# Optimizing Reinjection Capacities for Ngā Tamariki Power Plant

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## ABSTRACT

The Ngā Tamariki (NTM) geothermal power plant relies on a northern and southern reinjection pipeline system to return geothermal fluids to the reservoir. Commissioning of the Ngā Tamariki OEC5 unit will see the station's reinjection demand increase from 2,300 t/h to 3,150 t/h. Reinjection capacity through the southern reinjection system will be constrained by significant pressure drop along the common DN450 pipeline. This paper presents a case study using a steady-state hydraulic model developed in AFT Impulse to evaluate the reinjection system from the station's reinjection pumps through to the reinjection wells. The model incorporates as-built piping layouts and recent well injectivity data. Then it was calibrated using recent operating data from October 2024 pump trials to accurately reflect the pressure-flow profile. Various system modifications and scenarios were evaluated to meet the increased injection capacity, including:

- Reinjection pumps online and offline (bypassed) operation.
- Minor system modifications (New flow meters orifice plates and removing northern reinjection pipeline NCG static mixer).
- Major system modifications (New pipelines and repurposing redundant pipelines).
- Additional injection well cases (New wells and repurposing redundant wells)

The output of the hydraulic modelling was used to update the NTM Integrated Model (Reservoir, Steamfield and Station), enabling each case to be evaluated and ranked according to a 25-year project NPV. The overall analysis identifies optimal strategies and timing to enhance the reinjection capacity, ensuring reliable reinjection capacity at 3,150 t/h.

## 1. INTRODUCTION

The NTM power plant currently injects a mixture of geothermal brine and steam condensate through a DN600 northern pipeline to Pad NM1 and a DN450 southern pipeline to Pad D. Both reinjection lines are approximately 2km in length.

Reinjection wells currently in use are:

- Pad NM1 (North): NM8, NM9
- Pad D (South): NM6, NM10, NM14 (recently commissioned)

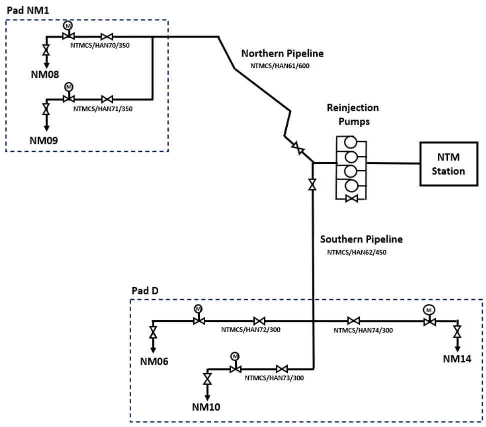


**Figure 1: NTM Reinjection system.**

NM14 is a new injection well drilled to accommodate the additional reinjection fluid from the OEC5 project. At the time of this study the next planned injection well (NM16), expected to be located at the Pad NM1 to support a balanced injection distribution. Following the commissioning of the OEC5 unit, the station's total reinjection demand is projected to increase by 37%, reaching approximately 3,150 t/h. While the southern wells have demonstrated superior injection capacity compared to the north, significant pressure drop observed across the DN450 southern pipeline is expected to constrain reinjection capacity in the south. Debottlenecking options for the southern pipeline were analysed in the study.

For the cases presented in this paper, commercial modelling software was used to simulate the existing reinjection system—from the station's reinjection pumps to the reinjection wells, allowing for the evaluation of multiple system modification options to improve overall injection capacity.

This study is a refinement of the NTM Reinjection Capacity Assessment, 2022 (S. Jordan, G. Allan).

## 2. SCENARIOS

Operation/modification scenarios analysed in this paper fall into four main categories: reinjection pumps in service, system components modifications, pipeline modifications and the addition of injection wells. A total of 11 cases were developed, as summarized in Table 1.

