Background:
Beginning in December 2012, a series of flood hit Queensland with at least 90 towns and over 900,000 people affected. The Bundaberg region encountered significant flooding as a result of record rainfalls which resulted in the failure of the Wide Bay Pipeline and release of natural gas from under the Burnett River on the 31st January 2013 as shown in Figure 1 below. Flooding from the severe rainfall was thought to have caused scouring of the overlying protective material at the northern banks of the Burnett River. The root cause of the damage was suspected to be caused by the impact from debris carried by the fast flowing water after the pipeline was exposed.

The Wide Bay Pipeline was constructed in 1999/2000 and covers a distance of 275km from Gladstone to Maryborough. The pipeline has four major waterways crossings including (from North to South) the Calliope River, the Boyne River, the Kolan River and the Burnett River. The pipeline also crosses over 20 minor waterways, such as small rivers and creeks (both permanent and intermittent). Documentation from the pipeline construction indicated that the pipeline depth of cover was 2.0m for major waterway crossings and at least 1.2m for minor waterway crossings. The location of the Calliope River, Kolan River, Boyne River and Burnett River crossings are shown in Figure 3 below.

The strategy for inspection was to complete a brief inspection of all waterway crossings immediately after the floods with more detailed inspections to follow. Vehicular pipeline patrols were the first form of inspection undertaken and identified a major land slip on the northern bank of Kolan River as shown in Figure 2 below.

Detailed inspections of waterway crossings were then conducted using hand held pipe locators and depth probes. The results of these investigations indicated that potential shallow pipe was present at Kolan River, Calliope River...
and Boyne River as well as a number of minor waterway crossings. Due to the limitations of the pipe locator equipment, it was not possible to determine the exact depth of cover for the pipeline under these riverbeds.

**Figure 2**  Major land slip on the northern banks of the Kolan River (bottom of picture)

**Figure 3**  Locations of Kolan River, Calliope River, Burnett River and Boyne River Crossings
Risk Management

APA undertook a risk assessment in accordance with the operating Australian Standard for the pipeline (AS 2885) and APA Risk Management Handbook in order to analyse the waterway crossing risks in terms of the consequences (Impact) and the likelihood of the risk (probability). The assessment used established evaluation criteria (i.e. Health & Safety, Environmental, Operational Supply, Customers, Reputation, Compliance and Financial) to produce an estimated level of risk and to rank and prioritise the risks. The risk assessment identified that the Kolan River, Calliope River and Boyne River as ‘HIGH’ risk asset issues.

An engineering assessment concluded that a high water flow or flood event could exceed the allowable pipe stress which may cause failure and subsequent loss of supply to the Wide Bay region. Given that a failure of this nature occurred in the Burnett River in 2013, a potential repeat of this scenario was considered to be very plausible. The most significant risk was identified as per below.

<table>
<thead>
<tr>
<th>Risk</th>
<th>Impact of debris with the pipeline causing full bore rupture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Likelihood</td>
<td>May occur during high water flow events during wet season (nominally November – March)</td>
</tr>
<tr>
<td>Consequence</td>
<td>Loss of supply to the towns of Bundaberg, Maryborough and Harvey Bay until a new pipeline can be constructed across the river</td>
</tr>
<tr>
<td>Risk Ranking</td>
<td>High</td>
</tr>
</tbody>
</table>

Hydrographic Survey of Trenched Pipelines in Shallow River Crossing

Subsequent to the pipeline patrol and inspection of waterway crossing using hand held pipe locators and depth probes, APA engaged Port of Brisbane Pty Ltd (PBPL) to perform a hydrographic survey for Kolan River, Calliope River and Boyne River in order to determine the exact location and burial depth of the pipeline under these riverbeds. APA had employed a number of different inspection methods which included the following:

- Bathymetric Survey Method
- Sub-Bottom Profiling Survey Method
- Side Scan Survey Method

Bathymetric Survey Method

Due to the shallow water in the Calliope River, Boyne River and Kolan River crossings, this presented significant challenges for PBPL to undertake the hydrographic survey. PBPL was required to mobilise and launch their small survey vessel (see Figure 3 below) near the Gladstone Power Station at a public boat ramp approximately 12km downstream of the pipeline crossing site. The vessel was then motored upstream, taking extreme care at all times during the travel as river depths were unknown and extremely shallow in places.

