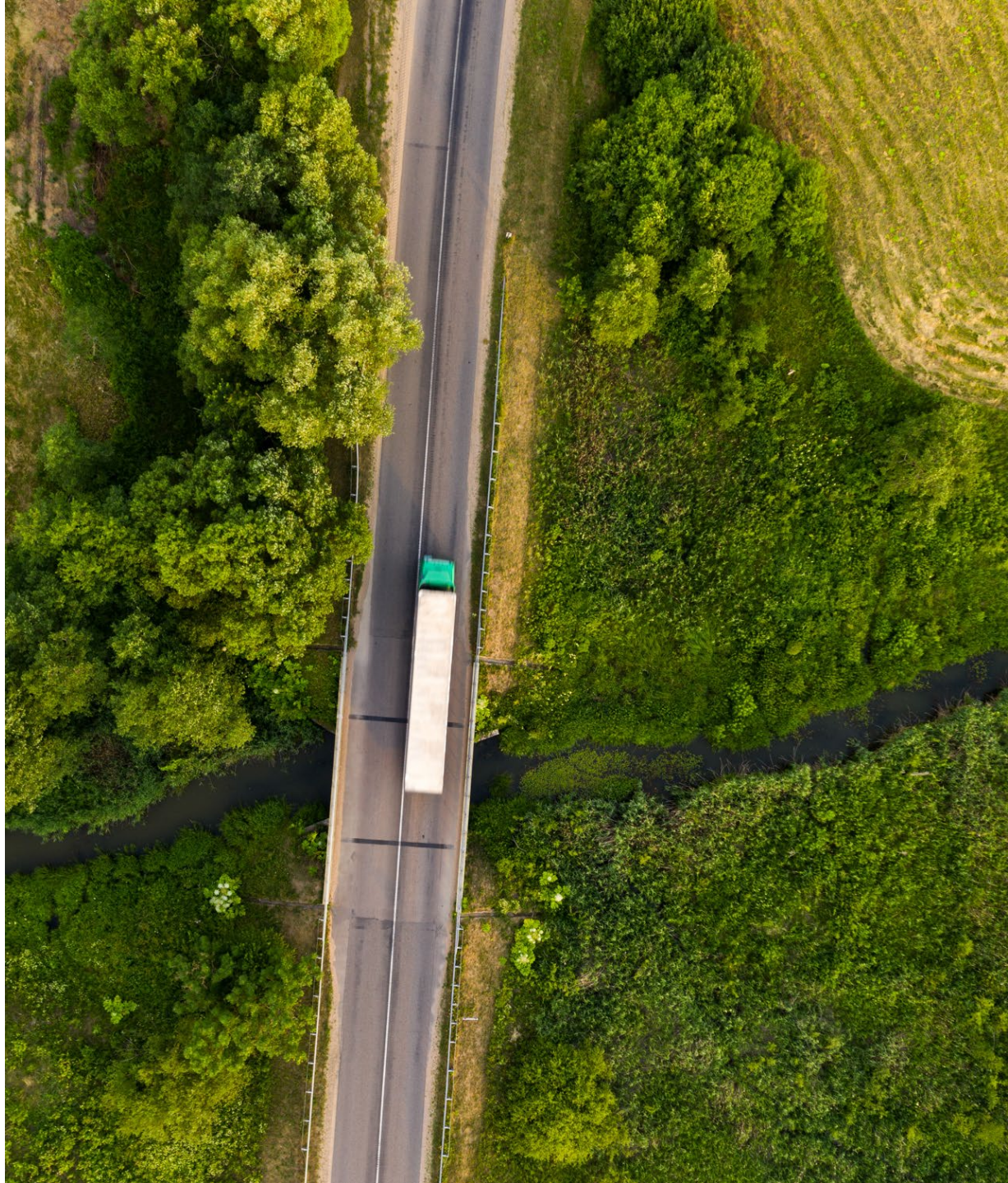
Cost-effective Pipeline Strain Management

