Proceedings World Geothermal Congress 2026
Calgary, Canada, June 8 – 11, 2026

The Process of Well Targeting in the Well Delivery Process, with a Case Study from the Ngā Tamariki Geothermal Field, New Zealand

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Keywords: Well delivery process, well targeting, Ngā Tamariki, Mercury NZ Limited

ABSTRACT

Geothermal well drilling represents a critical step in harnessing high-enthalpy geothermal resources for energy production. Well Targeting is undertaken during the planning phase of drilling, to determine optimal and fit-for-purpose drilling target(s). This paper presents an overview of the Well Targeting workflow, in the context of the Well Delivery Process. The process of Well Targeting begins with the definition of well requirements, largely shaped by business objectives and relevant technical inputs (e.g. reservoir, plant & steamfield, regulatory, etc.). A set of target options are identified and ranked initially, tailored to well requirements, leveraging geoscience and offset well data. Then a preferred target is identified, and a Well Prognosis document prepared, where the selected geological target is described in detail, geological/drilling conditions forecasted, testing requirements identified and contingency plans outlined. Prognosis enables subsequent development of well design and drilling programs. A case study from the Ngā Tamariki geothermal field is used to illustrate the use and application of well targeting emphasizing the interplay between drilling, reservoir, and asset management disciplines.

1 INTRODUCTION

Mercury NZ Limited (MCY) is an electricity and services company based in New Zealand. MCY's generation assets produce electricity from 100% renewable sources: hydro, geothermal, and wind. MCY operates five geothermal power stations in four geothermal fields: Kawerau, Mōkai, Ngā Tamariki, Ngā Awa Pūrua, and Rotokawa. In 2024, MCY generated 2,622 GWh from geothermal energy, equating to 30% of MCY's total annual generation for year 2024. Regionally, geothermal contributes to ca. 20% electricity needs of New Zealand.

This paper provides an overview of MCY's Well Targeting workflow in the context of the Well Delivery Process. Two case studies from the Ngā Tamariki Geothermal Field are presented to illustrate the use and application of Well Targeting and to exemplify the importance of standardized workflows in driving successful drilling outcomes.

2 WELL DELIVERY PROCESS

2.1 Overview

At MCY, Well Targeting and Prognosis sit within a broader process labelled Well Delivery Process (WDP). Figure 1 shows schematically the various components of MCY's WDP. MCY's WDP is designed to capture drilling-related activities and milestones from planning through execution to close-out. WDP is designed to ensure drilling is executed in accordance with business, technical and compliance requirements, with relevant risk mitigation and contingency plans in place. In the authors' experience, geothermal developers invariably and unavoidably end up developing some form of delivery process for drilling, although organizations will differ in areas of emphasis and degree of formalization and/or documentation. In MCY's experience, a well-documented WDP provides the foundation for consistent, systematic and successful use of a WDP. Readers can refer to Prihutomo and Arianto (2010) for a description of Chevron Indonesia's well delivery process, labelled internally "Project Development and Execution Process" (CPDEP). This paper provides a similar overview of how MCY has implemented its WDP to achieve success in geothermal well drilling.

At a project level, the WDP starts with a "Business case" where benefits and cost forecasts of drilling (at a drilling program level) are articulated and authority for expenditure is obtained. In the next phase of "Project Team", project staffing and resourcing is defined, and drilling schedules, sequence of wells, and budgets are produced. In the Planning Phase, procurement (long lead items, and rig and service contracts) is actioned. In the "Preparation" phase, lessons learned from previous campaigns are captured, Risk Registers and HSE plans are produced, consent and regulatory applications are progressed, and relevant rig and associated inspections and

Classification: General

contract due diligence are undertaken. In the Close-out phase, Reporting, post-drill Lessons Learned and After-Action-Reviews take place.

At a drilling level, a multidiscipline team is established which includes the Field Geologist, Reservoir Engineer, Drilling Engineer and Drilling Supervisor. This team, dubbed the Well Delivery Team (WDT), performs planning and execution of all drilling activities.

