GeoHackathon Field Development Plan Report

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1. Recommendations:

- Outline development plan includes all 12 available wells + 6 additional production wells (P11-P16) (**Figure 1**)
- D1 demand point connected to 4 producers and 4 injectors
- D2 demand point connected to 5 producers and 5 injectors
- LCOH (20 years): D1 - 4913€/MWh, D2 - 4325€/MWh

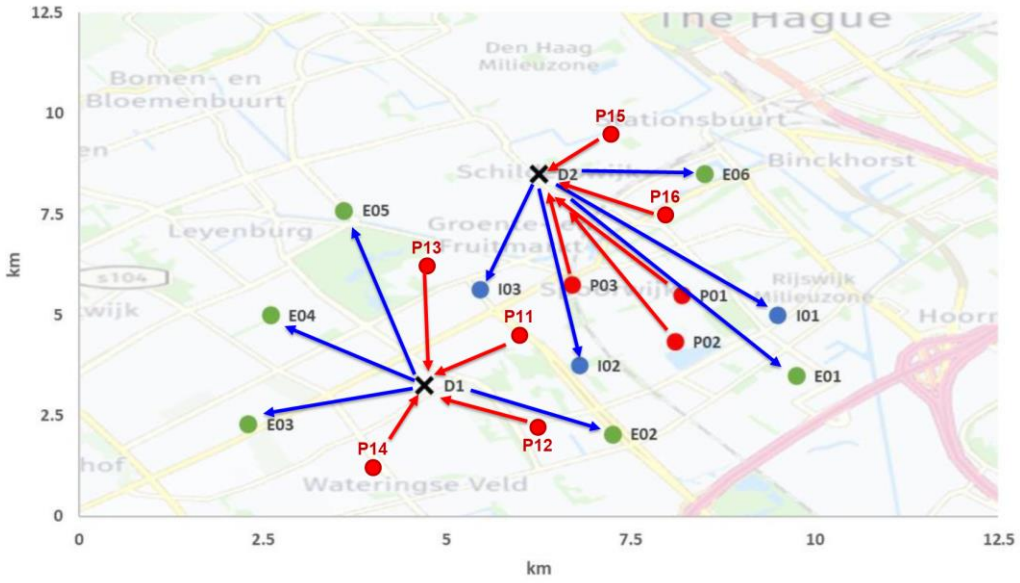

Figure 1–D1/D2 demand areas development plan with surface piping connection

2. Short background of the project

- In this project, we designed a development plan for a 12.5 km x 12.5 km block. We primarily focussed on fulfilling the demand for the energy at the demand locations D1 (80MW) and D2 (100MW). This demand is fulfilled by introducing six new injector wells in the field. We simulated various scenarios with different well locations, and different injector-producer pairs to optimize the cost of the field development while maintaining the generated energy from the field development plan. The locations of the

newly drilled wells are decided based on the porosity and permeability maps. Later, these wells were simulated for 20 years using the darts simulator. The locations with least expenditure and optimum energy generation were selected to make the development plan. The levelized cost of heat is calculated for different scenarios and compared, the best scenario with least levelized cost is presented in the development plan.

3. Information that was used

- Subsurface data was purchased based on available budget, which is established at €120,000. The data base has a total of 12 wells with logs and well test as shown Figure 2. The selection criteria defined in the well data acquisition process was 1) choose pair of injector and producer close to demand locations and 2) add exploratory wells on the periphery of demand locations. Figure 2 shows a map with 2 demand locations and 12 wells highlighting the 6 purchased wells with associated cost per data.