**Table 1: Study case scope**

| Scenarios | NM6 | NM10 | NM8 | NM9 | NM14 | NM16 | NM2 |
|---|---|---|---|---|---|---|---|
| **Case 1** – Current configuration | ✓ | ✓ | ✓ | ✓ | × | × | × |
| **Case 2** – Pumps offline and full bypass | ✓ | ✓ | ✓ | ✓ | ✓ | × | × |
| **Case 3** – NM14 | ✓ | ✓ | ✓ | ✓ | ✓ | × | × |
| **Case 3B** – NM14 (without north NCG mixer) | ✓ | ✓ | ✓ | ✓ | ✓ | × | × |
| **Case 4** – Southern pipeline twin | ✓ | ✓ | ✓ | ✓ | ✓ | × | × |
| **Case 5** – Pad B pipeline connection | ✓ | ✓ | ✓ | ✓ | ✓ | × | × |
| **Case 6** – Pad B pipeline connection and extension | ✓ | ✓ | ✓ | ✓ | ✓ | × | × |
| **Case 7** – New NM16 well | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × |
| **Case 8** – Utilise abandoned NM2 well | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ |
| **Case 9** – New NM16 well (NM14 offline) | ✓ | ✓ | ✓ | ✓ | × | ✓ | × |
| **Case 10** – New NM16 well (NM14 offline) + Case 5 debottlenecking | ✓ | ✓ | ✓ | ✓ | × | ✓ | × |

Case 1 represents the system configuration at the time of the study and serves as the base case. In Case 2, all pumps are offline, and the injection performance is evaluated under full bypass conditions. Cases 3 to 10 explore various scenarios that may potentially enhance the overall injection capacity. Southern pipeline debottlenecking cases were evaluated in Case 4 to 6.

Case 4 is based on the construction of a twin 450mm diameter pipeline, parallel with the existing southern pipeline.

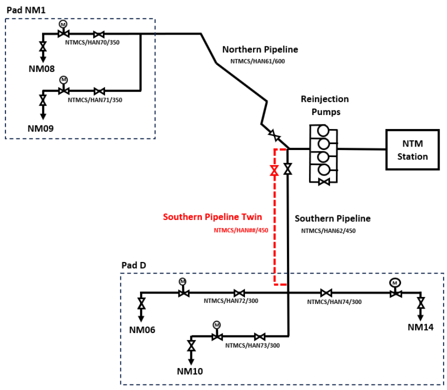


**Figure 2.0 Case 4 – Southern pipeline twin**

Case 5 is based on converting the redundant Pad B production pipeline to reinjection service and operating in parallel with the existing southern pipeline.

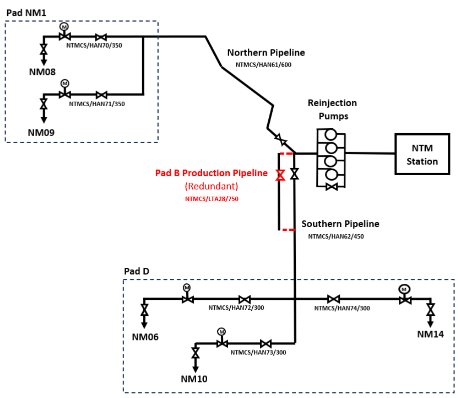


**Figure 2.1 Case 5 – Connection of redundant Pad B production pipeline.**

Case 6 involves completing Case 5 and extending the Pad B to Pad D. Both pipelines would be operated in parallel.

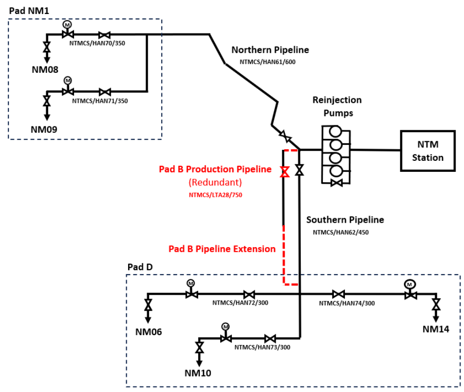


**Figure 2.2 Case 6 – Connection and extension of redundant Pad B production pipeline.**

Minimum, partially stimulated and fully stimulated injection capacity cases were analysed for the new injection wells NM14 and NM16. Northern injection wells typically take between 12-36 months to reach full capacity (fully stimulated), compared to southern wells that take between 6-12 months.

## 3. METHODS

The model was built in AFT Impulse, with the physical piping and equipment identified based on as-built drawings and equipment datasheets, ensuring that pipe sizes, lengths, and equipment performance were fully captured. The software provides standard input options for pipes, fittings, and valves. Pipe segments were connected using nodes, incorporating elevation changes throughout the system. The model was only run in steady state conditions. As a result, the system curve for each study case was plotted to indicate the pressure-flow balance.

## 4. HYDRAULIC MODELLING

### 4.1 Inputs and Assumptions

The operating conditions at the reinjection pump suction were agreed to be 9barg at 93°C, followed by fluid properties calculation as shown in Figure 3.