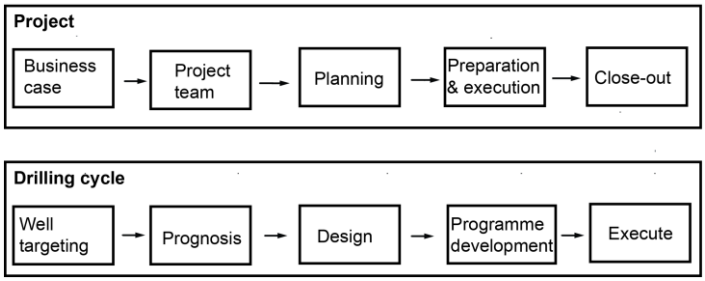


Figure 1. MCY's Well Delivery Process at a glance.

2.2 Well requirements

Preceding well targeting is the definition of well requirements. The workflow from Well Requirements through Well Targeting to Prognosis is illustrated in Figure 2. The inputs relevant to the definition of well requirements in Figure 2 are listed and explained in Table 1.

Table 1. Specific inputs for definition of well requirements, as pre-requisite for well targeting.

Input type	Description
Business	Review approved business case to determine business goals for the well, e.g. fuel supply certainty, exploration value, project requirements (e.g. timeline), drilling risk directive, fit to company strategy
Reservoir	Provide technical requirements (e.g. need to provide pressure support, need to achieve target enthalpy, capacity targets, etc.) Ensure consistency with any relevant documentation such as Reservoir Management Plans and System Management Plans Test reservoir requirements and assumptions against models, e.g. Conceptual Models, Reservoir Numerical Reservoir Models, Borehole Models, Geological models
Surface (steamfield, plant)	Review pipeline requirements (flows, costs, pressure ratings), design enthalpy, recommended operating wellhead pressures, fuel forecasts, existing infrastructure (surface and subsurface), topography, access, well pads, pipelines, etc.
Land & stakeholders	Review regulatory aspects of drilling, availability of land access, consent conditions, limits and constraints, check inter-reliance on fuel supply (e.g. direct users), ensure timely communication with and notifications to third parties and relevant stakeholders, etc.
Drilling	Review constraints on well design or drilling-related restrictions on well configuration, review casing, master valve and well head inventory, consider timeline for procurement (long-lead items), rig availability, etc.

2.3 Well targeting

The Well Targeting process is lead by the geologist with support from the WDT. The various components of well targeting, as shown in Figure 2, are listed in Table 2.

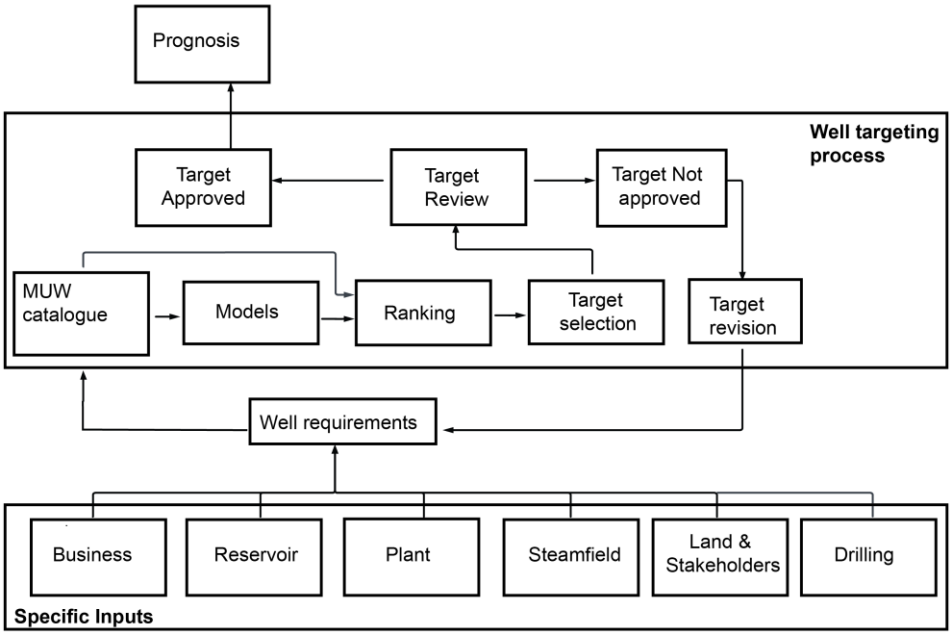


Figure 2. MCY's well targeting process. MUW = Make-up (replacement or new) well.

Table 2. Description of components of Well Targeting shown in Figure 2.