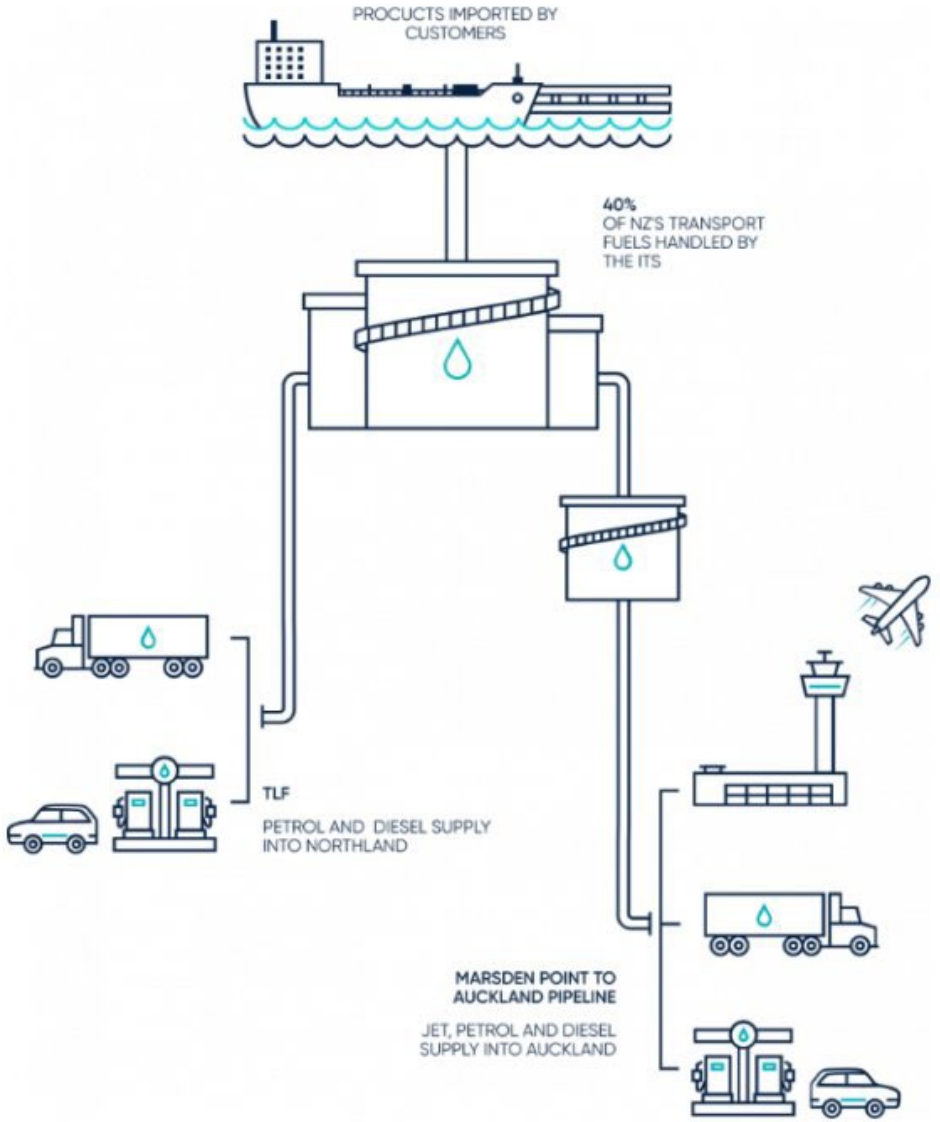
John Fang, Pipeline Manager

5th March 2026



About Channel's Terminal and Pipeline Services

- World class operator of import terminal and pipeline infrastructure
- Supply Northland and Auckland markets, which make up 40% of NZ's transport fuel demand
- Supply all of Auckland International Airport's jet fuel
- Import refined fuel using the deep-water harbour and jetty infrastructure at Marsden Point
- Store refined fuel in over 290 million litres of contracted storage tanks on site at NZ's largest fuel terminal
- Distribute fuel through Channel's 170-km pipeline to the Wiri Terminal (owned by our customers, bp, Mobil and Z Energy). Fuel is also distributed via truck.



