highlighted additional barriers to fish passage, beyond the physical barriers outlined in the Guidelines. In a challenging landscape, balancing the ecological, engineering and budget requirements appeared at times more onerous than the difficulties faced by aquatic life.

A step increase in traffic loads on State Highway 58 north of Wellington is expected on completion of the Transmission Gully Motorway. A 9km section of the road is being upgraded and widened to improve road safety prior to this increase, following a significant number of serious accidents on the road in recent years. As part of this project, the stormwater infrastructure is also being upgraded to meet current design standards, including compliance with the Fish Passage Guidelines released by NIWA in 2018.

It was considered that despite the number of culverts requiring design, a generalist approach to fish passage design was not feasible on this project. Instead, a variety of measures were required to ensure an economical design. Identification of specific culverts requiring fish passage, including detection of natural and manmade barriers early on was critical to project success. This required the input from a specialist freshwater ecologist during the preliminary design phase.

This paper discusses the issues and complications associated with upgrading existing stormwater infrastructure to meet the requirements of the Fish Passage Guidelines on a constrained and challenging site, while balancing ecology, stormwater and client requirements on a project where the primary driver is road safety improvement.

KEYWORDS

Fish Passage, Culverts, Design

PRESENTER PROFILE

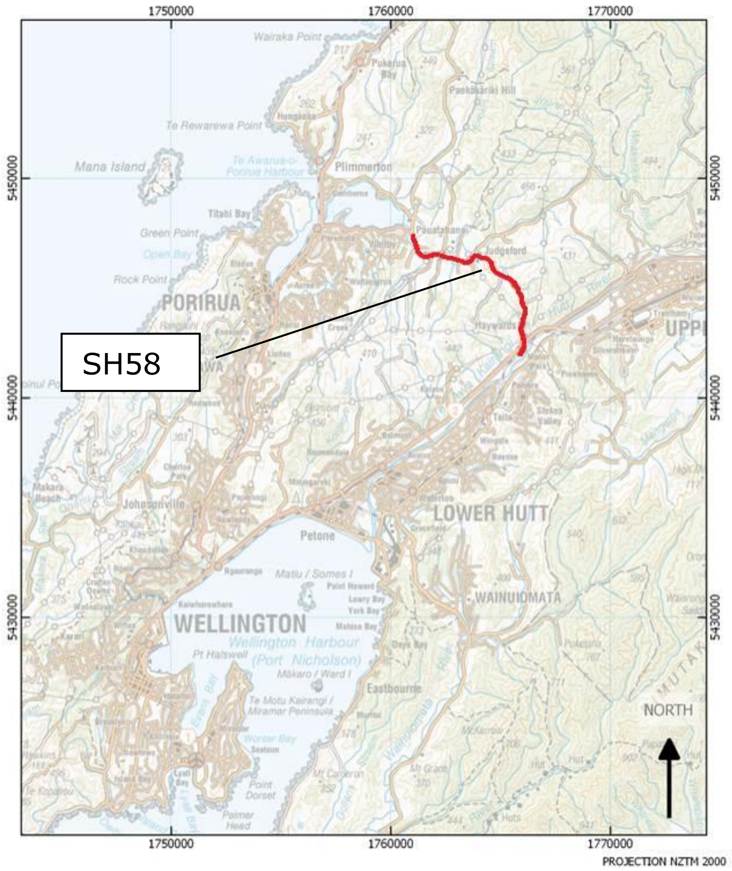
Colin Jermyn is a Water and Wastewater Engineer for Stantec NZ, based in Wellington. He has 6 years' experience across all three waters from concept and business case through detailed design and construction monitoring. His main expertise lies in stormwater design, particularly on management of stormwater quality and quantity through sustainable measures.

1 INTRODUCTION

State Highway (SH) 58 connecting the major urban centres within Kapiti and Porirua (SH1) in the west to the urban centres of the Hutt Valley (SH2) to the east. SH58 is narrow and winding and has many unprotected roadside hazards. Since 2008, there have been almost 200 crashes on this road, classifying it as the 12th worst performing corridor nationally in terms of collective risk. The scheduled opening of Transmission Gully in 2020 will result in an increase in traffic on SH58. New Zealand Transport Agency (NZTA) are upgrading a 9km stretch of this road to enhance the safety of travel on SH58.