Process activity	Description
(MUW) catalogue	The make-up well (MUW) catalogue identifies a broad list of wells selected initially, based on well requirements. In some cases, the MUW catalogue can be legacy information requiring minor refinement and updating. In other cases, it might require building from scratch.
Models	Identify models and model scenarios relevant to narrow down MUW catalogue options. These models may include: borehole models, reservoir numerical models, process models, integrated models (station, steamfield, reservoir, financial), conceptual models.
Ranking	Define the weighted well ranking method, typically considering indicators of enthalpy, permeability, long-term trends, risks, complexity, financial metrics (e.g. Capex, Opex), value of new information (exploration), and any other factors relevant to the well target scoring. A cross-disciplinary scoring system is encouraged.
Target selection	Document rationale for target selection, risks, impacts in reservoir strategy (if relevant) and recommendation for management

2.4 Geological Prognosis and Well Design

Geological Prognosis work is kicked off once a preferred target is identified at the end of Well Targeting. At MCY, the geological prognosis document is owned by the geologist who leads and coordinates collation of cross-disciplinary inputs from the delivery team and subject matter experts.

A Prognosis document describes the well objective (e.g. production vs injection, target productivity or injectivity) and target (depth, offset, etc.), outlines nominal directional path, casing depth, and production casing size, provides a forecast of subsurface conditions (temperature, pressure, geology, drilling conditions), and presents testing requirements and preliminary contingency plans. The prognosis document review process includes both a technical and managerial review before sign-off by the business owner (Figure 3). This formal sign-off is generally appropriate considering the level of investment and risk of geothermal drilling.

Geological prognosis enables subsequent conceptual well design and drilling program development by the well engineering team. In the initial phase of conceptual well design, preliminary well schematics, water supply specifications, pad layouts, and civil works scopes, among others, are prepared. In the following phase of detailed design, technical requirements (e.g. maximum design pressures, effective containment pressures, safe casing shoe depths, casing grade and weight specifications and connection type and associated load calculations, etc.) are determined. Following this, drilling programs including contingency plans are finalized. Drilling and associated ancillary drilling service contractors are tendered with contracts negotiated and awarded.

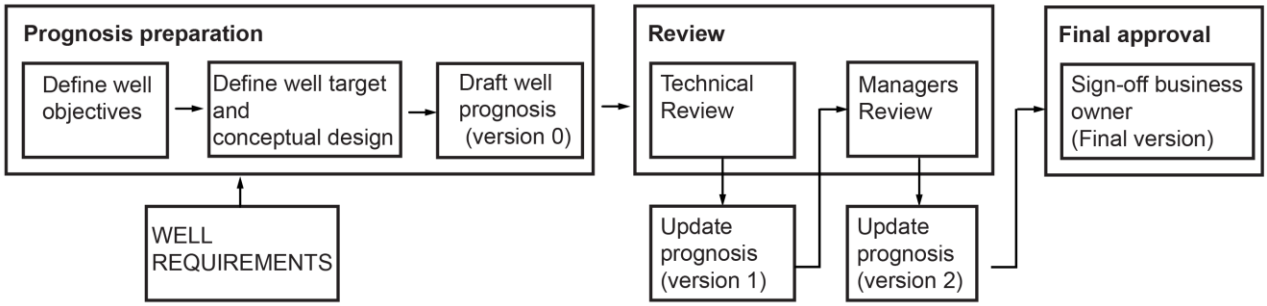


Figure 3. MCY's geological prognosis process.

2.5 Highlights from the drilling execution phase

During the next "Execute" phase, the WDT leads planning, supervision and support activities, such as Drill-Well-On-Paper (DWOP) and Test-Well-On-Paper (TWOP) planning sessions, reporting (e.g. daily reports, look-ahead reports, driller's instructions, completion test programs, etc.). and all day to day well drilling activities. The WDT also documents any significant deviations from the drilling program through MCY's management of change process and manages and supports all rig site operations. Once well construction is complete, the WDT performs After Action Reviews (AARs) with a Lessons Learned database and prepares all end of well reporting (EOWR) to meet regulatory and internal requirements.

3 CASE STUDY: NGĀ TAMARIKI EXPANSION PROJECT

3.1 Background

The Ngā Tamariki (NTM) geothermal field is located in the Taupo Volcanic Zone, in the center of the North Island of New Zealand. An 85 MWe binary power station was commissioned in 2013, with an initial resource consent to take up to 60,000 t/d of geothermal fluid (Boseley et al., 2010). As of 2025, the power station was supplied by production wells NM7, NM12 and NM13 (Figure 4), with reservoir temperatures in the range of 280-290 °C.

