Investigation of groundwater flow pathways in a Karst Aquifer using static & towed Electrical ResistivityTomography Data

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Introduction:

The Gort Lowlands in South Galway is a major karst region formed by extensive dissolution of the underlying Carboniferous limestones, resulting in an underground network of conduits and fissures that define the groundwater flow across the region. Caherglassaun Lough is located within this region, 5.5 km southeast of Kinvara, Co. Galway (Fig.1). Although technically a lake, Caherglassaun Lough behaves like a turlough. The lake is fed by a subsurface network of conduits which drain westward from the Slieve Aughty uplands. Typical winter rainfall conditions result in the karst system becoming saturated. The gradient of groundwater flow is low and Caherglassaun Lough, in conjunction with numerous turloughs in the area, act as large reservoirs which provide temporary storage to enable the transmission of large volumes of water in the system to the sea to the northwest. This poster focuses on a geophysical survey carried out between August and October 2011 to investigate the groundwater flow in to and out of the lake.

Fig.1; Location of Caherglassaun Lough (yellow box), SE of Kinvara.

Geological Background:

The lake has formed within the Hawkhill Member of the Burren Formation (Pracht, 2004) which underlies the entire region indicated in Fig.2 and is characterised by bryozoan-rich, skeletal limestones (Gallagher, 1996). The Burren Formation is classified as a 'Regionally Important Karstified Aquifer.'

In this area, groundwater flows (1) via the epikarst generally extending from 1-10m below ground level, (2) via solutionally enlarged conduits and cave systems, extending up to 30m below the epikarst; and (3) via smaller fractures and joints which are linked to the main conduit systems (GSI, 2004). In addition, some deeper flows can occur associated with faulting or dolimitisation.

In general, groundwater flow from Caherglassaun Lough is to the NW, discharging to large coastal springs with virtually no surface drainage in between (GSI, 2004). A 1998 report by the OPW into flooding problems in the Gort-Ardrahan area proposed a conceptual conduit model as indicated in Fig.2. This model was based on extensive tracing, water level monitoring, hydrochemical sampling, geological mapping and drilling however, limited information about the physical properties of the conduits was known. The model interprets 2 conduits entering the lake in the east and south east with 1 conduit leaving the lake in the northwest.

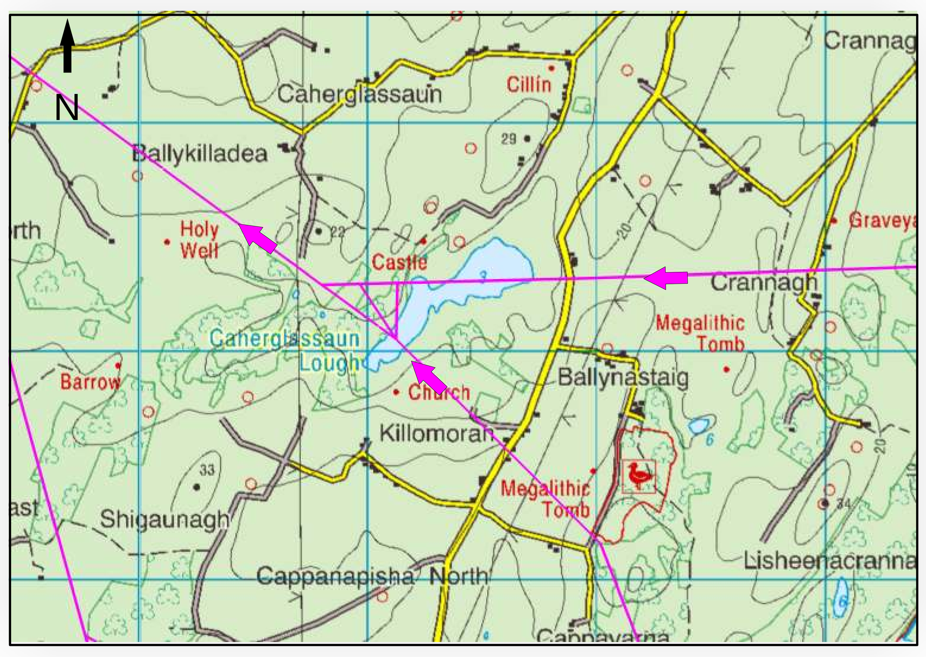


Fig.2; OS map showing Caherglassaun Lough with proposed groundwater conduits (pink lines) modelled in the 1997 OPW Report. Flow direction indicated by pink arrows.