Ruakaka to Auckland Pipeline (RAP)

- Pipeline commissioned 1985
- 170-km from Marsden Point to Wiri
- 10” diameter carbon steel pipe
- Maximum operating pressure 82 Bar (1200 psi)
- Capacity 10 million litres per day
- Multi-fuel pipeline - petrol, diesel, jet fuel

CHANNEL TERMINAL SERVICES

WIRI OIL SERVICES

RAP Route


McCathie Road - Valve S 17-MLV-3
Mair Road 17-MLV-2
Salle Road - Valve 17-MLV-4
Waipu River 17-MLV-5
Waipu Cove 17-MLV-6
Hakaru Valve Site 17-MLV-8
IPS1 Pump Station 17-MLV-9
Kaipara Flats 17-MLV-11
Komokoriki 17-MLV-13
Bald Hill 17-MLV-15
Waikoukou 17-MLV-16
IPS2 Pump Station 17-MLV-25
Taupaki 17-MLV-18
Henderson 17-MLV-20
Links Road Valve 17-MLV-21
Hillsborough 17-MLV-22
Ambury Park 17--MLV-32

Pipeline Integrity Management – Pipeline failure photo (Trans-Ecuador crude oil pipeline rapture 31st May 2013)

One of the largest impacts of landslides occurs when the slide severs an oil or gas pipeline, allowing a release into the environment. Given that pipelines are increasingly being built in landslide-prone terrain this is a real problem. A clear illustration of this occurred in Ecuador on 31st May, when the Trans-Ecuador pipeline ruptured in a landslide. This image, released by Petroecuador, shows the landslide site:

Pipeline Strain Detection – Industry Practice

Modern Integrated Approach

- Industry uses multi-technology geohazard monitoring combining ILI, remote sensing, and geotechnical data.

➢ Inline Inspection (ILI) Tools
- IMU bending strain identifies curvature changes from land movement.
- Axial strain ILI tools detect longitudinal loading from landslides; complements IMU data.

➢ Ground Movement Monitoring
- LiDAR, InSAR, SAR, DInSAR detect millimetre-scale terrain shifts to inform strain risk.

➢ Localised Strain Monitoring
- Vibrating Wire Strain Gauges (VWSGs) provide continuous strain tracking at high-risk sites.

Emerging Practice

- Low-cost IMU pigs allow higher-frequency bending strain monitoring between full ILI runs.

Industry Trend

- Shift toward combined (axial + bending) strain detection, more frequent inspections, and integrated data for risk-based decisions.

New Zealand Pipeline Industry – Geohazard related Strategy Prior to 2016

- There are a few pipeline LOC (Loss of Containment) & pipeline deformation incidents in NZ (recent years) pipeline industry due to land movement caused by earthquake and heavy rainfall, cyclone, etc. Examples include the 2011 Maui pipeline rupture - Over 48 million litres of milk were dumped, and total economic losses were estimated to be up to $200 million, caused by a large landslide. In 2021-2022, a $13 million project was undertaken to realign 370m of the pipeline at Gilbert Stream due to severe cliff erosion.
- Because of increased Geohazard events, our latest version pipeline standard AS/NZS 2885.1 & 3 have been updated.
- The pipeline Geohazard integrity management strategy in NZ –
  - 5 or 10 yearly ILI
  - Line flight and line walk
  - 5 yearly SMS workshop – review & update the pipeline risk
  - Geohazard survey & monitoring – ad-hoc based
  - Reactive remediation works – land stability/subdrain and pipeline stress release project works

RAP (Ruakaka to Auckland Pipeline) Integrity – Geohazard related Strategy

- Review all Geohazard related strategy & program in our system –
  - ❑ Recent years cleaning/ILI pigging –
    - 9th-11th of Sep 2024
    - 10th – 12th of Oct 2023
    - 26th – 28th of Mar (cleaning) and 10th – 12th of Oct 2022 (ILI)
    - Sep 2017/2019 ILI