NTM is world-class high-enthalpy geothermal resource. NTM has exhibited relatively stable pressure and enthalpy trends, and no detrimental effects to surface thermal features (Potter et al., 2020a). Among contributing factors to the stable trends are the relatively deep nature of the reservoir (top of reservoir 1.4-1.8 km deep) and successful implementation of ca. 100% infield injection distributed across north (NM8, NM9) and south injection areas (NM6, NM10; Figure 4). Supported by monitoring and field performance evidence collected to 2022, the field operator (Rotokawa Joint Venture, RJV) lodged a resource consent application in 2022 for an additional take of up to 24,000 t/d with a successful outcome. At the time of writing, the total allowed take is 84,000 t/d.

3.2 OEC5 Expansion project

The 2022 resource consent provided the basis for the NTM expansion project consisting of the addition of a binary unit (OEC5; at the time of writing, scheduled for commissioning end of 2025). One new production well and one new injection well were identified as part of the business case. Well targeting work undertaken in 2021 identified a preferred location for a production well target, named NM15-BC (base case), deviated towards the eastern margin of the production area (Figure 4).

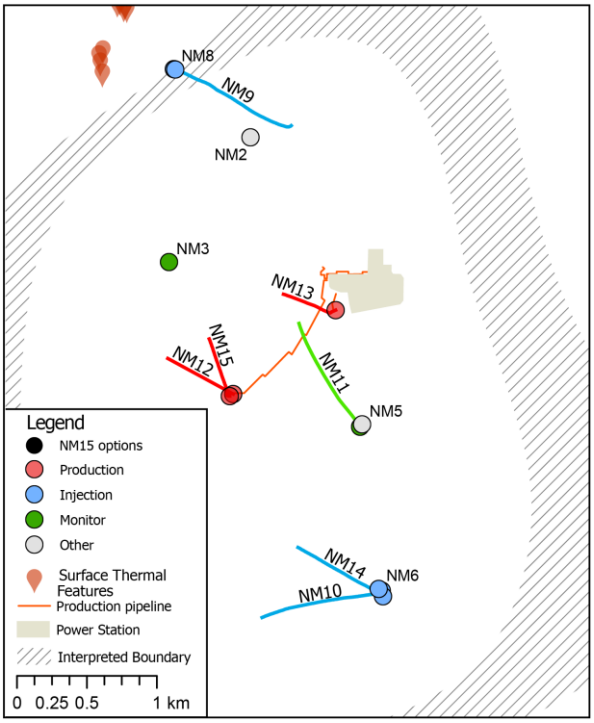


Figure 4. NTM map showing existing well assets, including NM14 and NM15 wells (as drilled).

3.2.1 Production

NM15-BC objectives included both meeting OEC5 fuel supply requirements, spreading production (minimal interference risk) and maximizing appraisal information for planning future production drilling. In 2022, the NTM numerical model indicated a non-negligible risk of NM15-BC encountering likely (P50) enthalpy lower than the average field enthalpy. This was initially deemed an acceptable risk and outcome, considering there was high exploration value to be gained on the upside. In 2024, closer examination of the OEC5 generation-enthalpy curve showed that NM15 P50 enthalpy could result in 5% MWe relative output loss compared to the scenario of NM15 enthalpy being equal to the average field enthalpy (Figure 5). With this information, well requirements were reset to achieving "target enthalpy equal or greater than average field enthalpy". This triggered a new iteration of well targeting schematically represented in Figure 6.

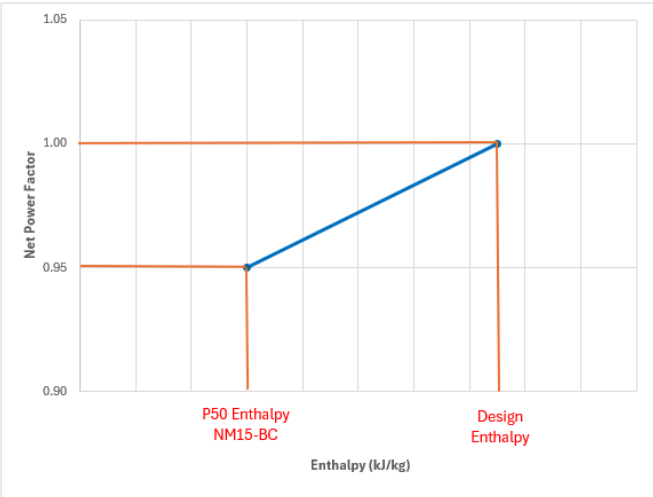


Figure 5. NTM OEC05 Geothermal Power Plant Enthalpy Curve illustrating the business trigger for review of production well requirements.