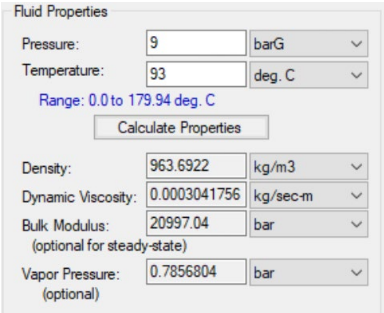


**Figure 3: Fluid properties for the study**

Pumps and valves were modelled based on supplier information and/or typical Cv values for the respective valve types. Injection well flow meters and the non-condensable gas (NCG) static mixer on the north pipeline were approximated using pressure–flow quadratic relationship to match the actual design and measured data. The latest validated injection capacities for the four existing wells were used as inputs, while P50 capacities at fully stimulated conditions were applied for additional wells NM14 and NM16. An estimated value was also included for the redundant well NM2, which is located along the northern injection line.

Friction losses within each well casing were excluded. The effects of NCG reinjection were not considered, as the software is limited to single-phase analysis. (Kevin Koorey, 2022)

### 4.2 Pump Station

#### 4.2.1 Injection Pumps

Ngā Tamariki station has 4 identical injection pumps that are arranged in parallel, each with a nominal capacity of approximately 1,000 t/h at the best efficiency point and a maximum capacity up to 1,400 t/h. Each reinjection pump has a variable speed drive to control pump capacity. Pump head and flow rate data were obtained from the vendor's performance curve and used to construct composite pump curves representing the operation of 3 and 4 pumps in parallel, operating at 80% pump speed. In this configuration, the composite pump curve reflects the sum of the individual pump flow rate at a given head, as the head remains constant across all pumps. These composite curves were overlaid on the system curves, enabling the identification of achievable injection capacity based on the intersection area under the respective pump curves.

#### 4.2.2 Reinjection Pump Bypass Valve

Ngā Tamariki station currently operates with the reinjection pumps shutdown and the DN500 pump bypass valve 100% open. The maximum Cv value from the datasheet was used to model the bypass valve, which was only activated in Case 2. A reinjection system pressure controller modulates the injection well flow control valves.

### 4.3 Well Flow Meters

Orifice plate flow meters are commonly installed in geothermal piping systems to measure flow rate. As fluid passes through the orifice, its velocity reaches the maximum at the Vena Contracta, causing a significant pressure drop. This results in an intermediate low pressure. Further downstream, in the pressure recovery zone, the flow expands and part of the pressure is recovered, giving a final pressure that is higher than the pressure at the Vena Contracta.

However, the pressure difference measured between the upstream and downstream tapping points, mounted on the orifice plate flanges, typically reflects a combination of the both the non-recoverable and recoverable pressure drop.

The non-recoverable pressure drop dω has been calculated by applying ISO 5167-2 and the resistance curve was then generated by quadratic approximation in the software. (ISO5167-2, 2003)

**Table 2: Flow meter non recoverable dω**

| Orifice | Flow rate - t/h | dω - bar |
|---|---|---|
| NM6 | 650.6 | 0.96 |
| NM8 | 518.6 | 0.71 |
| NM9 | 1009.7 | 0.21 |
| NM10 | 823.4 | 1.61 |
| NM14 | 774.5 | 0.33 |
| NM16 | 1009.7 | 0.21 |

New NM6 and NM10 flow orifice plates shown in Figure 4.0 were installed in July 2025. The new orifice plates were designed with a larger eccentric orifice size and larger vent hole to allow any gaseous NCG's to pass through to the injection well. An eccentric orifice plate design, offset towards the bottom of the pipe, is well-suited for fluids containing suspended solids, as it allows heavier suspended solids to pass through the orifice more easily. NM6 and NM10 have shown a significant reduction in flow orifice pressure drop and increase in downstream pressure shown above in Figure 5.0.