In order to obtain a complete bathymetric surface of the riverbed, the best technology to use would have been the multibeam sonar system as it has a much wider coverage of the seafloor mapping, a higher resolution and excellent data sample density as compared to a singlebeam sonar system. The multibeam sonar is a common offshore surveying tool that uses multiple sound signals (i.e. 512 single beam transducers) to detect the seafloor. Due to its multiple beams, it is able to map a swath of the river or sea bed under the boat, in contrast to a single beam sonar which only maps a point below the boat. Figure 4 below shows the multibeam sonar footprint below the ship. However, multibeam systems require a larger vessel than single-beam systems, which meant that this was not possible in the shallow water at these crossings.
PBPL proposed to use a high resolution dual frequency Singlebeam Sonar System to determine the depth of water and delineate the river bed. The Singlebeam Sonar System, like the Multibeam Sonar System relied on sound signals to detect the seafloor. In Singlebeam Sonar Systems, an acoustic pulse is emitted from a transducer and propagated in a single, narrow cone of energy directed downward towards the sea floor. This provides a single depth measurement for a location directly beneath the ship. The transducer then “listens” for the reflected energy signal from the sea floor. Water depth is calculated by using the travel time of the emitted pulse as shown in Figure 5 below.
Multiple survey lines were run parallel to the river bank at close line spacing of 3 - 5 m to maximise coverage, working from the deeper waters of the river reach into the shallows of the bank. The soundings were reduced to Australian Height Datum (AHD) relevant at the site. Singlebeam Survey technology is well established and data processing is relatively straightforward. The result for the Singlebeam Survey of Calliope River is shown in Figure 6 below.

The PBPL hydrographic team utilised Leicas Smartnet GPS network for high accuracy positional control. The Smartnet system provided GPS RTK (Real-time Kinematic) accuracy corrections to the Rover Receiver aboard the vessel. Using a base station established at the survey site, local survey control points were checked with a GPS Rover Station to check the integrity of the GPS positioning within the survey area before survey work commenced.
Sub-Bottom Profiling Survey Method

In order to be able to accurately determine the depth of cover of the pipeline below the riverbed, PBPL had utilised a Sub-bottom Profiler equipment with dual transducers to obtain sub-bottom profile data. Sub-bottom Profilers are typically used for buried pipeline surveys because they allow penetration of the substrate and generally produce a good reflector off the pipeline.

Sub-bottom Profilers work on the same principle as Singlebeam Sonar System, but use much lower frequency acoustic energy. The acoustic pulses penetrate below the seabed and into the sediment. Returning echoes from sub-bottom features such the buried pipeline are recorded by an array of hydrophones (usually towed further behind the vessel) or by a transducer (mounted to the hull) and creates a trace in the digital record. This is shown in Figure 7 below.

PBPL had previously utilised this technology to successfully locate and chart the Murarrie Pipeline crossing under the Brisbane River in 2012. However, due to the shallow waters in the Calliope, Kolan and Boyne rivers, the amount of acoustic power produced by the Sub-bottom Profiler, that is needed to penetrate the riverbed, caused acoustic noise interference in the shallower waters, which made it very difficult to accurately detect sub-bottom features.

APA worked collaboratively with PBPL to develop a suitable method for undertaking Sub-bottom Survey in the shallow river crossings. Significant work was undertaken by PBPL to test this technology for use in shallow rivers, requiring consultation with international expertise. Subsequent to design and testing, PBPL proposed to use the Innomar SES-2000 (a specialist shallow water Sub-bottom Profiler System) used in conjunction with dual TR-109 transducers set to the lowest settings (i.e. at 3.5 kHz with a 30° Beam width) and incorporating FM wide bandwidth signal processing (CHIRP) to provide high ground penetration and a higher resolution for sub-bottom profiling. The transducer was mounted on a pole over the bow of the dinghy, with the GNSS antenna located on the other end of the pole directly above the Sub-bottom Profiler transducer. The interpretation of a sub-bottom profile is very difficult and the extensive data collected across the width of the river was sent to a Geophysicist consultant for further interpretation and analysis.