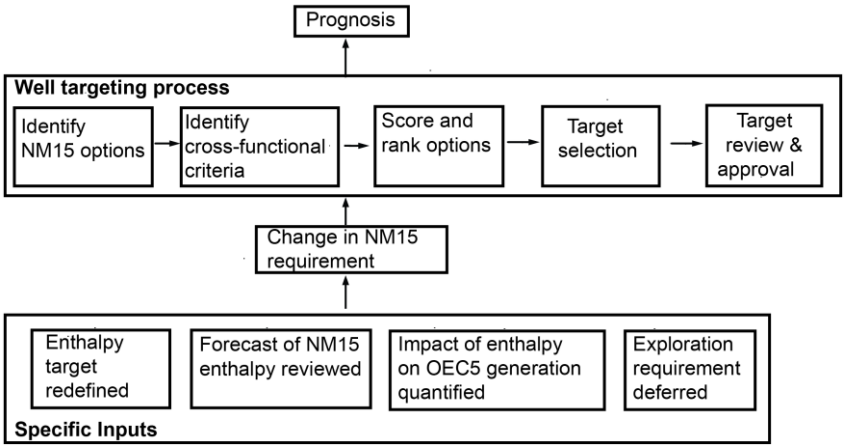


Figure 6. Well targeting process applied to 2024 NM15 well targeting

Four target options NM15-BC, NM15-C, NM15-NE and NM15 (Figure 7) were identified and ranked against cross-functional criteria (Table 4). From an enthalpy perspective, the most attractive options included NM15 (highest ranked) and NM15-C (second highest ranked), with option NM15-NE being the most exposed to injection-induced cooling from north injection. NPV was calculated for each target using an integrated reservoir-steamfield-financial model. Through early iterations of this process, the NTM technical team learned that high enthalpy alone would not guarantee unlocking financial benefits predicted by the generation-enthalpy curve (Figure 5). Well capacity and steamfield costs were found to have the potential to offset the gain from high enthalpy. This was not only due to additional cost but also increased risk of schedule delays for the OEC5 project. When assessing technical feasibility of connection to the existing production pipeline running from NM12 to the power station (relevant to options NM15 and NM15-C, Figure 4), it was determined that the existing pressure rating would pose a limit on maximum flow preventing use of well at full target capacity. In order to further understand options available (e.g. twinning versus re-rating production line), an engineering study was commissioned concluding it was feasible to re-rate the existing production line. This finding, combined with favorable forecasts of enthalpy and capacity, ultimately supported the choice of target NM15 as the preferred target (as shown in Figure 5). NM15 was successfully completed in April 2025 (as shown in Figure 4) meeting the target enthalpy and exceeding expected capacity.

3.2.2 Injection

Injection target NM14-BC (base case; Figure 4), located in the southern injection area, and deviated to the SE, was the preferred injection target identified during 2021 well targeting. NM14-BC had been designed to supply injection capacity, maximize appraisal information for future injection drilling options, and maintain the prevailing injection strategy of ca. 100% injection with deep, infield injection.

Deep NTM injection wells are unique in that they have all experienced, to variable degree, capacity improvements with time (e.g. Potter et al., 2020b), a behavior attributed to natural and gradual reservoir permeability stimulation by the action of injection fluids transiting from injection towards production reservoir. The time elapsed between drilling a deep injector and reaching full capacity has been observed to range between 2.5-5 years. This, combined with short- to medium-term decline trends (e.g. Figure 7), created some uncertainty for the OEC5 project, captured in the scenarios of Table 3.