The proposed solution includes widening and shape correction of the existing carriageway and construction of a new central wire rope barrier and new roadside barriers on either side of the carriageway. As part of the traffic safety improvements, drainage infrastructure, including over 40 culverts will also be investigated for required upgrades based on current design standards (NZTA P46 State Highway Stormwater Specification).

Figure 1-1: Site Location



2 EXISTING DRAINAGE

2.1 CATCHMENT DESCRIPTION

The project stretches across two main catchments. On the western side is the Pauatahanui Stream catchment which generally consists of gentle rolling hills and flood plains. The land is typically used for farming with relatively low amount of tree cover. The Pauatahanui Stream discharges to Te Awarua-o-Porirua Harbour.

On the eastern side of the hill, the catchment is significantly steeper and heavy bush growth. An unnamed stream collects runoff and discharges to the Hutt River which flows into Wellington Harbour.

Figure 2-1 Western Catchment

Figure 2-2 Eastern Catchment

An ecology report undertaken as part of the project identified that suitable aquatic habitats exist in both catchments. Longfin eels were spotted in some of the catchment areas upstream of culverts which cross SH58. These upper catchments could potentially support other species such as banded kōkopu, giant kōkopu, common bully and shortfin eel.

2.2 EXISTING DRAINAGE ISSUES

Construction of SH58 in the 1940s required crossing numerous watercourses along its length. Between SH2 and Bradey Road (approximately 9km), there are over 40 crossings. These vary from small ephemeral streams in 200mm diameter pipes, to 20m span bridges across the Pauatahanui Stream. A number of drainage issues have been identified on many of these crossings, which indicate the culverts not meeting current standards. These include:

- Insufficient hydraulic capacity to convey 1% Annual Exceedance robability (AEP) flows
- No headwalls at inlet or outlet
- Erosion and scour at the inlet and outlet
- poor access for inspections and to undertake maintenance
- Insufficient or non-existent provision for fish passage

Figure 2-3 Perched oultlet

Figure 2-4 Insifficient hydraulic capacity for design flows demonstrated by submerged inlet during typical rainfall event

3 FISH PASSAGE BARRIERS

3.1 OVERVIEW OF THE FISH PASSAGE GUIDELINES

The New Zealand Fish Passage Guidelines (FPGs) were released in April 2018 and set out best practice and minimum design standards for instream infrastructure to provide for fish passage for structures up to 4m span.

The FPGs are based on the following objectives:

- Efficient and safe upstream and downstream passage of all aquatic organisms and life stages resident in a waterway with minimal delay or injury.
- A diversity of physical and hydraulic conditions are provided leading to a high diversity of passage opportunities.
- The structure provides no greater impediment to fish movements than adjacent stream reaches.
- Continuity of geomorphic processes such as the movement of sediment and debris.
- Structures have minimal maintenance requirements and are durable.

The FPGs provide different requirements for new structures and remediation of existing. In general, new structures are required to mimic the existing stream as much as possible. This includes continuity of flow velocity, maintain existing stream grade and well graded substrate along the culvert bed. Remedial measures focus on common causes of fish passage problems and identifies a range of potential solutions for improvement. These range from removal (most effective solution) to smaller scale measures like fish ramps and spat ropes. Fish passage for both new and existing crossings needed to be considered on this project.

Table 3-1 Examples of some possible ecological prioritisation criteria for fixing instream barriers. Multiple factors may influence the priority of works to restore connectivity. This includes not only ecological criteria, but also economic, social and logistical criteria. Adaped from Franklin et al. (2014)

Criteria	**Explanation**
Proximity to coast	Barriers that are closer to the coast not only block access to a greater proportion of upstream habitat, but they also generally block a larger number of fish species
Potential habitat gain	The greater the total length of accessible river upstream of the barrier, the greater the potential habitat gain.
Habitat quality	Restoring access to higher quality instream habitat should be prioritised over providing access to degraded sites.
Proximity to protected areas	Connection with protected area networks may provide added benefits (e.g. constraints on fishing).
Number of species likely to benefit	Some sites are expected to naturally support a greater number of species than others, e.g. sites at low elevation close to the coast. Sites that are expected to support many species may be of higher priority than those expected to support few species
Conservation status of species	Sites expected to support species with a higher conservation status may be of higher priority for restoration of connectivity.
Preventing spread of exotic and invasive species	Maintaining boundaries on the spread of exotic and invasive species may be a desirable outcome of retaining barriers and should also be considered in prioritising restoration actions.
Protects threatened species	Barriers may protect populations of threatened fish species by preventing access to competing species, e.g. trout. Existence and protection of threatened fish populations should also be considered.

