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A modeling analysis of unitized production: Understanding sustainable management of single-phase geothermal resources with multiple lease owners

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ABSTRACT

A generally acceptable rule is that a geothermal lease is indivisible by its nature. Thus, production from any part of a unit affects all leases within the unit. One serious risk involved in the adequate and sustainable development of geothermal resources originates from multiple lease owners in the same area. Having two or more lease owners for a given resource area situation leads to the potential risk of offset production and interference effects between adjacent developments using the same resource. This can lead to legal entanglements and potential resource sustainability issues.

A well-known approach for the multiple lease owners' problem is unitization. Unitization, in simple wording, is the unit based operation of a geothermal resource by consolidating or merging the entire field or a substantial part of it as a single entity and designating one or more of the parties as operator.

This study outlines the importance of unitization on the geothermal resource development. Synthetic examples are used to quantitatively show the benefits of unitization. Lumped parameter models are used for modeling reservoir performance. The results of the lumped parameter modeling approach are discussed for better understanding the reservoir performance in terms of pressure and temperature and to demonstrate the interference effects when more than one lease owners tap the same reservoir. The results help to appreciate the problems of having multiple lease owners in the same area.

1. Introduction

Nearly 300 geothermal resource areas have been identified in Turkey. The commercial development of geothermal power and direct use has led to installations of power plants with a combined capacity of over 400 MW_e and a combined capacity of 2800 MW_t is for direct use as of December 2014. Most of this development has occurred in the last decade.

In the last five years, MTA, the Mineral Research and Exploration General Directorate, has held several auctions of geothermal licenses as part of an effort to engage private companies in the development of Turkey's geothermal resources. MTA offered more than 85 geothermal licenses in areas where some exploration work has been done (Dagistan, 2012). Any wells MTA has drilled in the licensed areas is transferred to the new holder. The fields offered have different resource characteristics. Several of the geothermal resources initially investigated by MTA are now generating power. Majority of the licenses and thus resources are offered to the private sector and/or local entities such as municipalities for continued development. Most of these fields are poorly understood geothermal areas with limited information about the resources. MTA opened up the competitive bidding process to accept nominations from qualified companies for geothermal lease. However, in some instances, the same geothermal resource or field is shared by more than one lease, which sets up risk of offset production and detrimental interference between adjacent developments that tap the same resource (Tureyen and Satman, 2013).

The mitigation strategy for the problem of multiple lease owners (license-holders) in the same resource area could include the encouragement of unitization, establishment of the basis of a unitization policy and legislation as well as exchange of data and information about licenses. It is expected that as the geothermal industry matures, there will be consolidation of geothermal resources through trading or joint ventures.

The current law in Turkey generally treats geothermal resources as a mineral right. Each owner in the lease underlain by geothermal resources has the right to produce his just and

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Nomenclature

A	area, m^2
c	rock compressibility, 1/bar
C	specific heat capacity, J/kg/°C
k	permeability, m^2
p	pressure, bar
t	time, s
w	net mass flow rate (=production rate – reinjection rate), kg/s

Greek letters

α	recharge constant, kg/bar/s
β	rock thermal expansion coefficient, 1/°C
ϕ	porosity, fraction
κ	storage capacity, kg/bar
ρ	density, kg/m^3
μ	viscosity, Pa s

Subscripts

0	initial conditions
Δ	difference operator
i	injection
r	rock
re	recharge
p	production
ss	steady state
t	total
w	water
1,2	inter-lease

equitable share. Although this situation defines ownership rights to geothermal fluids and geothermal resources, it is unclear, in a split estate situation, which owner has the right to develop the resource. This ambiguity could result in significant confusion over whether lease owners have the right to convey an ownership interest in the geothermal resources where such rights have not been determined clearly. The statute provides that geothermal resources are the private property of the lease holder of title to the surface land above the resource. The owner of the surface estate owns and can therefore separately dispose of this property right. It is clear that the owner of real property owns the rights to the underlying geothermal resources unless they have been reserved by or conveyed to another person.