Methodology:

The Electrical Resistivity Tomography (ERT) technique was employed at Caherglassaun Lough. This technique images lateral and vertical variations in subsurface resistivities. The resistivity of a material is a measure of how strongly that material opposes the flow of current. Limestone would typically exhibit relatively high resistivity values while clay or water-filled karstified limestone would be characterised by decreased resistivity values. Air-filled fissures and voids would be characterised by very high resistivity values.

Static ERT profiles were proposed at approximate right angles to the suspected conduit flow direction around the lake (Fig.3). Towed ERT profiles were proposed across the body of water to investigate subsurface resistivities beneath the lake and to map the bathymetry of the lake bed (Fig.3).

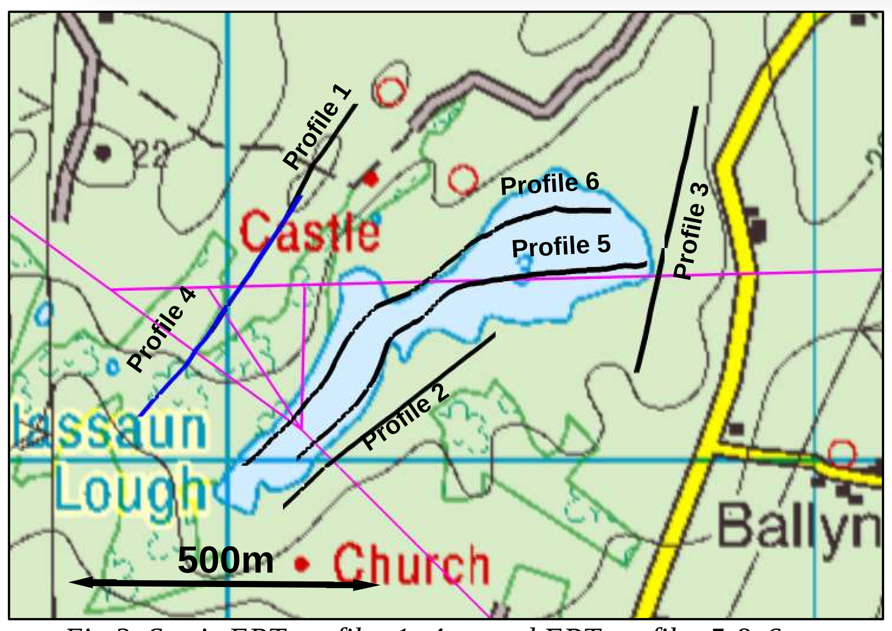


Fig.3; Static ERT profiles 1 -4, towed ERT profiles 5 & 6.

Topography:

A topographic survey was carried out concurrent with the geophysical survey (Sereikaite, 2011). The data was combined with bathymetry data from the towed ERT survey and topographic data taken from the OS Discovery Series map for the area (Fig.4). The lowest elevation recorded was -4.27 m OD, recorded in a sinkhole within the lake. The base of the turlough is broad and flat with elevations ranging from 1mOD to 2mOD in the centre and east of the lough, rising to 1.5mOD to 2.5mOD in the southwest of the lough.

