TRUST

High resolution monitoring, real time visualization and reliable modeling of highly controlled, intermediate and up-scalable size pilot injection tests of underground storage of CO_2

Contract #309067

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Executive summary

This deliverables summarizes the drilling activities that took place at Heletz in the frame of TRUST. The plan was to drill three wells to a depth of ~300 m for seismic monitoring and one well to a depth of ~1650 m for the purpose of direct monitoring. Due to budget restrictions we had to cancel the drilling of the deep well. The seismic wells were drilled as planned.

Keywords	Drilling, seismic monitoring.

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1. Objectives

This deliverable describes the drilling activities that were undertaken at Heletz in the frame of TRUST. Originally we planned to drill three relatively shallow wells (depth of 200-300m), down the bottom of the Saquiya clay formation below the Pleistocene (see below) fresh water aquifer, for the purpose of seismic monitoring and a deep well to a depth of ~1650 m for the purpose of monitoring the reservoir. We performed all the activities in order to obtain drilling permits for all the wells. However, due to budget restriction imposed on EWRE after the beginning of the project we decided cancel the drilling of the deep well. The drilling of the shallow seismic wells was conducted according to the plan.

2. Regional Geology

The Coastal Plain of Israel is compound of layers of Alluvium, Sand-dunes, Calcareous sandstone, Loam and Clay layers. Two strata groups are included in the Plio-Pleistocene sequence: the Saquiya and the Kurkar (**Figure 2.1**).

The Kurkar group, which ranges from early Pleistocene to Holocene in age, is composed of calcareous sandstone (known by the local name "Kurkar"), reddish clayey-silty sandstone (known by the local name "Hamra"), siltstone, marls, conglomerates, dark swamp clay-stones, and unconsolidated dune sands. The Kurkar group is unconformity overlaying Yafo Formation marl and clay, having a width reducing from 200 m to few meters eastwards (**Figure 2.2**).

In the west, along the seashore, there is a strip consisting of sand dunes extending to approximately 5-6 Km to the east. The sand is mainly composed of quartz grains and shell fractions. Stability stage differ from loose sand near the seashore, to cemented sand, or alternating layers of sand and calcareous sandstone. The sand dunes were created by Aeolian processes (deposited by the wind), and are characterized by a south-north ridge and asymmetric shape. The strip of dunes is bordered on the eastern side by Kurkar ridges.

Most of the Meditarenian coastal plain of israel is overlain by thick deposits of Calcareous sand ("Kurkar"). The sand is mainly composed of quartz grains and shell fractions, and it is cemented at varying degrees. Whether it is gravel sized concretions of calcareous sandstone embedded in relatively clean sand or sandstone layers of considerable unconfined compression stress, it is described as Kurkar. The Kurkar sandstone is the main water-bearing layer of the Pleistocene, Coastal Aquifer.

The Kurkar layers are unique and are typical to the coastal azone of israel and Tel Aviv area. Most of the Kurkar formations have structure, which is a reflaction of the relative amount of calcareous concretions. In many locations, along the Israeli coastal plain, Kurkar cliffes stand unsupported to heights of more than 30 m (Weizman, Hayati, & Frydman, 1970).

Red sand soils, also known in the local name as "Hamra", are generally found along the flanks of the Kurkar ridges. This soil is more characteristic of the eastern region. Hamra soils were probably created by mixture of sand particles, eroded from Kurkar ridge, with eolian materials or fine particles of alluvial

soils that were deposited along river streams. The reddish color relates to the oxidation of minerals containing iron. Loamy soils formed in two shapes: (i) as lenses and thin layers inside the Calcareous sandstone complex; (ii) As large irregular bodies.

The Kurkar layer is separated by intercalating clay layers of marine origin stretching from the coast line to up to 7 Km eastward. They can be classified by depositional environment into marine clays in or continental clays.

The Calcareous sandstone and intermediate clays layers have a westward inclination, causing exposure of older formations toward east.