Well	1 Log	1 Test
I03	€10,000	€15,000
P03	€10,000	€15,000
I02	€10,000	€15,000
E05	€10,000	0
P02	€10,000	0
E06	€10,000	€15,000
Sub-Total	€60,000	€60,000
Total	**€120,000**	

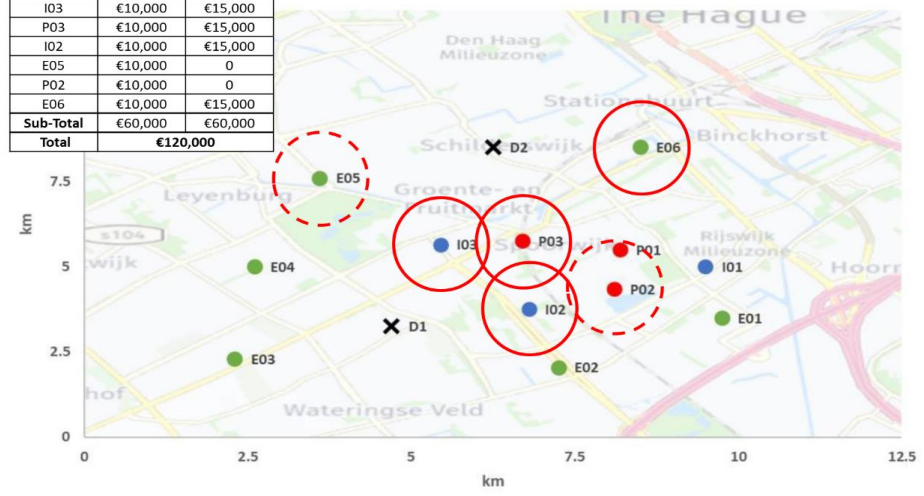

Figure 2–Map view showing wells and demand locations. red circles enclosed 6 purchased wells. Data acquisition costs are described in the Table.

- The purchased data is made of six (6) Sonic logs and four (4) well tests. From the sonic log, it was estimated porosity by using Wyllie *et al.* 1958 equation. It established that interval transit time (Δt) depends on both lithology and porosity filled by a fluid (See **Equation 1**).

Equation 1

$$\Phi s = (\Delta tlog - \Delta tma)/(\Delta tfl - \Delta tma)$$

where Φs = sonic derived porosity,

Δtlog = interval transit time in formation (log value)

Δtma = interval transit time in matrix, defined as sandstone (182 µs/m)

Δtfl = interval transit time in formation's fluid, defined as brine (620 µs/m)

- From well tests, it was estimated average permeability by using transient solution as proposed by TU Delft, Sandford, in DARTS (https://darts.citg.tudelft.nl/). **Figure 3** shows an example of I02 well test pressure data and transient solution estimation. **Table** 1 summaries well property data for the purchased 6 wells. Permeability log was estimated by using a logarithmic function that honours the average permeability and average porosity of 4 wells (P03, I03, P02, I02) shown in **Table 1**.