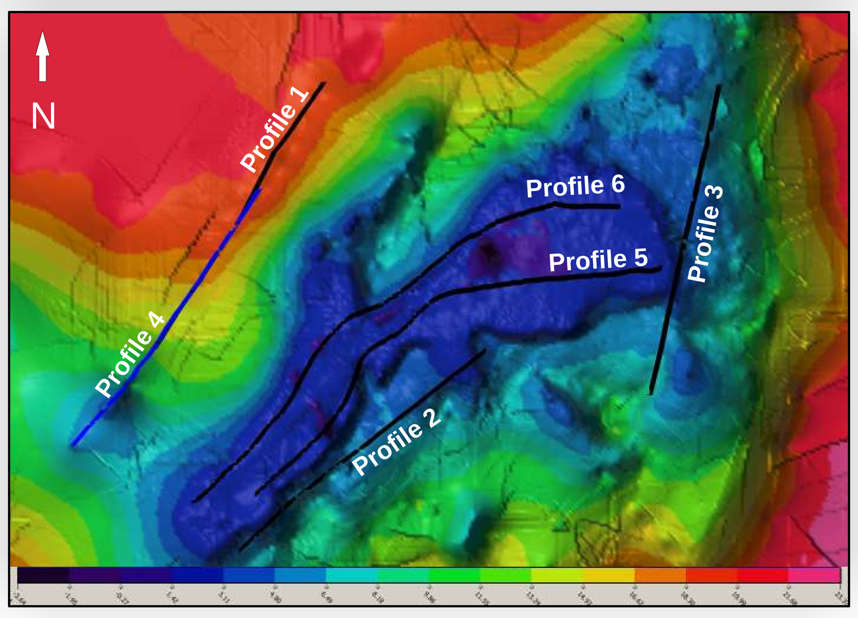


Fig.4; Topographic contours.

Data Acquisition:

Data was recorded as follows:

1. An Iris Syscal Pro resistivity meter recorded 4 x 470m static Dipole-Dipole ERT profiles (Fig.5).
2. A boat mounted Iris Syscal Pro resistivity meter recorded 2 x 800m towed Dipole Dipole ERT profiles (Fig.6).
3. An echo sounder was used to record water depth on the towed ERT profiles.
4. An RTK GPS was employed for positional information both on land and mounted in the boat.

Fig5 (left), static ERT Profile 2.

Fig.6 (below); ERT cable towed behind boat with instrumentation onboard.

Data Processing:

The static ERT profiles were inverted to produce pseudosections of subsurface resistivity values. A total of 5 iterations were carried out for each profile. The resultant pseudo sections are presented in Fig. 5, (a) to (d). RMS errors ranged from 5.3% to 11.4%.