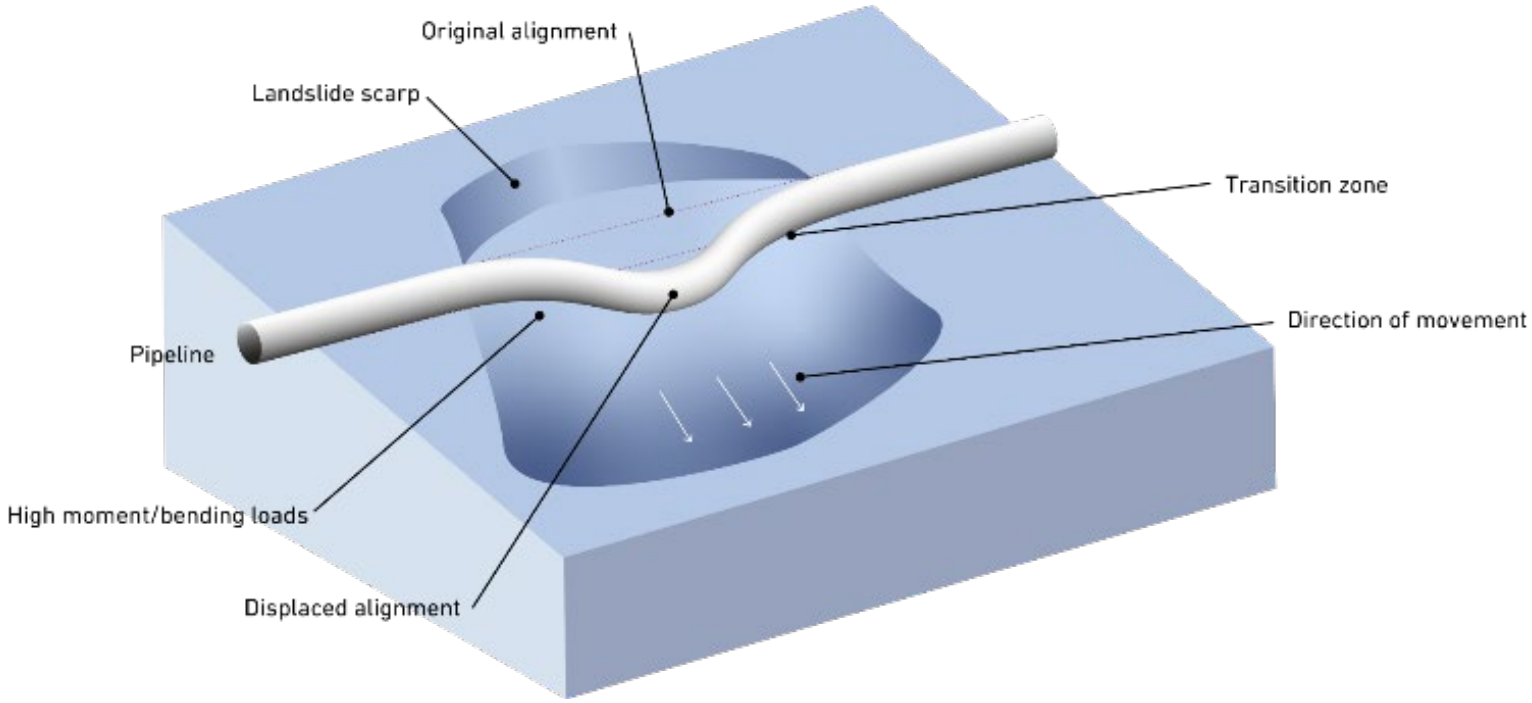
    Note: Annual cleaning/gauge pig and 5 yearly ILI pig
  - ❑ All ad-hoc remediation site work packs including reports and drawings
  - ❑ Current maintenance & site monitoring PMs (FGL easement team manages)
  - ❑ Geohazard risk ranking and pipeline risk register
  - ❑ Geohazard line flight annual report including all existing features observation, new identified features and recommendations.

RAP (Ruakaka to Auckland Pipeline) Integrity – Geohazard related Strategy

- Updated Pipeline Geohazard management strategy & program –
  - Follow up FGL/CTS Geohazard management process – Identify all Geohazard features, risk ranking assessment and pipeline risk assessment.
  - Updated Geohazard risk ranking and pipeline risk including all historic information, such as survey, monitoring and remediation works.
  - Condition monitoring all remediated Geohazard sites (drainage system function and land movement & underground water level monitoring points)
  - Monthly line flight by a competent Easement Technician
  - Annual Geohazard line flight & ad-hoc line flight as required after heavy rainfall & other weather events which may cause land movement by a competent Geotech Engineer
  - Landowner/occupier report & liaison in terms of any land movement
  - Site geotechnical survey as follow up actions if there are any identified changes or new features, complete the Geohazard feature risk ranking assessment, pipeline risk review and assessment.
  - Introduce new strain pig program from Q3 2025 (one strain pig run between 5 yearly ILI run) – AMP and PIMP
  - Consider LiDAR and satellite scan, other terrain profile changes detection methods
  - Continue to explore combined strain detection tool development status and industry feedback