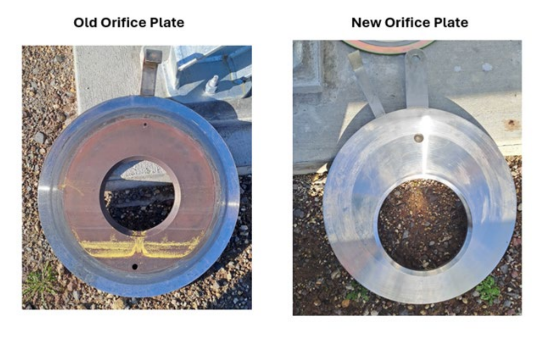


**Figure 4: NM6 and NM10 flow orifice plates.**

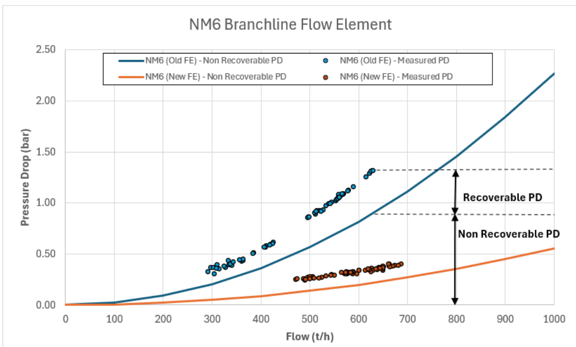


**Figure 5: Resistance curve of NM6 flow meter**

### 4.4 NCG Static Mixer

The NCG static mixer was used to reinject the NCG's from OEC3/4 into the northern pipeline, returning them to the reservoir. This mixer is redundant now that the station has transitioned to a unitized NCG injection system. The hydraulic model of the mixer was calibrated using upstream and downstream pressure measurements at varying flow conditions. Case 3B was conducted to assess the NCG mixer's influence on pressure drop along the northern pipeline.

### 4.5 Reinjection Wells

Linear well injectivity curves using Wellhead Pressure (WHP) were built into the Hydraulic model. The flow correlations were modelled in the form:

$$\text{Flow} = A \times \text{WHP} + B$$

## 5. MODEL CALIBRATION

### 5.1 Available Data

The reinjection pumps were started up and operated for a reliability trial in October 2024. Operating data from pump trials were used to calibrate the hydraulic model. Multiple data sets were taken to capture different dp characteristics for the northern and southern pipelines, improving model accuracy. The following operating cases were tested:

- High northern flow: control valves on NM8 and NM9 branch lines only are fully open to maximize flow through the northern pipeline.
- High southern flow: NM10 control valve fully open and NM6 control valve in pressure control, to regulate and maximize flow through the southern pipeline.

### 5.2 Methodology

The calibration process ensures the simulated pressure-flow data reflects the logged data at certain key locations, such as the station pump discharge, the high point in the northern pipeline, and the wellhead branch line pressure. The flow to each well was fixed to the measured value and the pressure drop from pump discharge to the wells was calculated. The model calibration was performed by iteratively adjusting the pressure drop across the NCG mixer and applying a pipe ID reduction of up to 6.3% in the southern piping. The adjusted model and data sets showed consistent agreement as outlined in Table 3.

**Table 3: Calibration results**

| | Observed (2024) | | AFT model | |
|---|---|---|---|---|
| **High Northern Flow** | **Pressure - barg** | **Flow – t/h** | **Pressure - barg** | **Flow – t/h** |
| Pump discharge | 14.05 | 2318.28 | 14.05 | 2315 |
| Northern high point | 12.64 | / | 12.64 | 1528 |
| NM8 line pressure | 13.63 | 518.58 | 13.63 | 518.58 |
| NM9 line pressure | 14.08 | 1009.71 | 14.00 | 1009.71 |
| **High Southern Flow** | **Pressure - barg** | **Flow – t/h** | **Pressure - barg** | **Flow – t/h** |
| Pump discharge | 11.66 | 2311.43 | 11.66 | 2307 |
| NM6 line pressure | 6.41 | 650.64 | 6.41 | 650.64 |
| NM10 line pressure | 5.76 | 823.4 | 5.76 | 823.4 |

The overall hydraulic model screenshot is presented in Figure 5.

Figure 6 illustrates the length and elevation of the northern and southern pipeline. The northern pipeline has a low point near NM2 (55.6m below the pump station), whereas Pad NM1 is 25.0m below the pump station. The southern pipeline has a low point at 6.5m below the pump station and pad D is located at 3.0m below the pump station.

Minimum, partially stimulated and fully stimulated injection capacity cases were built into the model for NM14 and NM16. These cases can easily be analyzed by opening a manual isolation valve on each well in the Hydraulic model.