The Sub-bottom Profiler records showed acoustic penetration of around 2-3 m towards the centre of the river and less along the river banks due to surface multiples and diffractions from the bank. For the Calliope River pipeline, a few survey lines exhibited what appeared to be a faint parabolic reflector (which marks the top of the pipeline) suggesting either shielding / protection around the pipe or a density of the surrounding sediments similar to the pipeline. The survey showed that the pipeline was only was buried to a range of 60-200cm of protective cover. This is shown in Figure 8 below as a semi-transparent unit overlying the more reflective river bottom suggesting that the overlying unit to be unconsolidated silt/mud.
It should be noted that there were some limitations with the sub-bottom profiler. Although the Sub-bottom Profiler System was successful in mapping the pipeline location and depth of burial across the Calliope River, detection had failed for the Boyne River survey. No clear parabolic reflector marking the top of the pipe was visible on any of the survey lines. The problems detecting the parabolic reflector could be related to the river substrate, the presence of biogenic gas masking the acoustic signal, the shallow survey depths (and associated multiples) and the material covering or protecting the pipeline.

Side Scan Survey Method

On receipt of the Sub-bottom Survey results, it became apparent that certain sections of the pipeline under the Calliope River could be spanning above the river bed in places. This is shown in Figure 9 above which shows the combination of the singlebeam and sub-bottom profiler survey results whereby the pipeline is shown to be spanning in two locations on either side of the Calliope River.

This result was however not conclusive as the resultant power generated by the Sub-bottom Profiler was not suited to pipeline detection above the surface and only measured the change of riverbed densities. To provide confirmation, PBPL decided to return to the site with additional equipment to confirm the potential spans. A high resolution Side Scan Sonar System was used to gather seabed imagery which would enhance and confirm if the pipeline was indeed on the surface of the river bed and spanning in places.
Side-scan Survey uses a sonar device that emits conical or fan-shaped pulses down towards the riverbed across a wide angle perpendicular to the direction of travel of the sensor through the water, which may be towed by a vessel as shown in Figure 10 below, or mounted on the ship's hull. As the pulse of sound emitted by the transducers interacts with the riverbed, most of the energy is reflected away from the transducer. The acoustic backscatter that is reflected back to the transducer is recorded in a series of cross-track slices. When stitched together along the direction of motion, these slices form an acoustic image of the riverbed bottom within the swath (i.e. coverage width) of the beam.

![Side Scan Survey Image](image)

**Figure 10** Side Scan Survey

Excellent imagery was collected and the Side Scan image shown on Figure 11 below showed that the pipeline was definitely spanning in two locations on either side of the river. The dark lines in the images are the shadows cast on the riverbed of the pipeline in relation to the location of the towed fish Side Scan Sonar. The bright lines are the ensonification of the pipeline by the Side Scan.

![Side Scan Image](image)

**Figure 11** Side Scan Image East and West Sides of the Calliope River
Divers Inspection Method

In order to further verify that the pipeline was exposed and potentially spanning above the riverbed in certain sections, APA engaged Moreton Diving and Marine Contracting to undertake an underwater visual inspection of the pipeline crossing as well as to examine the exposed section of the pipeline to determine if there was any damage. APA worked collaboratively with the diving crew in order to develop a Safe Working Method Statement for undertaking the inspection safely.