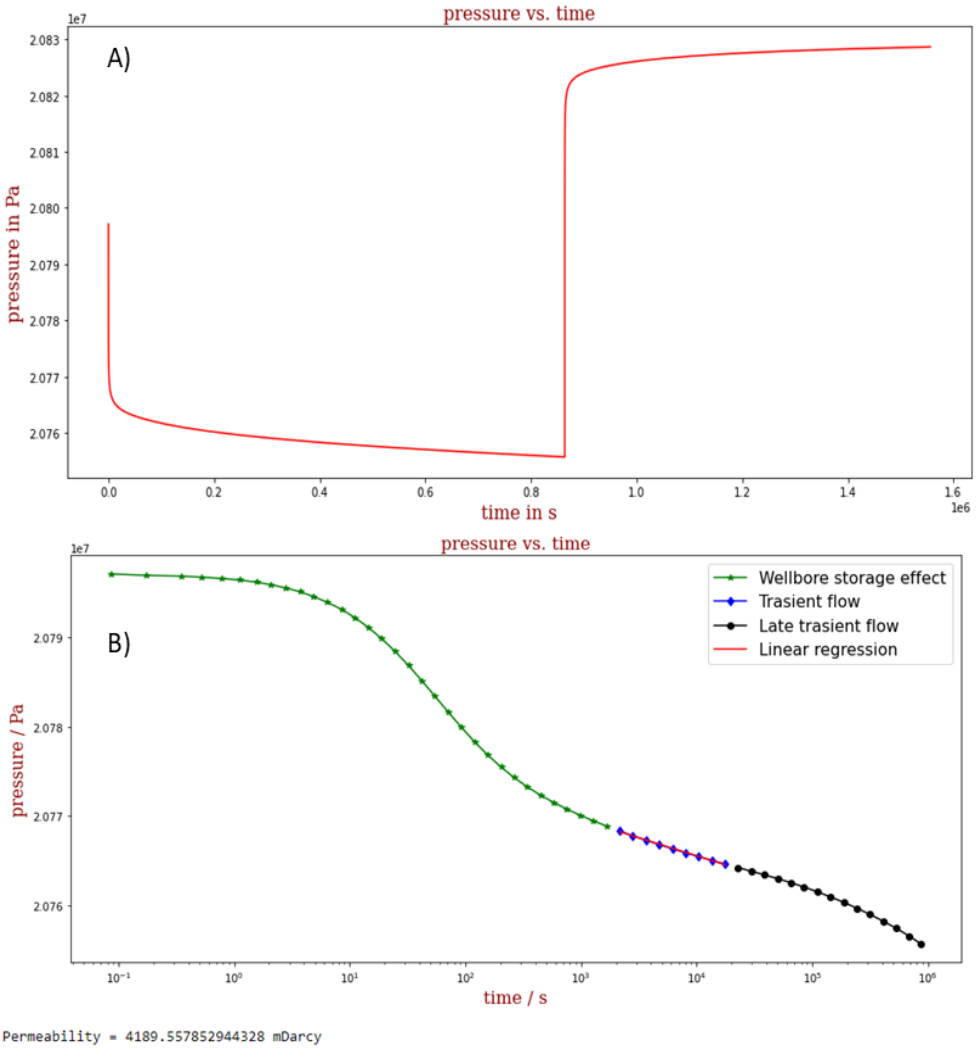

Figure 3–A) Well pressure test data. B) Well transient analysis and estimated permeability

Table 1–Well property data

Well	Top(m)	Bottom(m)	Thickness (m)	Av. DT (µs/m)	Av. PHI (frac)	Av. Perm (mD)	Temp(K)	Pi(bars)
P3	2060	2200	140	249.46	0.154	3719.38	350.29	210.29
P2	2137	2211	74	242.91	0.139	2532.07	347.41	209.21
I3	1974	2144	170	236.98	0.126	3516.63	350.64	210.30
I2	2017	2051	34	252.50	0.161	4189.56	346.25	208.29
E05	1842	1981	139	231.31	0.113	-	-	-
E06	1968	2045	77	242.68	0.139	-	-	-

4. Methodology

- A 3D grid was built using the same dimensions as DARTS model with the following resolution: 230 cells in X direction, 206 cells in Y direction and 95 layers, with a cell size of 50m x 50m x 4m. The model has a total thickness of 380 meters considering the highest and deepest depth of the well data. Stochastic methods were used to calculate sonic, porosity and permeability in the reservoir. For that purpose, sonic, porosity and permeability log were scaled up permitting a variography analysis in the reservoir. Gaussian Random function method was used for the propagation of these petrophysical properties. **Figure 4** shows a perspective view of 3D porosity and permeability properties with the available data. D1 and D2 represented as wells are the demand location points.