At the base of the Pleistocene stratigraphy column a thick layer of heavy dark marine clays, known as "Saqiye" group, is found. The Saqiye Group is dated from the late Eocene to the early Pleistocene and is composed mostly of open sea marls and clays. Its includes, in ascending order ,the Beit Guvrin Formation, composed of Calcareous Marl; the Ziqim Fm, composed of light gray shaly marls; the Mavqiim Formation, composed of anhydrite, gypsum and salt; and the Yafo Formation composed of marine marls and clays of Pliocene and early Pleistocene age.

The top of Saqiye group, which represents the coastal aquifer basis, is located at depths that vary from 180-220 m along the coast to less than a few meters at the aquifer eastern edges. The slope of the gradually eastwards rises Saqiye layer is about 1°. Saqiye layers form a trapezoidal shape, having thick side close to coast and thin in the east. Therefore, close to the Samaria Hills the Saqiye layer cannot be found, and thus sand layers appear on top of the older formations.

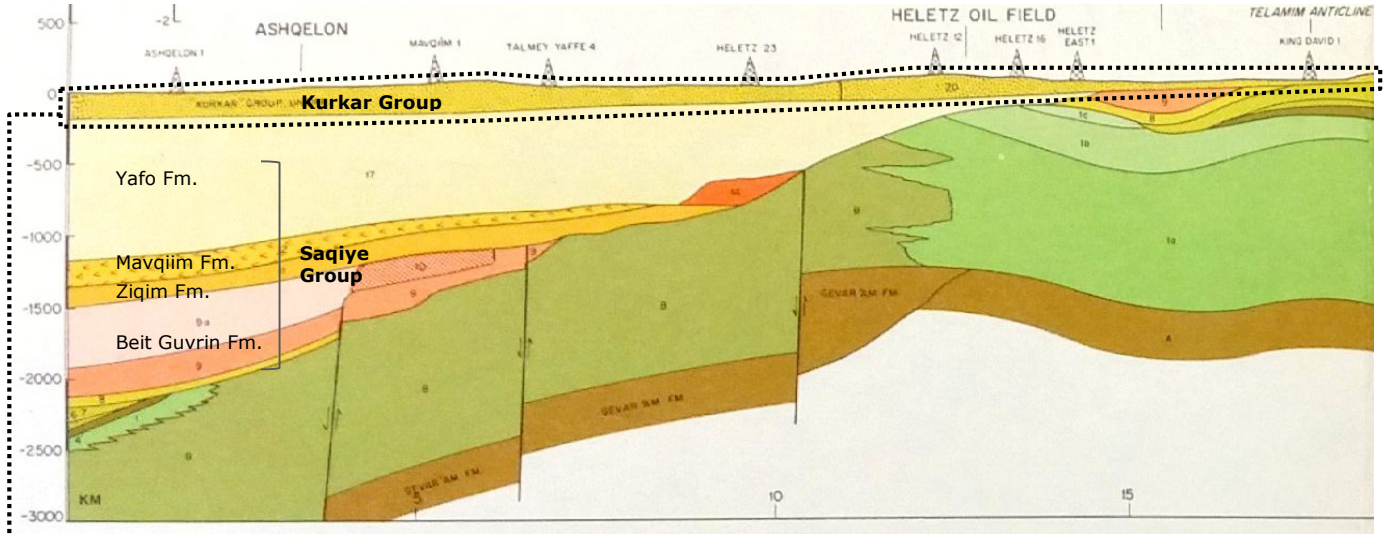

Figure 2.2: Top: Geological cross section along the coastal plain of Israel between shore line (left) to Heletz oil Field (Right) [1].

