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The Ormat Development Process and Reflections on Success Throughout

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ABSTRACT

Ormat has an operational portfolio of approximately 30 geothermal resources, with approximately 50 additional exploration-phase prospects globally, with many of these in the United States of America. Ormat has ramped up its exploration activity in recent years and has been working to improve and standardize its processes with an aim to decrease the time needed to achieve a successful development and to increase the likelihood of success during exploration and subsequent development. This has resulted in the creation of a *Development Process* that maps out the various phases of a project, along with the deployment of a project management approach to match these phases. The need to define how success is measured was identified, both at a phase level as well as at an individual well success rate level, in order to track performance metrics and continue to improve on processes.

The paper outlines the Ormat Development Process and provide definitions of *success* for each project phase as well as at the resolution of an individual well, alongside a discussion of exceptions and limitations. In addition, this paper discusses the management of risk throughout the exploration and development process.

1 INTRODUCTION

Achieving high well and project success rates is important for the geothermal industry, as it enables projects to be economically developed. Overinvestment on unfavorable projects results in less capital being available for favorable projects. Therefore, it is imperative that processes are in place to efficiently identify and expel unfavorable projects from a company's portfolio, as early in the exploration phase as possible, with a mindset of minimizing walk-away costs.

Significant bias in the scientific understanding and decision-making process through the exploration of geothermal systems has been known to occur, and all endeavors should be made to reduce the risk of this – a concept discussed in Melosh (2017) and elsewhere. A major consideration that has been reflected on both at Ormat and from feedback from other industry veterans, is that there is a need to ensure that individual well success rates are only assessed for large-diameter wells, and not when lower-cost small-diameter exploration wells are being drilled. The philosophy behind this is that the primary goal of these small-diameter wells is to glean insight into the resource conditions and geometry of a geothermal system, rather than be utilized as production or injection wells in a future development (noting that that small diameter wells can sometimes have utility in developed projects as monitors or for small capacity producer or injectors). As such, small-diameter wells that are drilled on the margins or completely outside of the targeted resource still achieve their purpose in increasing the definition of system boundaries.

One challenge associated with defining *Well Success* directly after drilling is that there is only a short-term view, based largely on indications from short-term injection/flow tests and preliminary heat-ups. There are some instances where wells that were initially deemed to be successful were not long-term successes due to a myriad of phenomena, e.g., the rapid cooling or excessive pressure decline under long-term production. Conversely, there are also many circumstances where wells that were initially deemed as unsuccessful for production purposes become utilized as injection wells in a development. An example of this is given in Libbey et al (2026). Additionally, wells initially deemed as unsuccessful for production or injection may stimulate or "clean-up" overtime and become successful wells that end up being utilized in developments.

This paper will discuss the Ormat development process and success criteria through each phase of the development process. This paper is written in the context of hydrothermal geothermal systems and in due course we expect to have an equivalent paper for enhanced geothermal systems.

2 DEVELOPMENT PROCESS AND PHASES

Ormat has a large exploration pipeline and is very actively trying to explore and develop geothermal prospects. The development process and the way that phases are broken out are shown in Figure 1. Throughout the paper these phases are referred to with the intention of bringing clarity to the activities undertaken in each phase and how success is determined.

Steps can be skipped, i.e. going straight to large-diameter drilling and not doing small-diameter drilling, however this increases risk to the subsequent phases with less information that would have been acquired in the phase(s) that were omitted.