RoGeo PD for Pipe Movement Detection - Pipeline Movement

- Pipeline movement is a common integrity threat.
- Pipelines can be exposed to excessive strain and fatigue.
- Consequences can be:
  - Formation of ovalities, wrinkles and local buckles
  - Failures at girth welds
  - Worst case = rupture
- Unless regularly monitored, this movement may go unnoticed until permanent damage has occurred, especially in remote and seismic active areas.



Note: Quote from Rosen

RoGeo PD for Pipe Movement Detection - Pipe Drift Service Approach

Bridge the gap between frequent measurements and a cost-effective service

Usage of proven ILI mapping technology without other technologies attached!

Framework:

- Increased screening frequency plus mobilization on short notice
- Fits any pipeline diameter ≥ 200 mm (8”)
- Minimal impact on flow rate
- Stand-alone technology
- Downscaled mobilization of personnel & equipment
- Minimized site operations
- Optimized reporting schedules
- Significant overall cost reduction

Pre-requisite: Baseline XYZ survey (RoGeo XT or comparable)

10“ CLP with RoGeo PD Unit

RoGeo PD Unit in 20“

Note: Quote from Rosen

RoGeo PD for Pipe Movement Detection - Operational criteria

Service performance

Length	Accuracy
< 100 m (< 328 ft)	0.2 m (0.66 ft)
100 m - 250 m (328 ft - 820 ft)	0.4 m (1.31 ft)
250 m - 400 m (820 ft - 1312 ft)	0.6 m (1.97 ft)

Note: The current performance specification is derived only from small scale testing and a limited number of field verifications.
'Length' refers to the length of the section of pipeline where bending strain meets reporting criteria.

Operating Conditions

Standard operating specifications	
Product temperature range	0°C – 65°C (32°F – 149°F)
Maximum operating pressure	15 MPa (2175 PSI)
Operating speed range	Up to 8.0 m/s (26,3 ft/s)*
Max. velocity variation per joint	0.3 m/s (1 ft/s)
Minimum pipeline bend radius	**1.5D**
Maximum operating time	Up to 80 hours @ 20°C (68 °F)
Maximum inspection length*	1440 km (880 miles)

Note: Contact ROSEN for more detailed information.
* This range may vary if the cleaning tool in use has a lower maximum allowed velocity

Equipment must be operated within specified service parameters, such as, but not limited to:

- Temperature
- Velocities
- Pressures
- Accelerations

Note: Quote from Rosen

Channel Geohazard Management Strategy – Strain Detection (10 year)

Options	Pros	Cons	Cost Estimate (NZ$, million)	Note
Option 1 – ILI (MFL)	Strain and corrosion data	High cost and operation risk	2.4	4 x ILI runs
Option 2 – Strain + ILI tool (preferred)	Strain/corrosion data and significant low cost		1.4	2 x ILI + 2 x strain run between ILI runs
Option 3 – Localised Strain Monitoring (VWSGs)	Direct inspection & monitoring	Very high cost, strain baseline accuracy issue.	14	Based on 69 x features
Option 4 – Ground Movement Monitoring (LiDAR and other methods)	Direct ground condition check	High cost, ground condition issue (vegetation cover…) Geotech/Pipeline Engineer experience – Not accurate/human errors	3	2 x 5 yearly Lidar survey + monthly line flight.