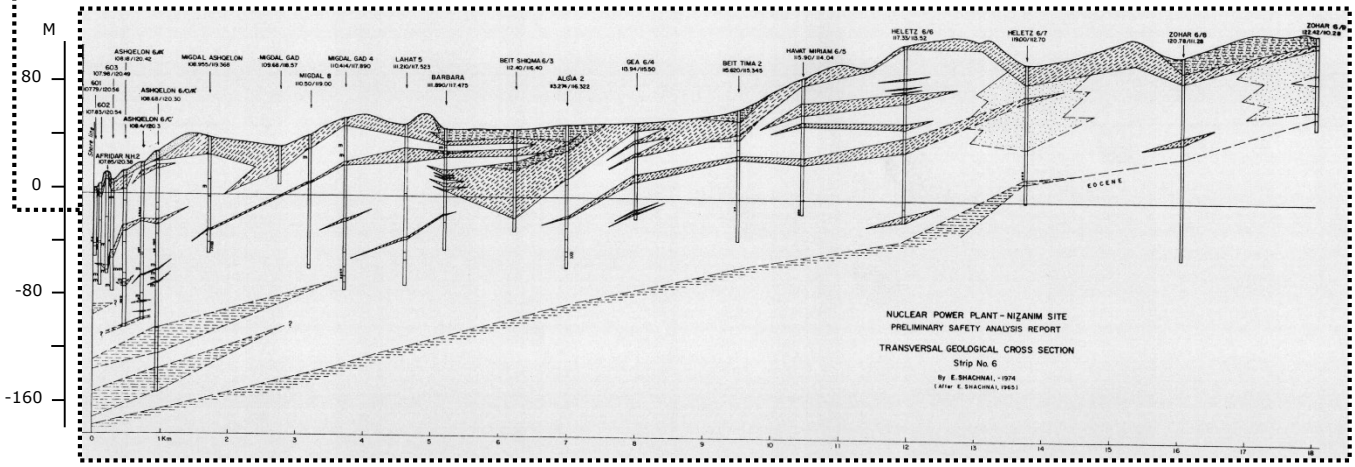

Figure 2.2: Geological cross section along the coastal plain of Israel of the Kurkar Group [1].

At the location of Heletz 18A, Heletz 18B and its surroundings, Yafo Formation (top Saqiye Group) is laying in unconformity above older formation of Eocene and Turonian age. A stratigraphy cross section of the shallow geology around the drill site is sown in **Table 2.1**.

Table 2.1: Stratigraphy table of the shallow geology in representative wells around the drill site.

	Heletz 18	Heletz 13	Heletz 14
Surface Elevation	114	120.5	105.4
Top Saqiye	149	152	134
Top Avedat	173		167
Top Judea	229	230	214

3. Well Location and design

3 wells were located around the Heletz CO_2 injection site at distances of 120-500 m (**Figure 3.1**). Well A is located 500m north of Heletz Site; Well B 330 m to the west; and Well C is located 160 m south-east of Heletz. Wells coordinates (Israel Transverse Mercator) are shown in the table herein:

	Easting	Northing
Well A	167113.8	613391
Well B	166595	612993
Well C	167002.7	612777.1

The Heletz Injection site and the proposed seismic wells, is located in an agricultural environment with little infrastructures above ground. Those includes mainly electrical wires, located along the path of the dirt roads and the traffic road, and few farming sheds. Most of the infrastructures are underground, including drinking water wells, water pipe lines, oil pipe line, communication wires and oil wells. Though surface infrastructures poses almost no limitation on the location of the seismic wells, underground ones create a major constraints.

The drinking water facilities create the largest footprint, thus reducing the area available for drilling. Two drinking water wells are located north and south-west of the site. Each well has three buffer zones, where no drilling is allowed, protecting from groundwater contamination in the proximity of the well. Water lines, maintained by Mekorot – Israel National Water Co., are located along the dirt roads. Drilling is not allowed within distance of 20 m from the pipe. Electricity and communication lines are located within few meters along the traffic road, from north to south, with one line branching towards Heletz 18 well.

Choosing the drilling locations has also to consider accessing the site with the drilling rig and equipment, there for the location cant excide a distance of 50m from the dirt road.