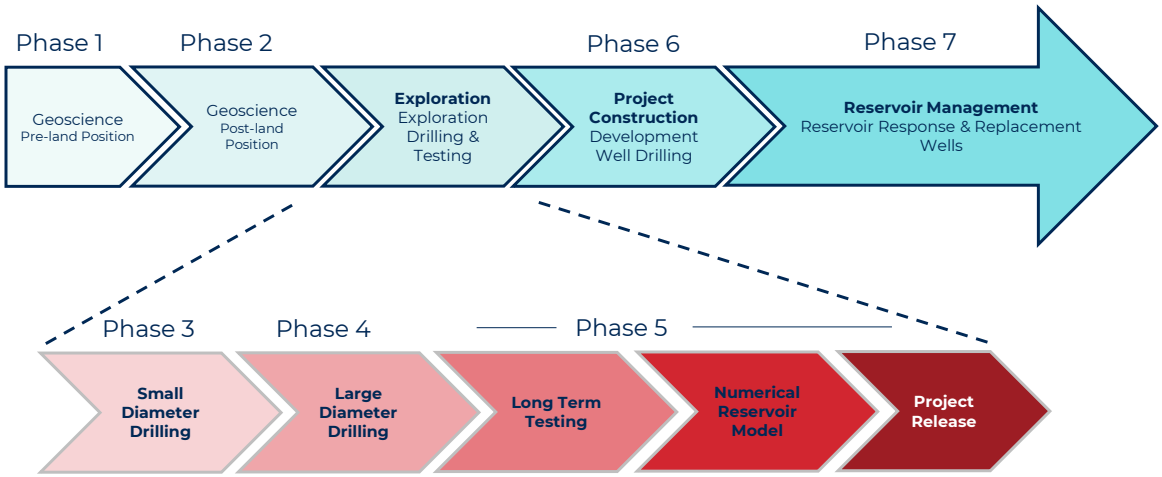


Figure 1: Ormat Development Workflow

2.1 Geoscience (pre-land position) – "Phase 1"

In Phase 1, geoscience activities are generally focused on geochemistry and geology. Regional geophysical surveys can be useful also, for example by Bibby et al. (1995) or by other approaches such as in the BRIDGE project recently in the US (Schwering et al., 2022).

Geochemical samples are collected from available springs, fumaroles, groundwater wells and any other reasonable sources of geochemical information that are informative to the project. A primary goal in many instances is to determine if the project has a favorable temperature (generally >130°C, depending on the development concept and *Permeability Regime*; Libbey and Murphy, 2026) and no signs of acidity.

Geologic understanding is achieved through regional structural reviews and preliminary mapping of key features to determine if the project has high-level favorability for temperature and permeability controls.

Ormat has developed a proprietary tool to assess geothermal prospects in a systematic manner to determine the probabilistic range of power generation potential and the risk-weighting of the prospects relative to one another; a process that has been calibrated to a large number of global analogs. This tool is central to the goal of assessing risk and capacity potential for Ormat's global portfolio, enabling us to focus exploration funds and efforts on the most favorable and high-reward opportunities.

2.2 Geoscience (post-land position) – "Phase 2"

Once a prospect has been acquired with no hurdles to development, more detailed geoscience work is undertaken. This generally involves the following work:

1. Detailed geochemical sampling
2. Detailed geologic mapping
3. Geophysical surveys (typically magnetotellurics, most often with gravity and magnetics)

Additional geoscientific work can be conducted on a case-by-case basis, including methods such as: 2-meter temperature surveys; shallow push wells for geochemical sampling purposes; 2D-seismic surveys, etc. It is important to assess the needs for geoscientific surveys to determine their value and relevancy to understanding likely conceptual models in the geologic environment they are located within rather than undertaking a standard program of surveys in every instance.

With detailed geoscientific surveys conducted, preliminary conceptual models are developed (Webbison et al., 2026), analogs are identified, which allows for the identification of success criteria which include multiple resource-related and development-related considerations, namely:

1. *Expected resource capacity exceeds the minimum thresholds needed*: Capacity is calculated with a volumetric heat-in-place method, utilizing probabilistic estimates of system geometry and temperature, and recovery factors linked to the expected permeability regime (Libbey and Murphy, 2026) and is compared to thresholds for a given market
2. *Identification of neutral pH chemistry:* Initial indication of high TDS or high non-condensable gas (NCG) fluids are also identified, as these factors can impact project economics.
3. *Identification of favorable extractability considerations:* This refers to the favorability of well flow conditions (either pumped or self-discharging) and is a function of anticipated permeability, water table depth, resource enthalpy, and chemistry (namely dissolved NCG concentration).
4. *Identification of favorable accessibility*: This refers to the resource being accessible from land that is available for this intended purposes.

2.3 Small-Diameter Exploration Well Drilling – "Phase 3"

With the continued exploration and development of many of the large geothermal systems around the world, many remaining undeveloped geothermal fields are either smaller in nature and/or represent higher risk development targets. The use of small diameter wells has been seen globally as being useful as part of reducing the risk of exploring for the presence of a geothermal system – allowing a cheaper failure analysis, so capital can go towards good projects (Mackenzie et al., 2017; Gossanyi et al., 2024).