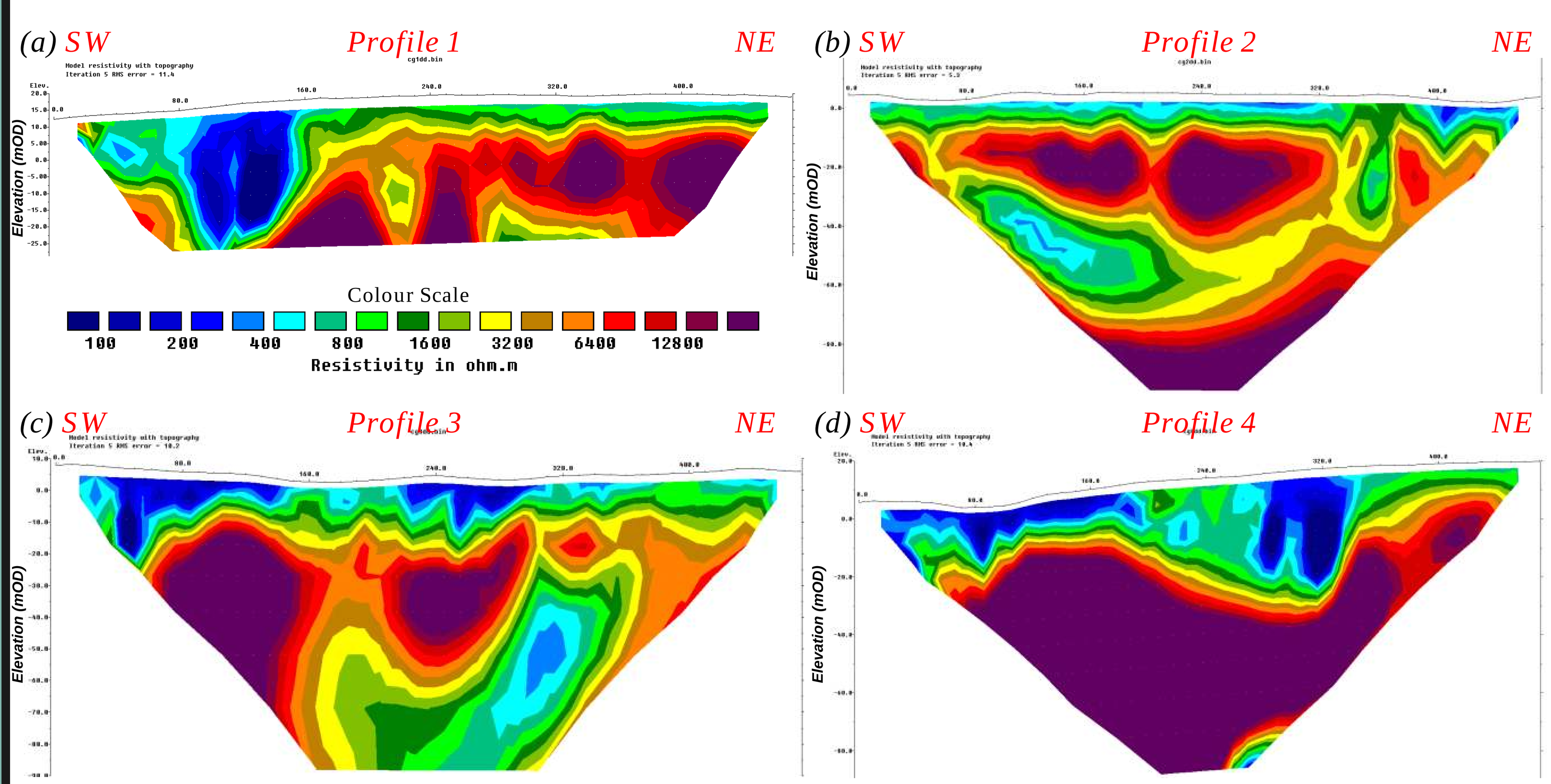
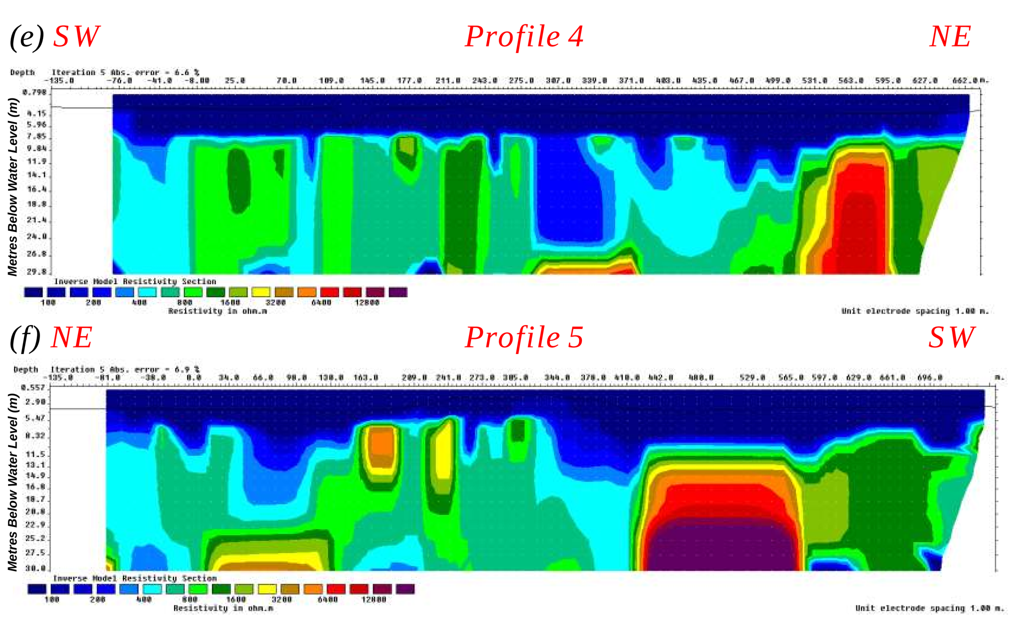


Fig. 6: (a) Profile 1, RMS error 11.4%, (b) Profile 2, RMS error 5.3%, (c) Profile 3, RMS error 10.2%, (d) Profile 4, RMS error 10.4%, (e) Profile 5, RMS error 6.6% & (f) Profile 6, RMS error 6.9%.

For the towed profiles, the water depth at each survey point was incorporated into the inversion as a water 'layer' boundary. Lake water conductivity was recorded using a hand-held meter and the output was incorporated in to the data inversion. The average recorded conductivity was 220 mS/m. Again each profile inversion involved 5 iterations (Fig. 6, (e) & (f)). RMS errors ranged from 6.6% to 6.9%.