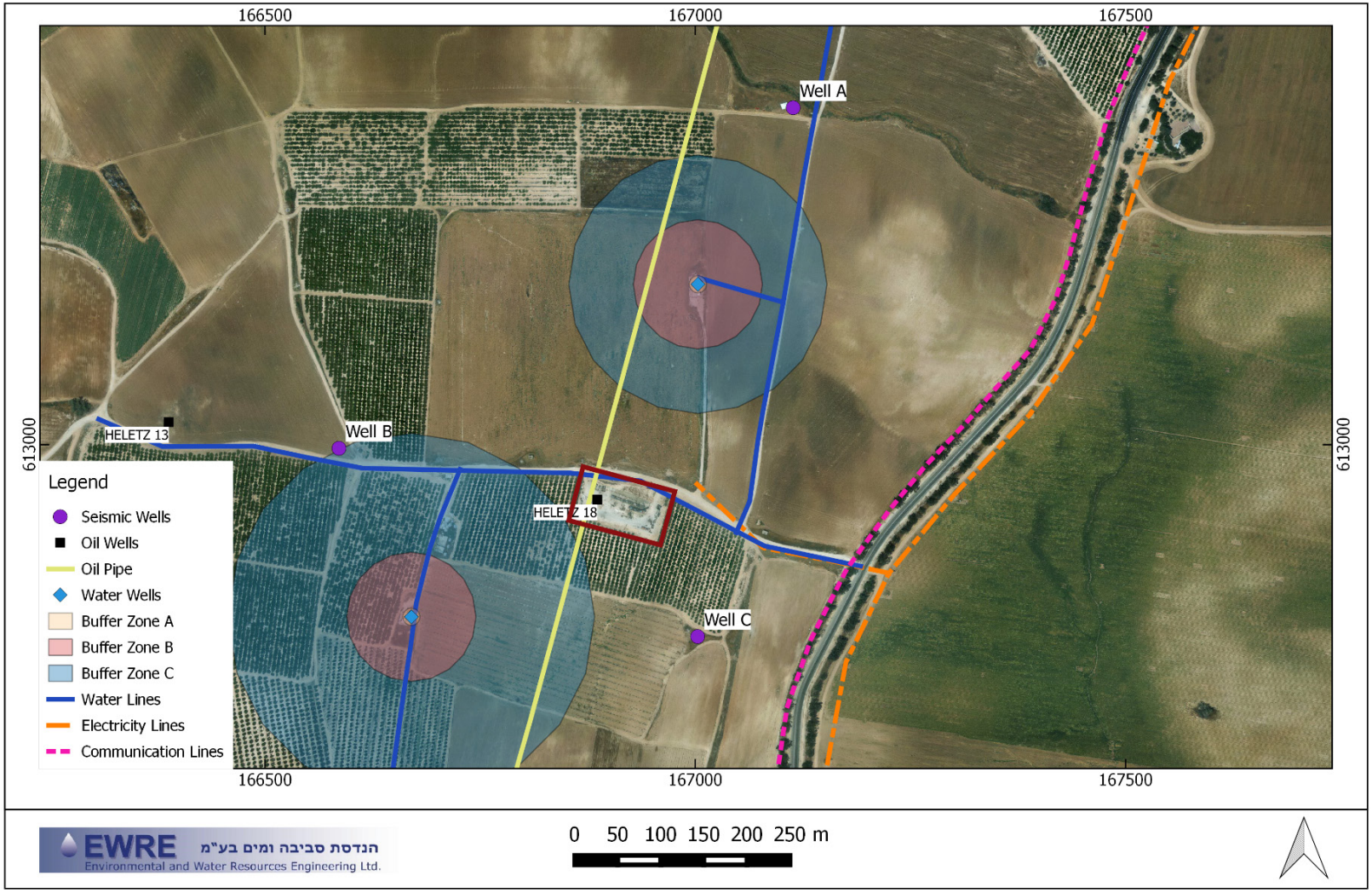

Figure 3.1: Location map of the Seismic Wells. Heletz Injection Site is located in the red box.

The seismic wells design as a 5.5” diameter blind carbon steel tubing inside a wellbore of 10” diameter. The space between the tubing and the wellbore is cemented with Portland cement, creating homogenous and continues cement layer (**Figure 2**).