There is a trade-off between the cost of small-diameter wells and large-diameter wells, which when balanced against project risk may result in the possible skipping of this phase and moving straight towards large-diameter wells. If the costs are too high relative to the power purchase price, then consideration of not undertaking any drilling should occur as it may be likely that no economic project can be achieved no matter the productivity of wells obtained. In many cases the investment in small-diameter drilling is seen to be a worthwhile investment prior to confirmation of a power purchase agreement, as this phase of activity helps inform project viability and is indicative of project size.

Recently in the United States Ormat has been undertaking small-diameter well drilling through the use of core wells (Gossanyi et al., 2024), with good cost reductions through time. The success criteria for small-diameter drilling is seen as being:

1. Confirm commercial temperatures within a geothermal system (e.g., >130˚C, or project specific threshold)
2. Increase the knowledge of the location, extent, and hydrology (e.g., upflow, outflow, and recharge) of the geothermal system.
3. Increase the knowledge of the permeability controls of the geothermal system (e.g., faults, lithologies, feedzone controls). Image logs of the reservoir section are acquired as a standard to provide insight into fracture characteristics and the crustal stress field.

The subsurface data provided by small-diameter drilling fortifies the conceptual model of the system and a revised assessment into the economic viability of the project can be made. Part of the aim of exploration is to understand if there is not an economically viable geothermal system present for the lowest cost possible, thereby reducing the walk-away costs and enabling effective capital expenditure on more viable alternative prospects. Therefore, the main aim of small-diameter drilling is to determine the project should commence forward into large-diameter drilling.

Individual well success rates are not factored in during Phase 3, as these small-diameter wells generally cannot be utilized for production or injection purposes due to their effective casing sizes, and because it is important that risk is taken in this part of exploration to understand the spatial understanding of the geothermal system with a view to testing proposed conceptual models and increasing resource volume understanding. The aim is to ultimately increase the likelihood of the success rates of large-diameter exploration wells and the best way to do this is through the cost-effective understanding gleaned from small-diameter wells.

Having small diameter wells as existing assets during the drilling of the large-diameter wells and during flow testing has proven to be very advantageous. With the installation of downhole pressure monitoring these wells

can help develop further insights into the geothermal system during the drilling and testing of large diameter wells drilled in Phase 4 and onwards (Murphy et al., 2026).

Well production casing sizes are typically 4-1/2" up to 7" for Phase 3 drilling. Due to friction, the 4-1/2" producing casing shoes offer very limited viability for anything other than being a monitoring well, whilst the 7" production casing shoes can have some utility for injection or minor production in some very rare cases.

2.4 Large-Diameter Exploration Well Drilling – "Phase 4"

Large-diameter exploration wells, also referred to as full-size exploration wells, are drilled primarily for the purpose of being able to be used for either production or injection. We therefore start measuring success rates of each well individually in this project phase, and the primary consideration is whether the well will be able to be meaningfully utilized in a future development.

Therefore, in some instances when exploring for production, success may not be found, but at a later stage this well can possibly be utilized for injection and the success rate should be updated at a later stage.

The first stage of exploring with large-diameter wells is to explore for production. Put simply, when exploring for the purpose of production, there are three major items that impact on the wells ability to provide commercial flow:

1. Temperature
2. Permeability
3. Pressure

These parameters are critical for our understanding as we explore with large-diameter wells. There are also secondary considerations that we wish to understand, such as: natural water table, geological context of permeability, fluid TDS/gas concentration/scaling potential, etc.

A general approach for exploration well design for low-medium enthalpy fields is to drill a well with a 13-3/8" production casing, which allows for higher flow rates when pumped. In many cases this size of well is also drilled for higher temperature settings, but 9-5/8" production casings are sometimes also considered.

Production well success is defined as the ability for the well to produce a meaningful amount of geothermal energy, in many instances targeting production >5 MW, but with a minimum success criteria of 3 MW in many instances; 3 MW is the same success threshold as is utilized in Sanyal and Morrow (2012) and inferred in IFC (2013). At higher temperatures, the required permeability to flow for a fixed generation level will decrease. Therefore, the required productivity indexes will go down as temperature increases, as is shown in Figure 2 (from Murphy & Libbey, 2026). Success rates for exploration phase large-diameter drilling is generally considered confidential to respective companies, but benchmarks of 59% are reported by the International Finance Corp (2013).