Note: The cost estimate is based on 2025 data

Pipeline Integrity Management – Geohazard Management

The RAP Strain Pig Operation was completed during November 2025

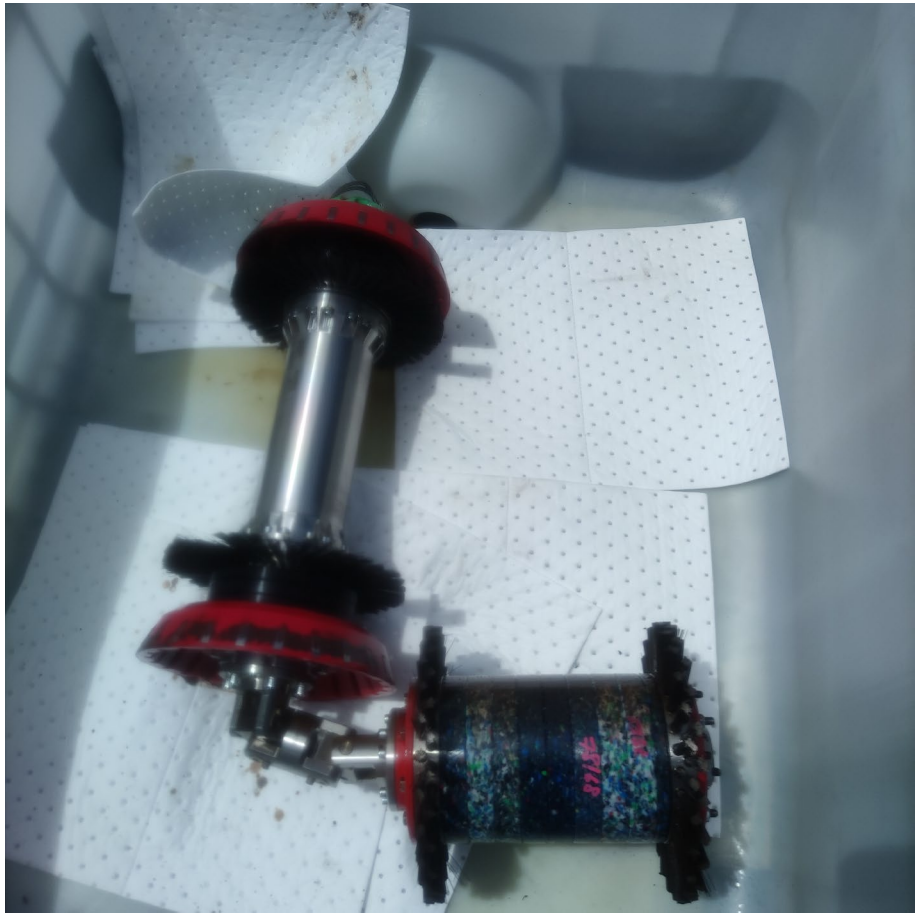
- Background –
  - Oct 2022: the last RAP ILI (In Line Inspection) was completed
  - Jan 2023: Auckland Anniversary Weekend floods due to a few days' heavy rainfall
  - Feb 2023: Cyclone Gabrielle
  - There were land movements on a few sections of the pipeline observed after the weather events
  - Current pipeline ILI is scheduled at 5-year intervals with the next being Sep/Oct 2027
  - A strain pig was added to the programme between the 5-yearly ILI runs due to increased geohazard risk on the pipeline.
- Our pipeline easement manager, Firstgas completed their 2025 ILI and reported high pipeline strain at some sections on their gas line. Note: Both RAP and Firstgas pipeline are buried in the same trench (0.5m apart) and run parallel.
- CTS and Rosen field Service Team successfully completed the first fuel line strain pig in NZ during Nov 2025 and measured the bending strain and pipeline movement areas. The total running time was around 41 hrs.
- The draft report from Rosen was received Jan 2026. CTS provided comments and site survey report back to Rosen team. The final report was released on 3rd of Feb 2026.