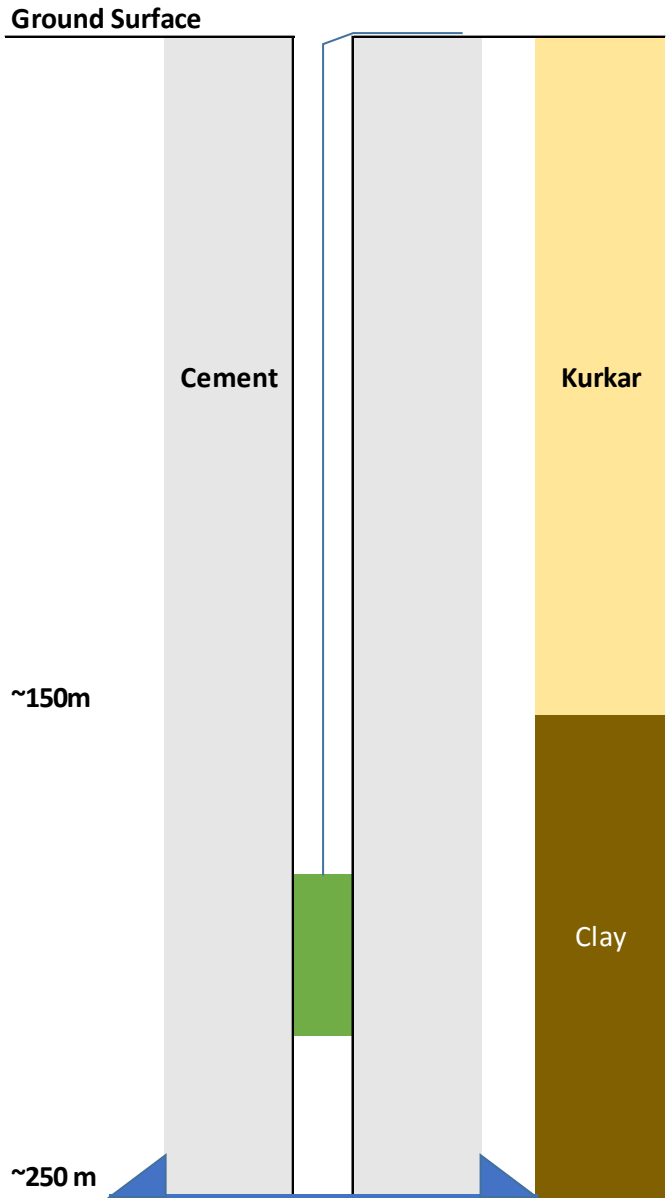

Figure 3.2: Pre-drilling Seismic Well design cross section

4. Drilling Permit

Prior to drilling, a drilling permit was applied from the Israel authorities. A drilling request was applied iteratively to the following authorities (Table 4.1).

Table 4.1: Israel authorities upon requested drilling permit

	Authority	function		Authority	function
1.	Israel Water Authority	Israel water management	8.	Hot Telecommunication Systems Ltd.	Cables Telecommunication provider
2.	Petroleum & Energy Infrastructures Ltd	oil products infrastructures	9.	Partner Communications Company Ltd.	Cellular communication
3.	Eilat-Ashkelon Pipeline Company Ltd.	transporting of crude oil	10.	Israel Electric Corporation	Supplier of electrical power
4.	Natural Gas Authority	Development of natural gas sector	11.	Israel Nature and Parks Authority	Management of nature reserves
5.	Israel Natural Gas Lines	construction and operation of the national natural gas transmission	12.	Israel Antiquities Authority	National antique Authority
6.	Bezeq The Israeli Telecommunication Corp Ltd	Telecommunications service provider.	13.	Jewish National Fund	Development of rural region
7.	Cellcom Group	Cellular communication	14.	Mekorot Water Company Ltd	Water supplier

Permits are presented in appendix A.

5. Drilling

The drilling took place from May 6, 2015 to June 9th 2016. All three wells were drilled using Schramm drilling truck and Water based mud, composed of bentonite and stabilizers chemicals. The mud was circulated, separating the cutting using Mud Separator. The drilling of each well was completed after about one week, and few extra days for mob/demob.

The geology cross section was manly Calcareous sand stone in the top 150 m, replaced by Saqiye clays and marls within the next 75 m. Wells depth was 222-224 m, was based on the location of Judea dolomites formation. Wells cross section is presented in Figure 5.1.