When exploring with large-diameter wells, at a project level we generally are looking to do the following:

1. Prove production (first objective);
2. Prove injection capacity. This should be in a favorable configuration for the expected development, generally targeting two separate structural areas and therefore differing flow paths back to production;
3. Achieve sufficient flow rates for a long-term test (typically 20-33% of total flow required); and,
4. System delineation that informs a numerical reservoir model and development of future geologic targets

As noted above, success criteria of individual production wells are often set at a particular generation level, with specific temperature and permeability success thresholds defined. Permeability thresholds are typically defined as a productivity index (PI), based on the expected temperature range. When drilling wells, often cold fluid from drilling will mask the initial temperature data and result in the inability to determine the natural-state temperature of the well. Therefore heat-up surveys are important, and the use of short-term flow tests can assist with accelerating the heat-up timeframe, with low-medium enthalpy wells typically being able to be flowed whilst the rig and blowout preventor is still present on the well. In many instances during well testing, the only mechanism of determining permeability is through the use of an injection test. Therefore the analysis and interpretation of the conversion of an injectivity index (II) to a PI is important (e.g., Wilmarth and Azwar, 2015; Perreaux et al., 2020), and introduces uncertainty to the initial success characterization of a well as the ratio between II and PI can vary depending on things such as the geologic setting and enthalpy of the geothermal system. Ormat has made use of Pressure While Drilling (Le Brun et al., 2020) over recent years when drilling

large-diameter wells (Spielman et al., 2026), providing high-value II information in the course of drilling to inform decision making and to give good confidence in permeability understanding in real-time. Utilization of pressure-transient testing to better inform the long-term performance of a well has been of high utility at Ormat.

Success criteria of individual injection wells is determined almost solely from permeability, as measured through an II. The required level of connection and subsequent pressure support back towards production will vary depending on the geologic setting and the unique characteristics of the geothermal system itself. There is a need to try to achieve a good placement of injection wells therefore, and it has been identified at Ormat that the economics of realignment of injection once a field is in operation is very challenging. This is discussed more in Section 2.9. In addition, the costs of a long-term test can be high and there is a desire to have a very low repeat rate of a long-term test if unfavorable connectivity between injection back to production occurs. At a practical level this results in the need to explore for more than one separate injection location that ideally is structurally different with likely differing flow paths back to production. In many instances only one of these injection areas will be successful and pressure monitoring whilst doing short-term flow tests can be very informative about if there are signs of suitable connectivity to determine if additional injection well targeting is required during this phase of project before committing ahead to a long-term test. The level of permeability and therefore injection capacity per well required depends on the geologic setting and specific project conditions.

There is variability across companies for how success is measured for large-diameter wells. There are two options: (1) measure each individual subsurface leg for success, or (2) measure the overall well no matter the number of subsurface legs undertaken. One of the challenges is that public data sets generally don't show how many subsurface legs were drilled, only the overall result of a well, therefore the most common approach is to measure the overall well, i.e., the success rate per wellhead rather than per leg.