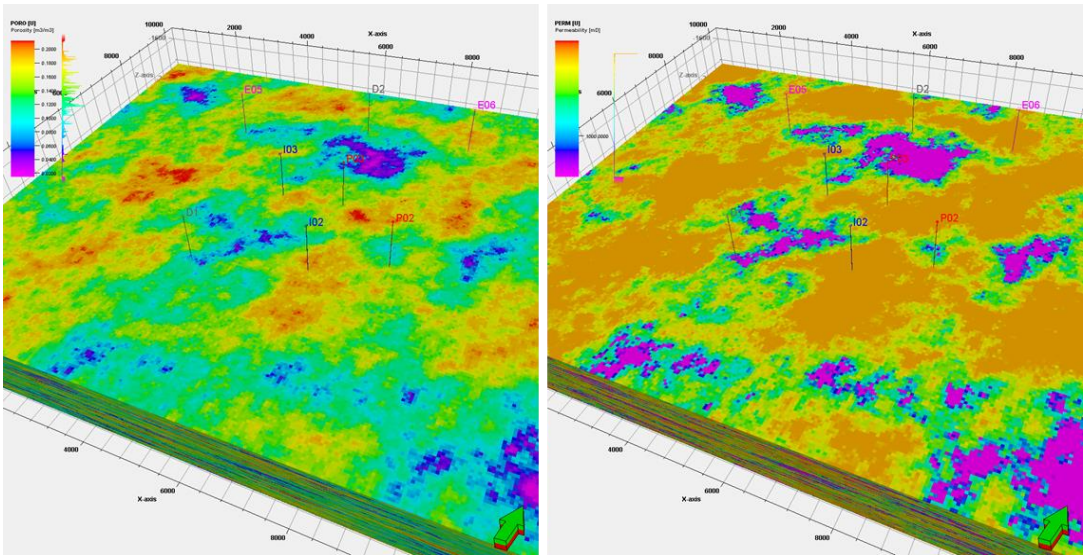

Figure 4– Perspective view of 3D porosity (left) and permeability (right) properties showing available wells

- Since there is no information about the geology of the area, an uncertainty analysis was performed considering the spatial variability, trends, and connectivity patterns. This was evaluated by using Monte Carlo analysis with the aim to identify a P50 case. From petrophysical properties of this case, it was created arithmetic average maps as shown in **Figure 5**. The maps were used to identify locations of potential wells that permit to cover the energy demand in locations D1 and D2. **Figure 5** shows the arithmetic porosity and permeability maps with 6 new producer wells (black) and existing wells (producers in red, injectors in blue and exploratory wells in pink).

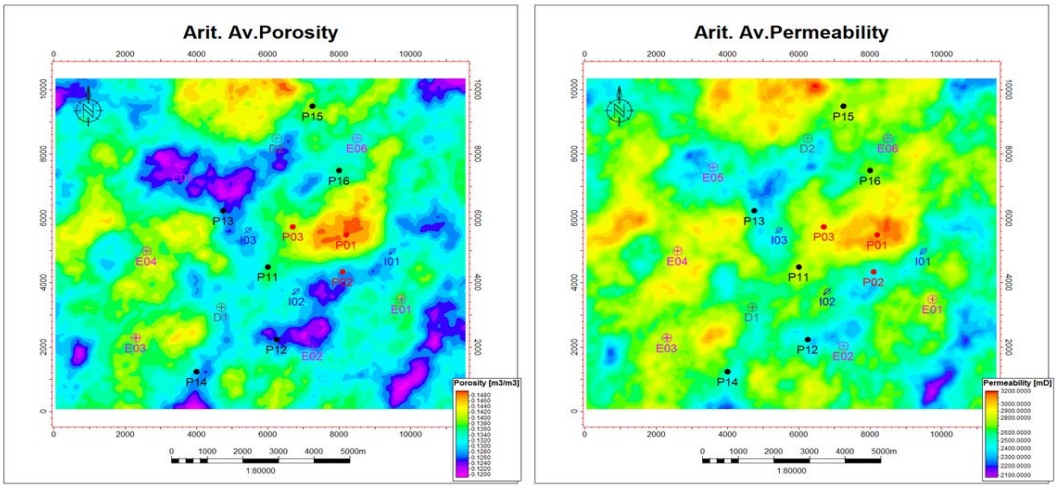

Figure 5–Arithmetic Average of porosity (left) and permeability (right) showing the existing wells, demand locations D1 and D2 and proposed wells P11, P12, P13, P14, P15 and P16.