For Calliope River crossing, the divers were able to confirm that on the western bank, the pipeline was exposed and was suspended approximately 10cm above the riverbed for approximately 20m. On the Eastern bank, the divers were able to confirm that the pipeline was suspended around 40cm to 50cm above the river bed for approximately 35m before burying itself into the muddy riverbed. The report from the dive team advised that that “scaly growth with some barnacle growth” was observed on the pipeline, indicating that the pipeline had been in this situation for a period of time, possibly well before the 2013 flood event.

Remediation Techniques

APA investigated numerous permanent and temporary repair options including the following:

- Kolan River bank stabilisation
- Installation of temporary geofabric sandbags in the river over the pipeline for protection.
- Replacement of the river crossing by horizontal directional drilling (HDD)

Kolan River Bank Stabilisation

APA engaged Civil Support to develop design and specifications for stabilising the river bank at Kolan River where the major bank slip had occurred. The repair involved excavating the material in the slip zone to remove debris, shaping the slip zone and the construction of a toe wall using bulk bags filled with stabilised sand in order to stabilise the toe of the slip face as shown in Figure 12 below. Rock and earth fill over geotextile lining was then used to reinstate the bank profile as shown in Figure 13.
Temporary Geofabric Sandbagging Protection

Civil Support was engaged by APA to develop a suitable temporary protection for Kolan River crossing in order to mitigate the risk of further scouring of the riverbed during the wet season and before the pipeline could be permanently replaced. Civil support had proposed the use of custom made 8m by 1.5m Geofabric sandbags with overlay flaps to be placed over the pipeline as shown in Figure 14 below. Each empty bag was first placed in position over the pipeline and a Dredge Pump used to pump wet sand into the bag. Subsequent bags were then placed over the previous bag’s flap and the process repeated in order to better secure the sand bags in position. Unfortunately, the Geofabric sandbags only had a recommended life span of 2 to 3 years and hence would need to be replaced repeatedly over the years.
Replacement of Pipeline by HDD Methods

APA evaluated a number of repair methods and decided that replacement of the pipeline crossing via Horizontal Directional Drilling (HDD) at both Kolan River and Calliope River to be the most suitable method for permanent repair, and which would lower the risk for these crossings to an acceptable level. For Kolan River, the HDD pipeline was around 600m long and was installed to a minimum depth of 10m below the riverbed. Stamping and welding of the pipeline was performed on pipeline roller supports as shown in Figure 15 below and scaffolding support where required as shown in Figure 16 below.

![Figure 15](image1.png)  
**Figure 15** Pipeline Roller Supports for Stringing and Welding of the Pipeline

![Figure 16](image2.png)  
**Figure 16** Scaffolding & Pipeline Roller Supports for Stringing and Welding of the Pipeline
Summary

There are significant risk and impact for trench pipelines installed under creeks and rivers due to scouring of the overlying protective material in the riverbed and embankment caused by flood events and resulting in the pipeline becoming exposed. Hydrographic survey has been proven to be a cost effective non-intrusion technique which can be used to proactively assess and managed risk for trenched pipeline asset in shallow waterway crossings. The surveys included a Singlebeam Bathymetric Survey, a Sub-bottom Profiler Survey and a Side Scan Survey. The Sub-bottom Profiler Survey was used as the primary geophysical tool in order to accurately locate and determine the depth of protective cover for the pipeline under the riverbed. The surveys had identified that for the Calliope River; the pipeline was exposed on the river bed and in certain sections was spanning above the riverbed. A number of temporary and permanent repair methods had been utilised by APA for mitigating the risk. This included bank stabilisation works at Kolan River as well as temporary protection of the pipeline by using geofabric sandbags. Other repair options such as reinstalling the pipeline crossing in a trench dredged in the river and reinstating permanent cover over the pipeline had also been explored but was not considered viable due to the levels of rock found in the river and the likely cost and environmental impacts. Therefore, the most robust and viable long term repair solution was to replace the entire river crossing using horizontal directional drilling method. This method would provide the greatest long term certainty over the integrity of the pipeline, with the lowest level of project risk throughout the design and construction phases. APA was thus able to use a number of hydrographic survey technology and methods to proactively assess and manage its risk for waterway crossings.