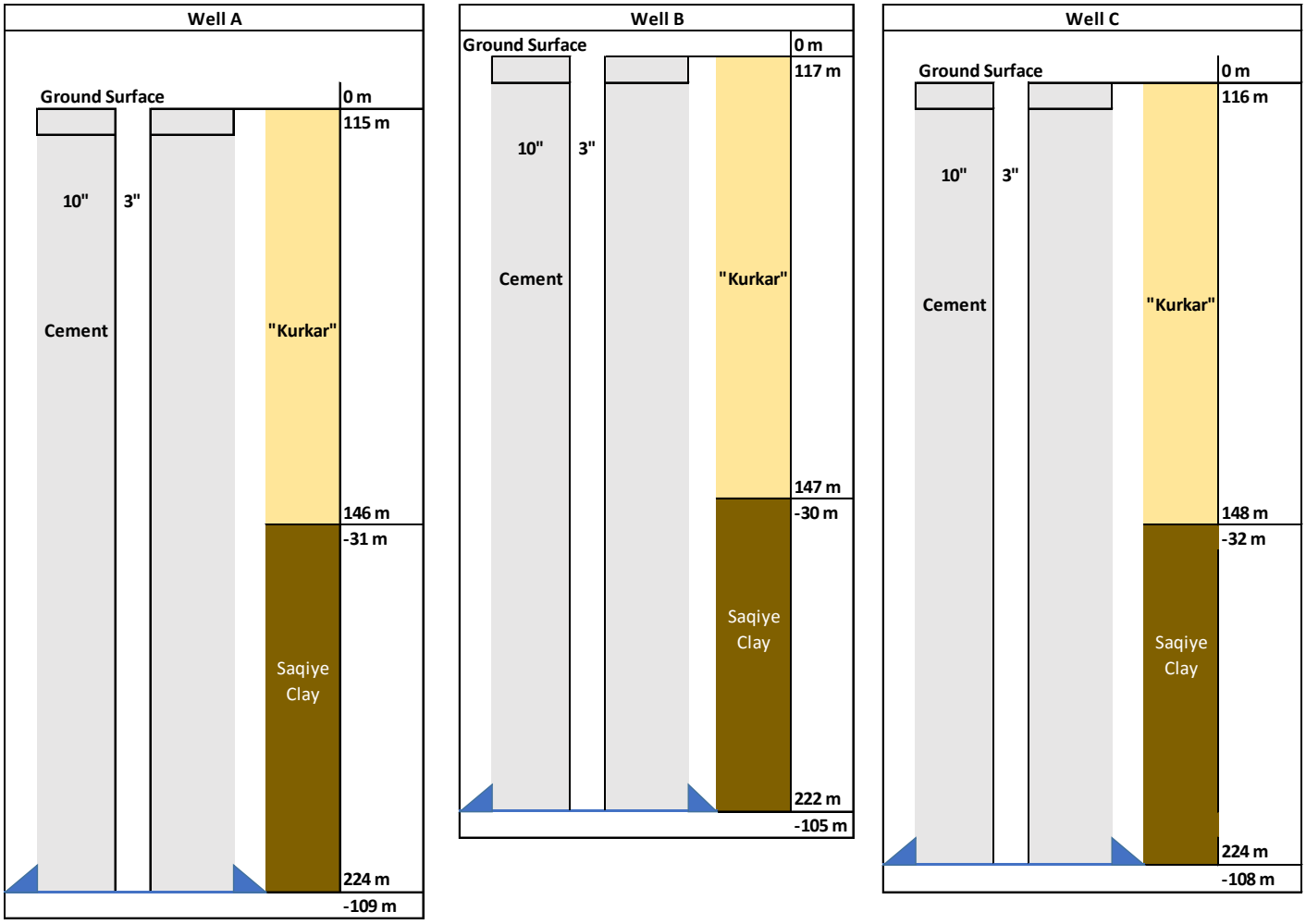

Figure 5.1: Post-drilling Seismic Wells cross section

6. Well Termination

At the ground surface we have installed a pit of 1m diameter with a perforation of 6 inches in its wall. The bit bottom is coated with cement. At the top of each pipe inside the well we installed a flange in order to allow the hanging of the seismic monitoring arrays. These devices will be connected to the control room via wires, in order to allow a fast transmission of the data being gathered and in order to optimize the costs of data transfer.

7. References:

[1] Gvirtzman. G, "The Saqiye Group In the Coastal Plain and Hashephela Region, Israel," *Institute For Petroleum Research and Geophysics*, 1969.

[2] Ecker. A, selected Geological cross-sections and subsurface maps in the coastal aquifer of Israel, GSI, 1999.