Launched the tool at Marsden Point on 18th Nov

Received the tool at Wiri on 20th Nov

Pipeline Integrity Management – Geohazard Management

Tool before launching

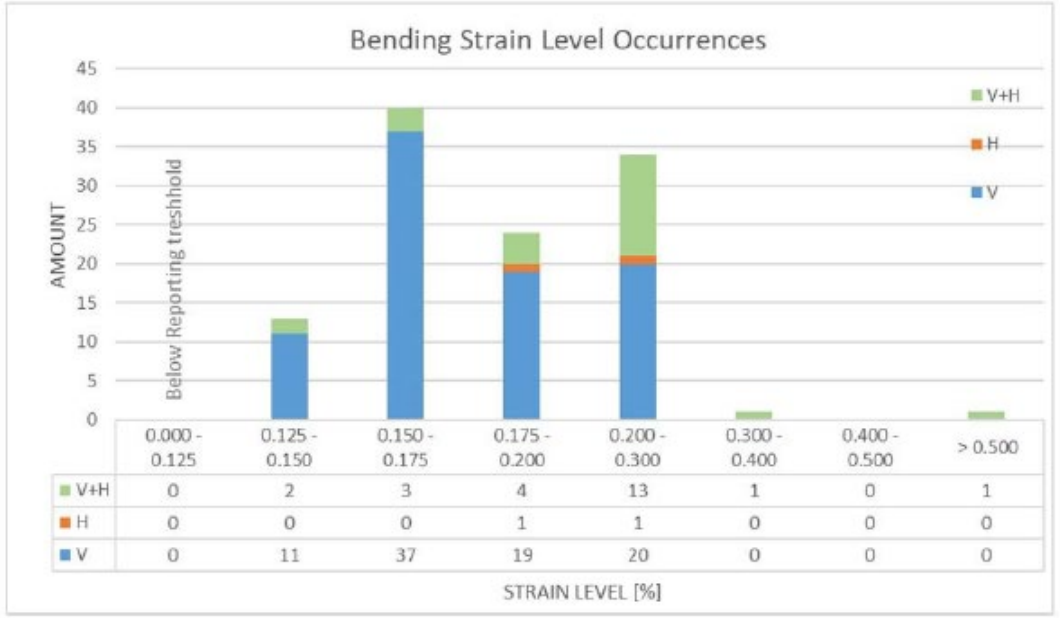


Tool after receiving

Pipeline Integrity Management – Geohazard Management

Data Analysis

- The Nov 2025 pipeline movement data was compared against the 2022 Rosen ILI data sets.
- A bending strain evaluation was performed – all conspicuous bend areas with more than 0.125% bending strain were visually interpreted and classified.
  - There were 2 areas with horizontal bending strain.
  - There were 87 areas with vertical bending strain.
  - There were 24 areas with horizontal and vertical bending strain.
  - There are no areas with possible construction irregularities (COIR) found.
  - The maximum calculated total bending strain value is 0.500%.
- There are 2 areas of pipeline movement with measured movement of greater than 0.200m (maximum measured movement 0.426m).
- Industry threshold for pipeline strain is 0.6% for further assessment.
- Reported bend strain areas grouped based on strain level and bend direction:



	0.000 - 0.125	0.125 - 0.150	0.150 - 0.175	0.175 - 0.200	0.200 - 0.300	0.300 - 0.400	0.400 - 0.500	> 0.500
V+H	0	2	3	4	13	1	0	1
H	0	0	0	1	1	0	0	0
V	0	11	37	19	20	0	0	0

Report Recommendations

- The bending strain of 0.500% and maximum measured pipeline movement of 0.426m necessitates a Level 2 Bending Strain Assessment.
- This detailed assessment provides a more rigorous evaluation of pipe stress, deformation behaviour and potential interaction with geotechnical conditions.
- Level 2 assessment is supported by further geotechnical and engineering investigation to confirm ground stability, and assess potential for continued displacement.

Pipeline Standard and Good Practice Reference – AS 2885.3

6.4.5 Land instability

In locations where land instability has been identified as a credible THREAT to the PIPELINE SYSTEM, monitoring shall be undertaken to demonstrate the ongoing suitability of the constructed arrangement of the PIPELINE SYSTEM, and to assess the effectiveness of controls.

NOTE 1 Periodic, accurate geospatial positioning of the pipeline and the surrounding area should be utilized where ground displacement is a credible THREAT to identify pipeline movement input for engineering analysis.

Where pipeline surveillance identifies a new or a change to a land-instability THREAT, or indicates that a control has not been effective, an assessment shall be undertaken to determine whether the pipeline is safe for continued operation.

NOTE 2 AS/NZS 2885.1 contains guidance on design considerations for land instability. Controls are varied and may include accelerometers and STATION ESDs, land instability monitoring, ground stabilization measures, increased isolation facilities, leak detection systems and pipeline realignment.

NOTE 3 Increased stress may also cause coating disbondment and increase susceptibility to corrosion and ENVIRONMENTALLY ASSISTED CRACKING.

Q & A