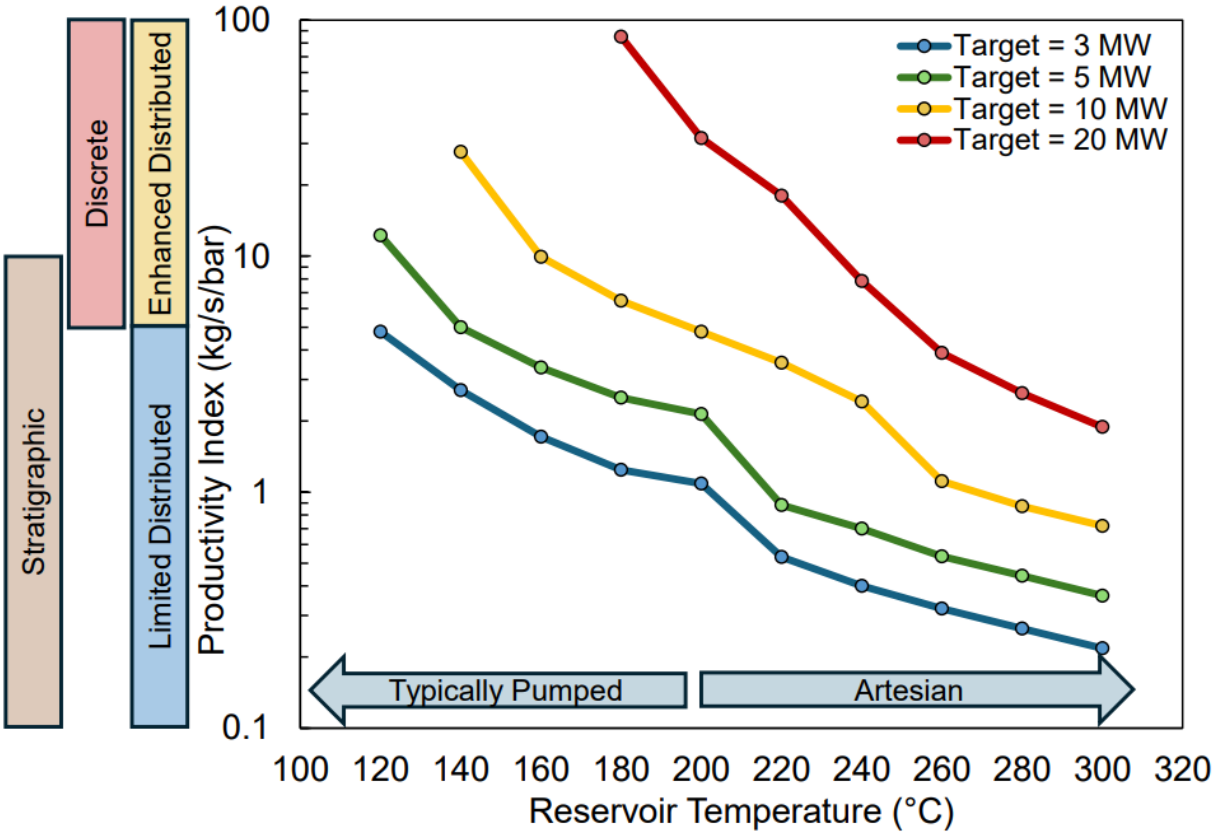


Figure 2: Productivity Index and Temperature Impact on Well Output (Net MW, Including Pump Parasitic) Reproduced from Murphy & Libbey (2026)

2.5 Long-Term Testing – "Phase 5"

Long-term testing is where fluid is produced from a production well, the liquid portion injected into an injection well, and pressure interference is measured in idle monitoring wells in the geothermal system. In many regulatory environments, the injection of the produced fluids is required and therefore often there are two main perturbations made to the geothermal system, with one being production and the other being injection. In an

ideal test the production and injection perturbations can be staged and observed separately for a time. At Ormat this is accomplished through periods of no injection using temporary surface fluid storage, or where allowed through ground soakage which provides a more robust test. Often when undertaking this testing, it is advantageous to inject in more than one location depending on the geothermal system. In some geologic settings, for example in lower temperature fracture-hosted systems, the injection of fluids and the testing through approaches such as reservoir tracer tests helps inform the conceptual and numerical models more than just pressure interference data would. This is discussed in more detail in Murphy et al., 2026.

These long-term tests need to be undertaken for a sufficiently long duration to demonstrate stability in the response of the geothermal system. Reviewing global tests has informed Ormat that a long-term flow test should be conducted generally for 60-90 days, with a base-plan of 60 days and the ability to extend further as-required based on results, and a goal of testing 20-33% of total flow required for a project (Murphy et al., 2026).

The success criteria of a long-term test are:

1. Confirm the ability to produce and inject into the wells in question at desired flow-rates
2. Confirm low risk of rapid cooling or major production issues (i.e. significant pressure changes)
3. Collect high-quality chemistry information for constraining the geochemical understanding of the system (i.e. geothermometry; indications of fluid types and their locations; NCG content) and production challenges (i.e. scaling or corrosion risks)
4. Collect sufficient interference data to calibrate a reservoir model that allows for reliable forecasts decision making. In appropriate permeability regimes and depending on well spacing, this often includes the undertaking of a reservoir tracer test. A reservoir tracer test is standard in low-temperature, fracture-hosted systems typical of the Great Basin, USA



Figure 3: Long Term Testing at a recent Greenfield Project in USA

2.6 Numerical Reservoir Model Build & Scenarios – "Phase 5"

Once a long-term test has been undertaken successfully, the project then moves formally into the finalization of a numerical reservoir model. Based on the understanding gained throughout the previous phases, early construction of reservoir models may have commenced to help accelerate this phase. The reservoir modeling process generally has three phases: (1) natural state modeling, (2) history matching, and then (3) forward scenario forecasting. The modeling approach is covered in more detail in Murphy et al. (2026).