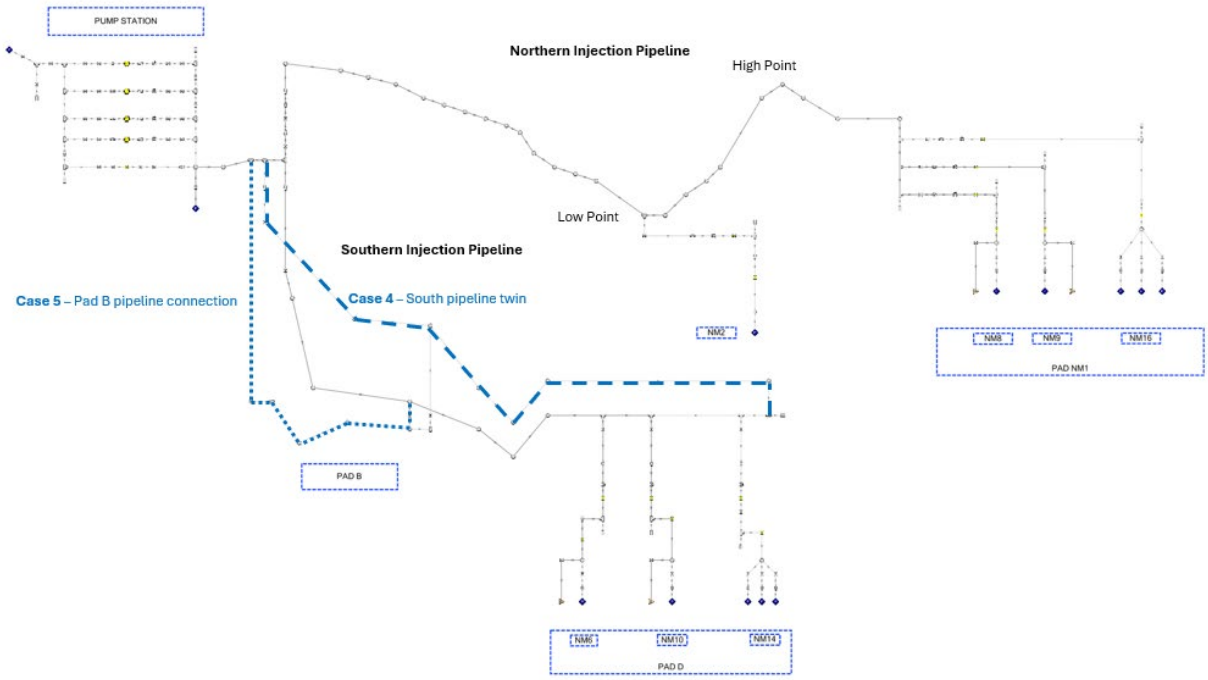


**Figure 6. Model network**

## 6. SIMULATION RESULTS

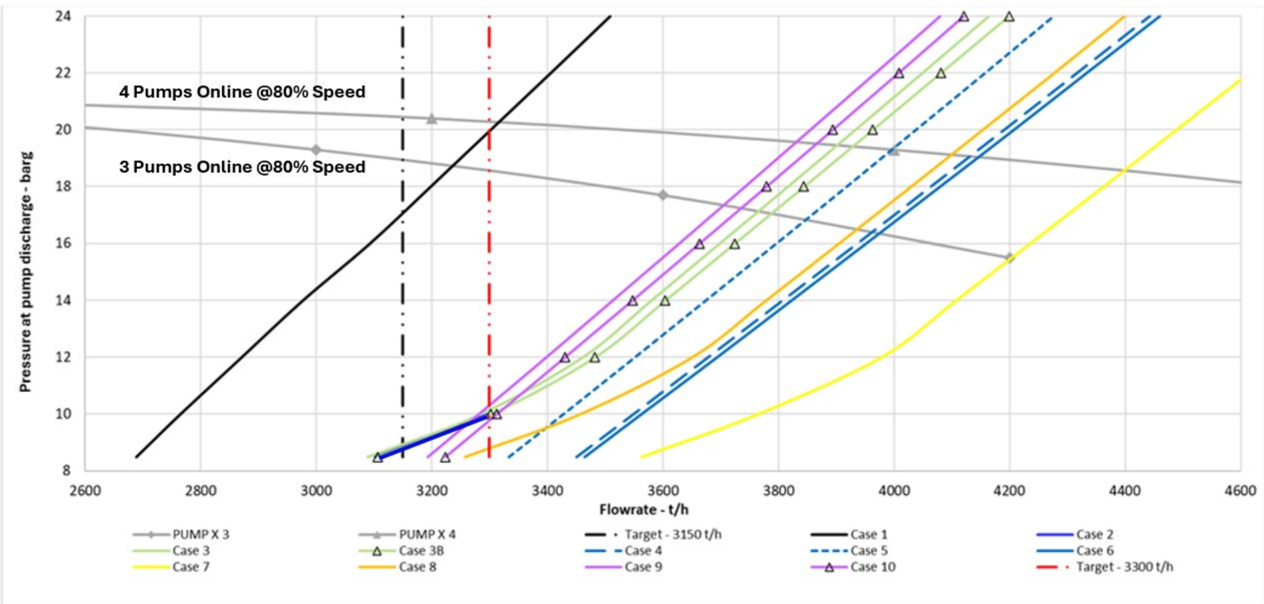


**Figure 7. Composite system curves for all cases**

Simulation results displayed in Figure 7 are based on the performance of the existing NTM injection.

### 6.1 System Curve

Composite system curves for the entire scope were generated as shown in Figure 7. The Y-axis represents the pressure at the pump discharge, which is assumed to be the system starting pressure, and the X-axis represents the corresponding combined injection flow, calculated by the software. Since the pump curves have been overlaid, the corresponding injection capacity for each study case can be identified by reading X values at the intersection points of the system curve and the pump curves. The future target flow is set to 3,300t/h, this includes a 150t/h control margin to account for reinjection system pressure control. Each study case was evaluated with all the control valves on the branch line fully open, representing the maximum flow case.

With the current system configuration (Case 1), the target flow (3150 t/h) can be achieved when system pressure is raised to around 17 barg by three pumps, and the maximum capacity reaches up to 3,317 t/h when all four pumps are running.



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In other cases, a gain in total flow was observed due to addition of new wells, as well as modifications of pipelines and/or components. However, flashing is expected at high flow rates and low starting pressure when NM14 is brought online, and the reinjection pumps are bypassed. Flashing limited flow is shown by the nonlinear sections in Cases 3, 7 and 8 system curves at low supply pressures.

NTM has four identical reinjection pumps controlled with individual variables speed drives. Reinjection pump curves for three and four pump operating at 80% pump speed are shown in Figure 7. Pump speeds are manipulated by the control system to meet the station reinjection demand.