3.2 BARRIERS TO FISH PASSAGE

3.2.1 TYPICAL BARRIERS

The most common barriers to fish passage are:

- Excessive fall heights
- High water velocities
- Insufficient water depth
- Physical blockage

For each of these barriers, the FPGs demonstrate multiple fixes for removing or improving this barrier. These are physical solutions which typically involves some level of construction or demolition on site. Removal of the structure is almost always the preferred solution, however alternative measures to recreate fish passage are also available, such as ramp fishways, baffles and mussel spat ropes.

3.2.2 IMPLEMENTATION BARRIERS

Throughout this project, fish passage was impacted by the constraints around implementation of measures as much as the physical barriers themselves. The FPGs discuss the prioritisation of structures for remediation, and indicates that ecological, economic, social and logistical criteria all have an influence on the prioritisation process.

Although noted that this list is not exhaustive, this magnitude of these constraints, in addition to several other new ones identified during this project, have been a major challenge to overcome - a process which is still ongoing.

These constraints stem from trying to balance the requirements of three main parties – ecology, engineering (hydraulics) and project manager.

The ecology team was responsible for identifying streams and watercourses which require fish passage, existing barriers and providing prioritised list of upgrades from an ecological perspective.

The engineering team, as designer of proposed infrastructure, was responsible for ensuring the design conforms to relevant codes and standards, and meets the client's requirements and objectives. Initially, this focussed on condition and hydraulic capacity of the culverts. Additional factors such as constructability and maintainability were also identified as the design developed.

The project manager's responsibility is to deliver on the project objectives - in this instance to enhance the safety of travel on SH58. As a publicly funded project, they are responsible for delivering the project in an economically efficient manner. Health and safety of users, constructors and maintainers of the road are of utmost importance. The project manager also has a focus on costs and programme of the works.

Overall the purpose of the team as a collective is to help the client meet their environmental requirements.

The following list identifies the main implementation barriers to providing fish passage:

ACCESSIBILITY

SH58 is a steep winding stretch of road, particularly within the eastern catchment. Parts of the road were built on significant fill embankments, up to 10m high. This poses multiple challenges when it comes to fish passage design. Access to conduct surveys (ecological, topographical, visual inspections) is impeded leaving a knowledge gap in the information and an initial design based on several assumptions.

CONSTRUCTABILITY

The location and extents of culverts pose significant construction issues. Trench depths greater than 3m are typically avoided in favour of trenchless construction. Techniques such as pipe jacking or pipe ramming may not be feasible as the steep slopes on either side of the road are unsuitable for this machinery.

HYDRAULIC PERFORMANCE

Hydraulic efficiency is based on maximising available flow area and high velocities. The FPGs requires 25%-50% embedment depth, and velocities not exceeding adjacent those in adjacent reaches. To maintain compliance with the FPGs, infrastructure needs to be oversized by up to 5 pipe sizes. Often existing culverts are undersized by 3-4 sizes based on current design standards. The overall upgrade can therefore increase the pipe by up to 9 pipe sizes, i.e. 600mm to 1500mm diameter.

EMBEDMENT WASHOUT

Culvert embedment involves sitting the invert of the culvert below existing bed level. This allows the natural channel to deposit within the culvert and provide continuity of the stream bed material and is a standard requirement for new culverts designed in accordance with the FPGs. Many of the culverts on this project are constructed at steep gradients (>10%). This grade results in high velocities which can wash out the embedment material faster than it is replaced through natural deposition from upstream. This can be particularly troublesome where there is minimal upstream bedload entering the culvert, often caused by the presence of ponds or wetlands upstream.