It is important that the reservoir model is conceptually realistic, and therefore the approach of documenting the conceptual model up until this point needs to be done well (Webbison et al. 2026). The reservoir model process benefits from external review by an experienced and trusted expert, helping to prevent bias being present in the numerical model. To improve the reliance on the conceptual model and the uncertainties present, meaningful review of the conceptual elements and model itself is highly advised.

The following outcomes will come out of the reservoir model:

1. Confirm starting resource capacity and design points
2. Provide forecasts for enthalpy and flow rates
3. Validate development drilling strategy
4. Sufficiently informs the financial model for key parameters allowing a business decision to be made to progress the project

The success criteria of this stage of the project is that the model can be relied upon for its reasonableness of its forecasts and is able to test sensitivities in a meaningful manner, with a path forward towards a project that is economically viable.

2.7 Project Release – "Phase 5"

Upon the completion of a reservoir model, that can be relied upon for its reasonableness of its forecasts, forecasts are provided to the engineering team and to a development team (which is the Projects team at Ormat) to undertake an iterative design and project optimization. In this process various configurations are tested, such as a larger and smaller project than the base case, varying locations of wells and changing injection temperatures.

The success of this stage is that an optimum project development is determined and that it passes the economic thresholds of the investors in the project. In some markets the power purchase agreements only allow for a certain amount of generation decline to take place throughout the lifetime of a project. Generally, in higher enthalpy systems, any decline in resource temperature or pressure results in make-up wells to be drilled to maintain generation levels. In low/medium enthalpy systems, especially pumped-binary systems, temperature decline over the project life for a fixed flow rate results in generation decline through the life of the project. This is a normal occurrence and needs to be allowed for under the power purchase agreements to a reasonable level.

Experience at Ormat and other developers is that the appropriate initial development may be smaller than the resource potential and the field is optimally developed in multiple phases. Expansion projects are discussed more in Section 3.1.

One of the key outcomes as a project moves through a Project Release and forward out of Phase 5 is also the identification and contextualization of the level of resource-related risk going forward for the project into the development (e.g., risks associated with development drilling) and into operation (longer term performance risks and the likely range of the number of wells in Phase 7).

2.8 Project Construction (Development Drilling) – "Phase 6"

In this phase of the project, large-diameter wells are drilled with success criteria of individual wells very similar to that described for Phase 4. The goal of Phase 6 drilling is to achieve the project requirements for the production and flow rates overall, with sufficient additional buffer to allow for decline upon start-up.

Once a drilling campaign for development is completed and a power plant is commissioned, it is typical to not require additional drilling for 2 years+, so sufficient buffer is required for this purpose. Remote locations that have high mobilization costs may also be a consideration to cause additional drilling to lower the cost of additional wells that will be required later, however this needs to be traded off against the additional information gathered from the operation and optimal well placement that would subsequently follow if drilling was done at a later date.

Often the drilling sequence for development drilling is a complex and challenging thing to determine. In general construction of infrastructure (pipelines, wellpad power etc) should only occur to locations where there is a high degree of confidence in the success of drilling in that location. Therefore, it is better to take risk early into a campaign rather than on the back end from a risk management approach, wherein earlier drilling helps confirm assumptions and designs of infrastructure, with sufficient time to respond to unexpected outcomes. In some jurisdictions permitting or financing may also constrain the drilling sequence, for example where there is a long time period between drilling and injection well and before it is able to be utilized.

The success of this stage is that production and injection capacity is sufficient for the constructed power plant, with a suitable buffer to allow for decline in the early period of operations.