### 6.2 Injection Capacity

#### 6.2.1 Case 2 - Pumps offline and full bypass

The 8.5 barg station back pressure will yield a capacity of 3,102 t/h when NM14 is commissioned. High pressure loss along the southern line and high pressure drop across NM6 and NM10 flow meters, restrict injection capacity. Replacing NM6 and NM10 orifice plates with a low pressure drop design will increase the NTM injection capacity by another 50 t/h.

#### 6.2.2 Case 3 & 3B – NM14 with/without NCG Mixer

The target flow can be easily achieved at low pressure, and the system curve exhibits a similar nonlinear characteristic to Case 2. Removing the northern pipeline NCG mixer will increase NTM injection capacity by another 20 t/h.

#### 6.2.3 Case 4 to 6 – Southern pipeline debottlenecking

A new DN450 parallel pipeline which twins the existing southern injection line was evaluated in Case 4. Case 5 outlines an option to utilise a redundant DN750 production pipeline for injection service. This line runs about 0.9 km along the southern piping route, from NTM station to Pad B. Tie-in sections are required at both ends to connect the production line to the reinjection system. Case 6 combines benefits of Case 4 and 5 where the production line from Pad B is utilized and an extension DN450 line is built from Pad B toward the south reinjection pad.

Case 6 yields the highest capacity among three options while Case 5 has the lowest complexity and lowest capital cost while partially debottlenecking the southern injection line.

### 6.3 Injection Velocity

Fluid injection velocities in the northern and southern lines were plotted against flow rate. Without debottlenecking, the southern line velocity reached up to 5.2 m/s in Cases 3 and 3B, about twice that of the northern line, indicating undersized piping. This is, however, within an acceptable range without major concerns.