With this pattern of relatively low initial capacity followed by improvement with time, it was unclear whether it would be possible to achieve high initial capacity for OEC5 prior to commissioning, considering the multiple factors controlling well injectivity (e.g. reservoir stimulation, silica scaling, operating well head pressure, etc.) and unknowns regarding reservoir stimulation (e.g. near-borehole vs reservoir-wide effect). At NTM, microseismicity concentrates near injection areas and tracer tests show ca. 25% injection returns from NM10 to NM05 (Figure 7). It was conceptualized, based on microseismicity, tracer tests and general pressure and enthalpy trends, that high microseismicity areas constitute the footprint of permeability-enhanced reservoir. NM14 well requirements were redefined prioritizing high certainty of well outcome over exploration information (as with NM15). Accordingly, a new targeting process was kicked off in 2023 with the new mandate to maximize the chance of high initial capacity with minimal exploration risk (SC3 in Table 3).

New targets labelled NM14-N and NM14 (Figure 7) were introduced in early 2024 and evaluated against NM14-BC option, with selection criteria as outlined in Table 4. NM14 target, deviated to the NW towards high seismicity areas (Figure 7), was ultimately selected as the preferred target, leveraging available NM10 formation image for fine-tuning geological targets, considering:

- greater chance of encountering already stimulated reservoir and high initial capacity;
- lower risk of injection-induced cooling to production (enthalpy) compared to north injection options (observation supported by numerical model and tracer tests);
- lower risk of capacity decline (after initial improvements) compared to north injection where transient, post-stimulation decline trends had been observed and attributed to silica scaling (Figure 7).

NM14 was completed in early 2025 becoming the first injector at NTM to deliver high initial capacity. Southern injection pipeline improvements are forecast in the medium term to maintain full injection capacity.

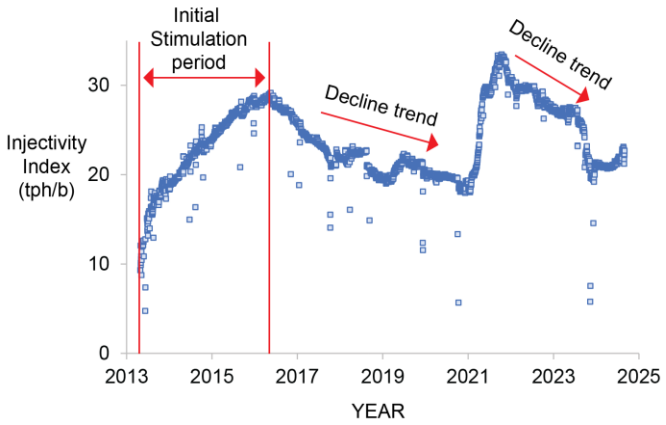


Figure 7. NM09 injection path, as an example of changes in injectivity with time observed at NTM injection wells. The decline trends are attributed to silica scaling effects.

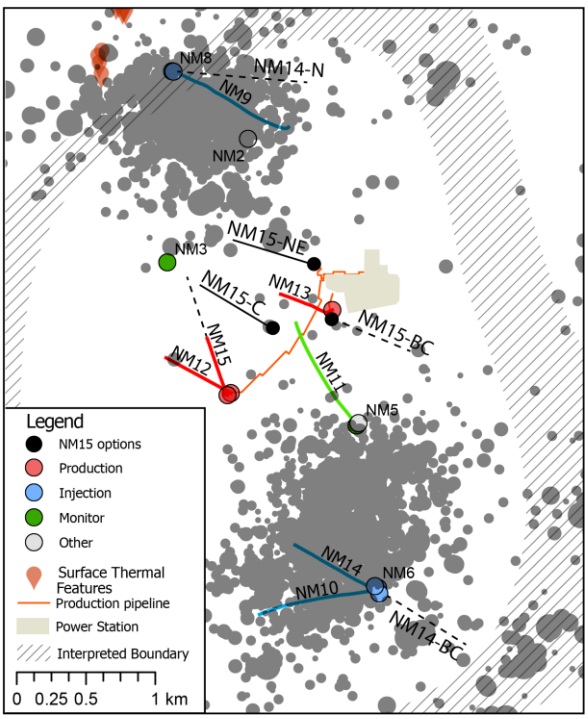


Figure 8. NTM map as in Figure 4 showing production and injection targets considered as part of the well targeting process. Areas of high microseismicity (period 2013-2022) are also highlighted.