2.9 Reservoir Management / Operations (Reservoir Response & Replacement Wells) – "Phase 7"

Through the active operation of a geothermal field, there are often changes in the reservoir parameters that effect a wells performance, these being one or more of the following: temperature, pressure or permeability. These

reservoir parameters generally result in the performance decreasing of an individual well, necessitating new wells to be drilled to make-up for the performance decline. Therefore wells drilled in this phase are often referred to as being "make-up" wells. Alternatively, there is acceptance of the performance decline and subsequent generation decreases through time. However, there can also be performance improvements of an individual well through time, for example in production wells a pressure reduction can subsequently result in reservoir boiling that can result in performance increases due to increasing steam fractions, as is shown in the earlier operation of the Mokai geothermal field in New Zealand (Melia et al., 2022). When performance increases occur, generally these result in the deferral or can completely take away the requirement for new wells.

Mechanical failures of wells, due to things such as casing collapses or parted casing from thermal shock, can result in a step-wise reduction in capacity of a well and therefore a replacement well may need to be drilled, often relatively quickly. When these occur, if the reservoir performance is good from that location, generally wells are drilled to twin the original well and there is often a very good success rate associated. Having a good conceptual model understanding of the field, that is refreshed at a reasonable frequency, assists in optimizing well targets if a mechanical well failure occurs and production is subsequently reduced (Webbison et al., 2026).

An important observation at Ormat has been that the economics of optimizing injection once a field has commenced operation can be challenging to meet investment thresholds for material changes. Often the benefits of optimizing cooling are over a very long-term, so the time-value of money makes these economics challenging. The exception to this is if there is significant and immediate detrimental impacts from injection to production, which generally does not occur if there has been a long-term test with sufficient quality that has taken place. The reality of these challenging economics to do material changes to the injection configuration after a new power plant comes online puts more focus on (1) during exploration drilling focusing on attempting to explore for more than one injection location to ensure optimization of injection is done from the start, and (2) ensuring a high quality long-term test is conducted.

Through time, success rates of Operations wells should increase as knowledge of the field increases, however when a field is over-developed or there are late-stage issues success rates can decline. This is partly economic; where you have existing infrastructure on the surface that is now under-capacity, the economics of wells with a lower success rate still are good. But it is also reflective of the need to often step-out and undertake some level of exploration to test new areas or possible boundaries of a geothermal field. If power prices lift through time, such as for example with new power-purchase agreements, this creates a strong economic return that can tolerate lower success rates.

Expansion of operational geothermal fields is discussed in more detail in Section 3.1 "Expansion Projects".

3 DISCUSSION

Breaking up geothermal projects into respective phases assists with clarity on tools utilized and what makes sense with regards to measurements of success rates. There are very limited studies that publish success rate data in a meaningful manner, with the most important study being the ESMAP study (International Finance Corporation, 2013) with the benchmarks shown in Table 1. There is a lot of subtlety to the method of measurements in this type of study, for example not counting individual well legs and only the overall well result, which warrants insight when looking at the overall benchmarks of this study. Another major item is that these studies are based on historical geothermal fields, which have been generally larger and more forgiving than future geothermal fields.

Table 1: ESMAP Drilling Success Benchmarks (International Finance Corporation, 2013)

Phase of Drilling	Success Rate Benchmark
Exploration	59%
Development	74%
Operations	83%

Ormat internal data has shown that *Expansion* warrants its own category. This is discussed further in the next section.

3.1 Expansion Projects

Expansion projects occur when an operating field has its installed capacity increased associated with a mass/flow rate increase. Unless a field is significantly underdeveloped relative to its potential (Libbey & Murphy, 2026; Murphy & Libbey, 2026; Libbey et al., 2024), reviewing global case studies as well as Ormat's own history has resulted in a general rule that there should be around two years of operational monitoring to inform a reservoir model and a subsequent investment decision about expansion. This time period also allows for any observation of unexpected operational conditions, such as calcite scaling, to be observed and factored into any expansion consideration through updating economics and decline assumptions etc. With Ormat developments generally taking around two years to execute, this results in an approximate four-year expansion cycle.

As part of the identification of opportunity for expansion there may be a requirement to confirm additional volume to a resource before an investment decision is considered and therefore wells need to be drilled that in some instances are considered *Exploration* type wells. At the same time, these wells are in an operating field and so could be considered *Operation* wells. We would expect that these wells generally have higher success rates than typical *Exploration* wells, but likely lower than *Operations* wells due to the step-out nature. Once an expansion is committed to, then the wells are more like *Development* wells, and would typically have a higher success rate for these wells than typical *Development* wells because the understanding of the geothermal system is higher than a true greenfield development. Success rates therefore are likely to be a blend of *Exploration, Development* and *Operations*, and it would be fair to assume a success rate higher than typical *Development*, but lower than *Operations*.