Results:

The ERT profiles appear to confirm the 3 modes of groundwater flow throughout this region. Bedrock is very shallow in the vicinity of Caherglassaun Lough (Teagasc Subsoils Map, GSI). As such, the low resistivity values (100 to 1000 Ohm-m) recorded from 1 m to 10m below ground level (Fig.7 (a) & (b)) would be indicative of epikarst.

Underlying the epikarst, more competent bedrock has resistivity values ranging from 1,000 to 50,000 Ohm-m. These very high resistivity values are indicative of clean limestone, possibly with air-filled fissures.

On Profiles 2 & 3 on the east and south east of the lake, zones of low resistivities (300-1000 Ohm-m) occur at elevations between -25 and -70 mOD (Fig.7 (a)). These profiles are up-hydraulic gradient from the lake. These broad zones of low resistivities may indicate zones of more diffuse groundwater flow comprising water-filled fractures and joints but which can be represented by the idea of single conduit (OPW 1998).

Profiles 1 & 4 along the west of the lake and down hydraulic gradient from the lake, recorded resistivites as low as 25 Ohm-m focused as two adjacent solutionally enlarged conduits at depths from approx. 0 to -20 mOD (Fig.7 (b)).

The towed profiles indicate the water layer overlying a thin layer of low resistivity (25-100 Ohm-m) probable marl (Fig. 7(c)). The underlying bedrock has varying resistivites with some very low resistivity zones (<400 Ohm-m) again indicating probable conduits.