The regulations existing in Turkey grants surface owners the rights to any geothermal fluid that lies below the surface. The rule of capture grants rights to geothermal fluid only upon extraction. Ownership of the in situ stock cannot be established without controlling all of the surface access to the reservoir. The migratory nature of geothermal fields makes it prohibitively costly for a surface owner to defend rights to "their" stocks against neighboring leases. Surface landowners routinely transfer rights, through lease contracts, to firms that specialize in exploration and production of geothermal fluid. Through this process of leasing from multiple surface owners, many firms can gain access to a single reservoir.

The rule of capture gives each firm the incentive to drill and drain without regard for the effects on total reservoir production. Economic waste follows with high capital costs (duplicate wells and surface facilities), with reduced total heat recovery, and with intertemporal misallocation of production.

Geothermal project development poses some novel challenges for two-party and multi-party development of projects. Geothermal development, including substantial geological and geophysical work as well as drilling during the exploration stage, is often very expensive. The magnitude and timing of these development costs are difficult to predict in advance. Also, the appropriate sequence of steps in the development process is highly technical matters and is often highly discretionary. As a result of these realities, owners often struggle to negotiate workable agreements respecting the control of development and the obligation to fund development at different stages.

Unitization procedures offer another tool for facilitating joint development where a resource is partially controlled by multiple parties. The purpose of the Unit Agreement is to bring together the properties associated with a specific geothermal resource in order to coordinate the efficient, productive development of that resource by having the parties agree to aggregate the land and allow a single operator to undertake the development. There has been significant concern that having separate parties and operators attacking the same geothermal resource from adjacent lands will result in the wasting or inefficient use of the resource.

1.1. The geothermal energy conservation and sustainability

Typically, a geothermal reservoir may exist in a variety of states, with or without two phases (liquid + gas) and with a strong or weak natural recharge. The energy which drives the geothermal fluid to the producing well is provided mainly by the expansion of gas (steam and/or non-condensables such as carbon dioxide) in the two phase conditions and displacement by water when an active natural recharge is present. Rock and water expansion are also production mechanisms however of a smaller magnitude. As the geothermal fluid is produced from a well the reservoir pressure is decreased and the neighboring area is drained. The extent of this drainage depends upon subsurface pressures, temperatures, and the permeability and porosity of the reservoir rock. These characteristics vary across the reservoir generating variation in well productivity. As more wells are drilled, the reservoir is drained more rapidly and, without outside pressure support, the reservoir pressure decreases. At the same time, increases in the rate of production may in certain cases (such as production from the lower temperature parts of the reservoir), reduce the heat recovery of the entire reservoir. Steam (gas)–liquid water ratios increase as reservoir pressure decreases resulting in inefficient production of the reservoir liquid and dissipation of reservoir energy. In case of cooler natural recharge, the reservoir cools.

The strong natural recharge drive mechanism often found in geothermal reservoirs moves water toward the production wells. It is obvious that those wells near the natural recharge boundary will be positively affected by recharge. Those wells at the greater distance from the boundary would get less pressure support. In view of the fact that the location of the natural recharges boundary and the distance of the wells to the boundary is a highly significant factor in the recovery and productive life of a property. It is only natural that the leases that are closer to the natural recharge boundary have greater pressure support and hence a more sustainable lifetime compared to leases that are farther away from the boundary.

The sustainable management can be defined as managing the use, development, and protection of geothermal resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well-being and for their health and safety while; meeting the needs of future generations, safeguarding the environment and avoiding, remedying, or mitigating any adverse effects of activities on the environment. In short, sustainable management is defined as the sustaining of the potential of natural and physical resources to meet the reasonably foreseeable needs of future generations. Sustainably managing a region's total geothermal resource should be preferred to managing individual systems sustainability. Thus, unitization of designated