3.2 Success Rates of Projects compared to Wells

With a large and active portfolio, Ormat is progressing numerous projects at once and through time will be in a position to identify in a statistically meaningful manner the success rates of individual projects as they move through each project phase. The establishment of clearly articulated project phases, alongside success criteria to move into the next phase, enables improved forecasts on how many projects need to come into the portfolio and to understand the impact of project timeline changes. An example would be to skip small-diameter drilling and move straight to large-diameter drilling to attempt to accelerate a project.

3.3 Approach to Success Rates of Small-Diameter Wells

Given the relatively sparse public data of true success rates, numerous studies have been conducted through time to try to take publicly available data to help understand what has been historical success rates. An example is Shevenell (2012), where a key part of the study was looking at what was tagged in the regulatory process as being exploration wells and then at a later stage seeing how many of these wells were being utilized in operation. A major challenge to this approach is that many exploration wells are in fact small-diameter wells and that these are not intended to have utility in the operation phase for either production or injection, and therefore the statistics are subsequently artificially lowering the actual success rates for large-diameter exploration wells that are intended to have utility if successful.

Additional discussion was made in Section 2.3 about why we don't measure individual success rates of small diameter wells. Through time and with exploration of enough projects, further insights will be gleaned into the impact of small diameter wells on the success rate of full-size drilling.

3.4 Approach to Success Rates of Monitoring Wells

Monitoring wells are typically drilled for regulatory or reservoir management purposes. Often the most important parameter to measure is pressure and the required permeability to be able to measure a pressure response is often very low. Monitoring wells are sometimes also drilled to be able to measure temperature to observe cooling fronts, or to enable geochemical samples to be collected. It is very common that monitoring wells are required solely to monitor for potential environmental effects of the geothermal development, and therefore some countries or regulatory jurisdictions have significantly different numbers of these wells compared to others.

Due to the highly varied requirements of monitoring wells which differ significantly across different regulatory frameworks and jurisdictions, it is not recommended to measure success of monitoring wells. Monitoring wells are explicitly not included in success criteria at Ormat accordingly and are not recommended for other companies for tracking success rates.

3.5 Managing Risk

Throughout the history of geothermal exploration and development there has been a need to manage the risk through the lifecycle of a project's exploration, development and operation. One of the challenges that has been observed at a macro level is about when is the best time to take risk and how large of a risk to take; for example, the decision to step out to prove more volume. As a general rule, without over-capitalizing on a project too much, it is better to take risks earlier than later to such that the results of the risk may be factored into the conceptual model and development plan. This becomes very important during the *Development* phase because of the parallel construction activities of pipelines and other infrastructure.

Reducing risk in well drilling success rates is often achieved through twinning wells and therefore this can increase the risk of insufficient spread of production and/or injection in a geothermal field, increasing the risk in the long-term performance of a field through things such as: increased likelihoods of well interference; channelized flow causing increased cooling trends or insufficient heat-sweep. This may also lead to efforts to reduce individual well costs through targeting shallower reservoir depths, instead of realizing the benefit of drilling deep enough to increase the volumetric size of the produced resource.

3.6 Future Work

We at Ormat aim to publish our success rates through time, with clarification on the methods employed to calculate success or failure, with a discussion of the pro's and con's of these methods, and any limitations to the work. We would like to assess success rates through time in various geologic environments, e.g., the *Permeability Regimes* described in Libbey and Murphy (2026).

Historically success rate benchmarks have been limited to *Exploration, Development* and *Operations* wells and it would be worthwhile to further investigate representative success rates for *Expansion*.

4 CONCLUSION

Defining the Ormat Development Process into the respective phases has been highly advantageous to increase the level of tracking, system-level thinking and to be more enabling for improvements in the delivery of projects through time. With such a large portfolio of operational fields as well as fields across both exploration and development, the need for system-level thinking is more elevated at Ormat than most other respective geothermal companies. The end goal of this is increase online installed capacity in the most economic manner as is possible, and in a timely manner. A major driver of these elements is to have good success rates of the wells drilled.

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