Thicker layers of larger material may not offer a suitable solution either as low water flows may not rise above the gravel layer creating a new barrier (Bates, 2003)

MAINTAINABILITY

Access to many of the culverts on this project has been difficult during the design phase, as outlined previously. Access during construction is expected to be facilitated through clearance and temporary works. Many of these accessways are not expected to be kept on completion as they may constitute hazards in an uncontrolled environment, e.g. scaffolding, reduced embankment stability due to lack of vegetation. Without the ability to safely inspect and maintain culverts and fish passage devices, their installation may only provide a short term solution.

LANDOWNER UNWILLINGNESS

This infrastructure is being upgraded to serve the State Highway. Beyond the road reserve, the watercourses continue through private property. These are often culverted again to provide crossing points for livestock and farm machinery. The property owners are under no obligation to upgrade these private culverts which do not match the current standards used for the state highway infrastructure. Although fish passage measures could be installed as part of the proposed culverts, the benefit may be very low based on the additional upstream barriers outside the project boundary.

Further complications have been encountered with determining the ownership of culverts which extend well beyond the road reserve into private property.

SERVICE CLASHES

Existing services can have a major impact on culvert upgrades. Constrained by existing invert levels of the stream, upgrades (typically increase in available flow area) must spread out or up. Pipes are most commonly used up to 2.1m diameter and offer installation measures such as ramming, slieveing and bursting, in addition to open excavation. Particularly for larger size increases (>5 pipe sizes) the new higher top of pipe level may be clash with existing services. For some services (laterals and small diameter pipes/wires) these can be diverted relatively easily. Other times a large trunk main, HV cable or high pressure gas main may impose significant cost, programme and health and safety implications if it is to be diverted.

HYDRAULIC ASSESSMENT OF VARIOUS FISH PASSAGE DEVICES

Standard culvert hydraulics are relatively straightforward with numerous design spreadsheets and software packages readily available and understood within the industry. Incorporation of fish passage devices into the culvert design adds a new layer of complexity to these calculations, e.g. defining roughness coefficients for spat ropes and baffles, cross sectional loss from embedment and the impact of plunge pools and fish ramps. Quantifying the impact of different solutions versus the relative benefit of each one requires a level of assessment generally beyond the scope of the project.

On larger projects where standardisation and efficiencies of scale expected, adding a suite of new variables to each culvert can lose these benefits.

4 BALANCING STAKEHOLDER REQUIREMENTS

This section provides examples of where different stakeholder requirements required balance in order to achieve the best result for the project.

A generalist approach to fish passage design was not feasible on this project due to the economic constraints. Identifying the requirements for each culvert to meet the standards, and the benefits compared to status quo was necessary for maximising the value of the project. This does result in greater input from stakeholders during the design phase.

4.1 CULVERT 1

4.1.1 CUVLERT DESCRIPTION

This culvert is an existing 45m long DN900 RC pipe across SH58. The culvert has an upstream catchment of approximately 80ha. The pipe appears to be in good condition with no structural issues noted. The culvert has been constructed at significant depth (up to 10m below road level. Access to the upstream side is also particularly difficult due to steep slopes and heavy vegetation. The pipe has hydraulic capacity for a 1 in 70 year storm event (including climate change) without surcharging onto the carriageway. This does assume an upstream water depth of over 6m. The invert of the culvert is at stream bed level.

Figure 4-1 Upstream channel

Figure 4-2 Existing outlet

4.1.2 DESIGN REQUIREMENTS

ECOLOGICAL

A natural stream bed should be provided along the length of the culvert. If a new structure is proposed, this should be designed with 25-50% of the culvert depth embedded below existing bed level.

HYDRAULIC

To achieve hydraulic capacity for a 100 year flow, plus allowances for embedment and blockage factors, a new 2100mm diameter culvert is required.

ECONOMIC

The overall project shall achieve a Benefit Cost Ratio (BCR) >1.5.

4.1.3 DISCUSSION

The existing culvert does not meet the requirements of FPGs and P46, however the true performance is well above average on the network, i.e. no vertical jumps, 100 year capacity (excluding climate change) without surcharging onto the carriageway.