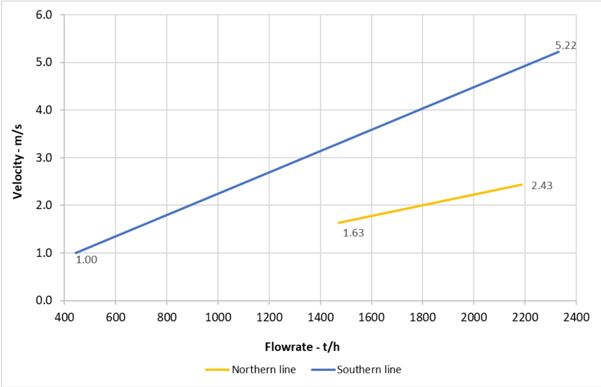


**Figure 8 Injection velocities in north and south pipeline**

The economic reinjection velocity, balancing pipe capital costs and pump operating costs, typically ranges between 1.5 and 3 m/s. Higher velocities can still occur in practice. Operating experience has been obtained for a reinjection pipeline operating at velocities up to 5.6m/s. (Kevin Koorey, 2021)

An industry study identified the critical flow velocity for erosion/corrosion in carbon steel pipes as high as 7.4 m/s. (Z.B. Wang, 2021) Additionally, water-phase velocities in two-phase lines are commonly higher than those in reinjection lines.

## 7. NTM INTEGRATED MODEL

The NTM integrated model is an excel-based financial, steamfield and station model used to evaluate investment cases and scenarios. The AFT Impulse hydraulic model results were used to tune the integrated model for the southern injection pipeline options and pipeline debottlenecking costs were applied for each case. Injection well decline rates are applied to each well based historical data.

The NTM Integrated model runs a Monte Carlo simulation using reservoir and steamfield uncertainties and distributions. Each reinjection system debottlenecking option was assessed to allow comparison over a 25-year project life.

The following reinjection system debottlenecking options were included:

- Southern pipeline – Pipeline twin.
- Southern pipeline – Pad B Connection.
- Southern pipeline – Pad B Connection and extension.
- Drill new NM16 well.
- Utilize redundant well NM2.

The optimum reinjection solution was the southern pipeline – Pad B connection and extension (Case 6), followed by the delayed drilling of NM16, shown in Figure 9 below. This option is contingent on pipeline inspection and pipeline rerate /suitability study.

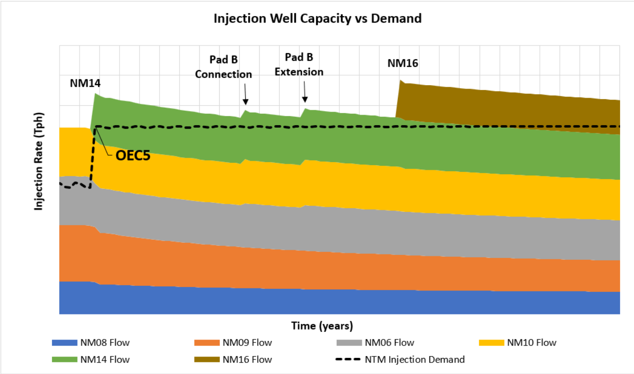


**Figure 9. NTM projected injection system capacity**

## 8. CONCLUSION

Commercial hydraulic modelling software like AFT Impulse offers a comprehensive and cost-effective approach to evaluate a geothermal reinjection system. By incorporating as-built and actual data for key components such as reinjection pumps, pipelines, valves, and geothermal wells, the model accurately reflects the actual system configuration. Overlaying composite pump curves onto system curves enables clear identification of reinjection capacity under various operating scenarios.

This study demonstrates that system optimisation can be achieved by exploring various modification scenarios, ranging from component upgrades to pipeline reconfigurations and well additions, allowing the station to meet its increased reinjection demand efficiently.

Integrating hydraulic modelling results into the NTM integrated model enables comparison of debottlenecking options over a 25-year project life and supports selection and phasing of the most effective reinjection strategy.

## REFERENCES

K. Koorey, “Modelling a Reinjection Network,” in *New Zealand Geothermal Workshop*, 2022.

“ISO 5167-2 Measurement of fluid flow by means of pressure differential devices inserted in circular-cross section conduits running full - Part 2: Orifice plates,” 2003.

K. Koorey, “Mokai Reinjection Pump Process Design Report,” 2021.

Y. Z. Z.B. Wang, “Critical flow velocity phenomenon in erosion-corrosion of pipelines: determination methods, mechanisms and applications,” *Journal of Pipeline Science and Engineering,* pp. 63-73, 2021.

S. Jordan, G. Allan, “NTM Reinjection Capacity Assessment. 2022