5. Results

- The length of surface piping is 56.6 km
- The total cost of piping installation is €34M (**Figure 6**)
- The net volume of the produced and injected geothermal fluid equal to zero
- Demand for 20 years: D1 - >80 MW, D2 - >100 MW (**Figure 7**)

COST	D1	D2	BOTH
Drilling per well	16,452,000.00 €	8,226,000.00 €	24,678,000.00 €
Injection Pump per well	4,800,000.00 €	6,000,000.00 €	10,800,000.00 €
ESP per production well	11,200,000.00 €	12,800,000.00 €	24,000,000.00 €
VSD per production well	1,200,000.00 €	600,000.00 €	1,800,000.00 €
Christmass tree per new well	1,000,000.00 €	500,000.00 €	1,500,000.00 €
Degasser per doublet	4,000,000.00 €	5,000,000.00 €	9,000,000.00 €
Heat exchanger per doublet	8,000,000.00 €	10,000,000.00 €	18,000,000.00 €
CHP per doublet	6,400,000.00 €	8,000,000.00 €	14,400,000.00 €
Filter per demand location	90,000.00 €	90,000.00 €	180,000.00 €
Piping	12,832,423.84 €	21,125,698.34 €	33,958,122.18 €
CAPEX	65,974,423.84 €	72,341,698.34 €	138,316,122.18 €
Inj Pump (OPEX)	1,200,000.00 €	1,500,000.00 €	2,700,000.00 €
Christmass tree (OPEX)	1,600,000.00 €	2,000,000.00 €	3,600,000.00 €
Degasser (OPEX)	300,000.00 €	300,000.00 €	600,000.00 €
Heat exchanger (OPEX)	200,000.00 €	200,000.00 €	400,000.00 €
CHP (OPEX)	2,000,000.00 €	2,000,000.00 €	4,000,000.00 €
Filter (OPEX)	1,400,000.00 €	1,400,000.00 €	2,800,000.00 €
Piping (OPEX)	377,889.68 €	622,110.32 €	1,000,000.00 €
OPEX	7,077,889.68 €	8,022,110.32 €	15,100,000.00 €
TOTAL COST	73,052,313.52 €	80,363,808.66 €	153,416,122.18 €

Figure 6–Project development cost calculation

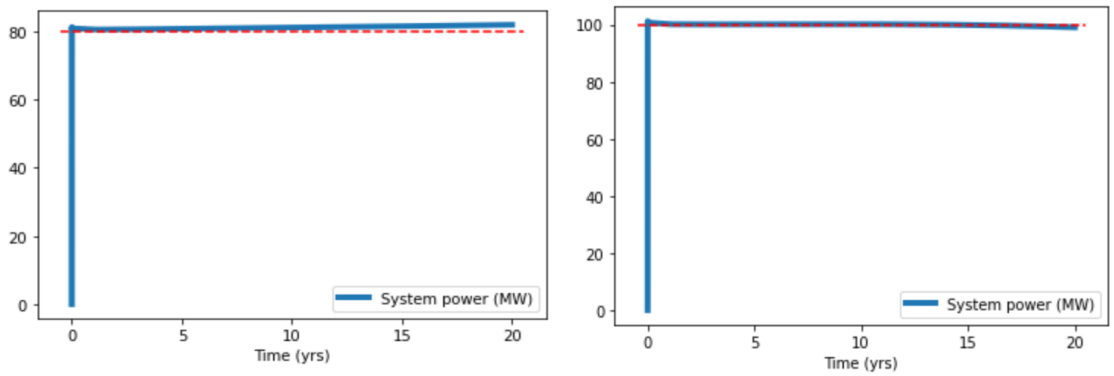

Figure 7–Demand for 20 years – D1 (left) and D2 (right)

6. Conclusions

- Well data was acquired based on the specific criteria with the aim to build a 3D reservoir model with porosity and permeability properties. They permitted as to identify the connectivity patterns for the location of 6 produced wells to achieve energy demand in D1 (>80MW) and D2 (>100MW)
- Proposed development plan requires drilling of 6 additional production wells (4 for D1 and 2 for D2 demand)
- LCOH for 20 years: D1 - 4913€/MWh, D2 - 4325€/MWh
- CAPEX - €138.3M (including €34M for 56.6 km of piping). OPEX - €15.1M