Given the size, depth and accessibility of a new culvert to meet the current standards versus the relative improvements which would be achieved, it is not considered reasonable to upgrade this culvert. As the existing culvert is less than 1.2m diameter, mussel spat ropes can be installed to facilitate fish passage through the culvert.

4.2 CULVERT 2

4.2.1 CULVERT DESCRIPTION

This culvert is an existing stock underpass with a small diameter pipe below the main culvert to convey typical flows. The main culvert is 20m long, 1.m diameter with a flat base. The low flow pipe is 40m long, 200mm diameter, The main culvert is in good condition, the low flow pipe is steel which has significant corrosion where visible. The pipe appears to be broken along its length as water is not existing at its outlet but rather through the substrate below.

The system has adequate capacity for 100 year flow.

The pipe is fully perched and the apron also presents a barrier to fish passage. The current configuration does not provide fish passage.

Figure 4-3 Main culvert

Figure 4-4 Existing low flow outlet

4.2.2 DESIGN REQUIREMENTS

ECOLOGY

The upstream catchment has potential to provide fish habitat. Fish passage should be provided to allow upstream habitat to be accessed.

HYDRAULICS

No upgrades required. Despite issues with the low flow pipe, its capacity is negligible compared to the main culvert which has adequate capacity for the design flows.

PROJECT OBJECTIVE

The project objective is to improve resilience and road safety for vehicles on SH58.

4.2.3 DISCUSSION

The main culvert meets the requirement of P46 and has suitable design life remaining. The system is a barrier to fish passage upstream. Provision of fish passage would require construction of a fish ramp at the outlet and replacing the existing low flow pipe or constructing a new fish friendly channel within the main culvert. As the main culvert is currently used as a stock underpass, any changes to its use as an underpass would significantly impact the landowner. These works also offer no improvement to the safety or resilience of SH58. Given the habitat availability upstream, a rock fish ramp is proposed at the vertical jump between the Pautahanui Stream and the culvert outlet. Consideration had been given to installing a spat rope in the pipe however further inspections of the pipe are now required based on the apparent damage.

4.3 CULVERT 3

4.3.1 CULVERT DESCRIPTION

This culvert is an existing 80m long 1.8m high arch. The culvert has an upstream catchment of approximately 25ha with consists of indigenous scrub and low forest. Forest plantation was felled in recent years upstream of the culvert. Downstream is a small length of open channel, 50m long, before reaching the Pautahanui Stream. The inlet is set back about 20m from the road edge at the bottom of a steep sided valley with difficult accessibility. The outlet protrudes from a steep rockface 40m from the road into an open paddock.

The culvert has adequate hydraulic capacity for 1 in 100 year flows. The inlet and outlet are set back far enough from the edge of the road that they are not impacted by any widening or realignment of the carriageway. The culvert barrel is in good condition.

There is a 900mm drop from the outlet into a stone-lined concrete channel.

Figure 4-5 900mm step at outlet

Figure 4-6 Existing downstream stone lined concrete channel

4.3.2 DESIGN REQUIREMENTS

ECOLOGY

Remove existing vertical jump which acts as a significant barrier to fish passage upstream

HYDRAULICS

Construct new headwall and debris screen at the inlet to reduce risk of blockage

OTHER CONSTRAINTS

Ownership of the culvert is unconfirmed.

4.3.3 DISCUSSION

The proposed solution involves construction of a new fish ramp at the outlet to remove the 900mm step between the outlet and the bed immediately downstream. Improvement works along the base of the culvert (installation of spat ropes or baffles) pose installation and maintenance challenges, give the long, tortuous nature of the culvert.

5 CONCULSIONS

This project has demonstrated the challenges of providing fish passage on existing schemes. Achieving various stakeholder requirements is not as straightforward as applying the relevant standards. In reality, for a road upgrade project, and in particular a safety improvement project, there needs to be a balance of ecological, hydraulic and client requirements where fish passage is an issue.

The FPGs provide guidance on prioritising works based on the ecological benefits however on a project with a constrained and challenging site, should upgrade works be prioritised on the wider cost-benefit to the project?

Overall, stakeholders should focus on the main project objectives, but balance their requirements appropriately to maximise the restoration opportunities of fish passage and reconnect aquatic organisms with available habitats upstream

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