Table 3. Selected scenarios (SC) for NM14-BC identified prior to 2023-2024 well targeting. Medium term ~ 5 years

SC	NM14-BC outcome	Project outcome	Comment
SC1	Low initial capacity: capacity improves with time following a "typical" NTM stimulation path;	OEC5 is not fully fueled initially due to injection capacity shortage.	Most likely scenario considering the observed historical behavior of NTM injection wells.
SC2	Low initial capacity: capacity does not improve with time; OEC5 is not fully fueled	Permanent fueling shortage for OEC5. Make-up drilling plans are to be introduced reactively	Worst-case scenario.
SC3	High initial capacity: capacity remains relatively stable with time	OEC05 is fully fueled, no make-up drilling required in the short- to medium-term	Best-case scenario.
SC4	High initial capacity; capacity declines with time	OEC05 is fully fueled, make-up drilling required in medium- to long-term	Possible scenario. Risks were deemed acceptable and manageable through performance monitoring and make-up drilling contingency planning

4 CONCLUDING REMARKS

Standardization and documentation of internal processes add value to geothermal well drilling beyond the drilling project life cycle. A recent drilling campaign provided MCY with the opportunity to apply, refine, and improve a Well Delivery Process. In this paper, we show specifically how well targeting is implemented at MCY with case studies that illustrate how the interplay of various technical disciplines drove successful drilling outcomes for the OEC5 expansion project at Ngā Tamariki. The 2023-2024 targeting process highlighted:

- The value of having a clear opportunity statement and well- defined objectives.
- The importance of cross-disciplinary interactions between reservoir, drilling and asset management disciplines. The value of integration and quantification of information in decision making (e.g. through integrated reservoir-steamfield-financial models)
- The iterative nature of well targeting

Acknowledgements

The authors would like to thank Mercury and Rotokawa Joint Venture for permission to publish this paper.

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Table 4. Qualitative description of target selection criteria for NTM production and injection well options.

Criteria type	Criteria type	Required		Description
		NM14	NM15	
Reservoir	Initial enthalpy forecast		x	This is initial enthalpy ("year 0"), informed from a combination of offset well data, numerical model and conceptual model.
	Enthalpy trend forecast		x	Generally informed from reservoir numerical model and tracer tests. It includes components such as risk of cooling due to injection returns, downflows or peripheral recharge.
	Initial Capacity forecast	x	x	This involved: 1) conceptualization of permeability, using conceptual model, geological model, fault model, formation imaging (particularly relevant for NM14, due to available formation image log at NM10), feedzone distributions, microseismicity, etc. 2) modelling (borehole model).
	Capacity trend forecast	x	x	Most relevant for NM14, consists in forecasting capacity, capturing relevant processing (e.g. reservoir stimulation for injection targets; calcite scaling potential for production targets)
Strategic	Exploration value	x	x	Evaluated as a function of distance to existing production / injection areas combined with geophysical boundary. Evaluate if target provides exploration information & potential to unlock new production and/or injection areas. This criterion was given low priority during 2023-2024 well targeting.
	Injection strategy	x		Evaluate if target is aligned with reservoir management goals (e.g. injection provides pressure support to production)
Asset	Effects on field operations, technical feasibility of connection to steamfield	x	x	Effects on assets and current operations were assessed, from a risk perspective. Examples: 1) assess risk of injection-induced cooling to production area; 2) assess risk of production target causing pressure drawdown / adverse effects on shallow hydrology / thermal features; 3) assess technical and economic feasibility of connection to existing production and/or injection pipeline; 4) assess interference effects on existing production / injection 5) assess future performance of injection system / pipeline (hydraulic modelling)
Business	OEC5 project risks	x	x	Assess risks on cost and schedule associated with new steamfield infrastructure. Also consider notice periods to third parties, and technical complexity (e.g. topography consideration for new production pipeline, etc.).

ABBREVIATION GLOSSARY

Abbreviation	Definition
AAR	After-action-review
CPDEP	Project Development and Execution Process (Chevron, Indonesia)
DWOP	Drill well on paper
EOWR	End of well report
GWh	Giga-watts hour
HSE	Health, Safety and Environment
MCY	Mercury New Zealand Limited
MUW	Make-up well
NPV	Net present value
NTM	Ngā Tamariki, also spelt Ngatamariki (old publications)
OEC05	Ormat Energy Converter Unit 5
P50	Forecast with 50% probability of occurrence
RJV	Rotokawa Joint Venture
t/d	Tons per day
TWOP	Test well on paper
WDP	Well delivery process
WDT	Well delivery team