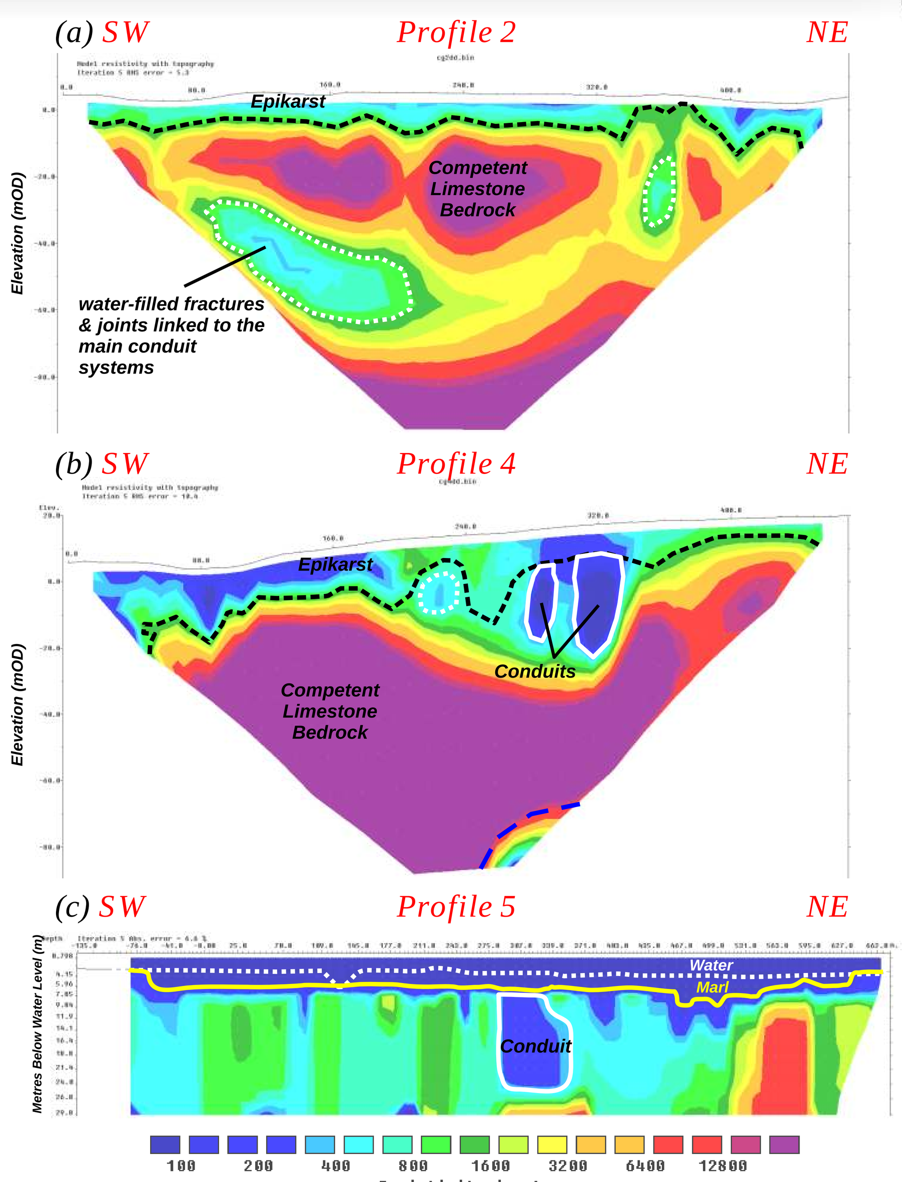


Fig. 7: (a) Profile 2 SE of lake & (b) Profile 4 W of lake & (c) Profile 5 across the lake.

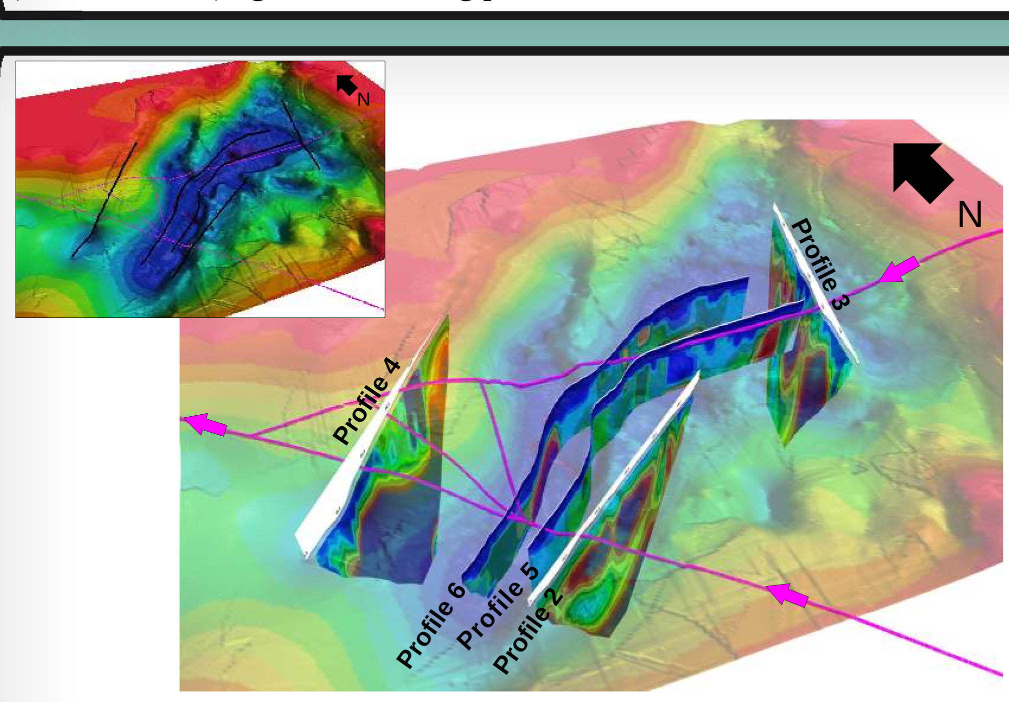


Fig. 8: 3D representation of profiles overlaid with topography.

Interpretation:

A 3D representation of 5 of the profiles is presented in Fig.8, overlaid with the topographic map. The OPW conduit model has been draped over the map to assist with the visualisation of the groundwater flow system.

The ERT profiles delineate the geometry of 2 prominent conduits on the west of the lake. These appear to be 25m to 30m in diameter and their location agrees well with the locations suggested by the conceptual conduit model.

East and southeast of the lake, the groundwater flow is both epikarstic and deeper & more diffuse, flowing approximate to the locations indicated by the model. Groundwater movement from these deeper zones to the shallower conduits on the west of the lake implies movement upslope beneath the lake.

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