Radio-location at Wakulla Springs, Florida

*The use of radio-location equipment by diving expeditions as told to John & Rosy Rabson by **Brian Pease**.*

Introduction

In 1987, an international team spent ten weeks exploring the amazing artesian cavern at Wakulla Springs, Florida. Using high pressure, open circuit diving apparatus and diver propulsion vehicles, they mapped 3,310m of previously unexplored subterranean passageways. The Woodville Karst Plain Project (WKPP) continued the exploration of Wakulla Spring and other nearby sinkholes to see if they were connected. They managed to get 5,500m from the closest known cave entrance, using conventional open circuit diving (Scuba) apparatus and, more recently, semi-closed circuit rebreathers. In 1998 – 1999 a further expedition was mounted, to make a 3D virtual reality map of the underwater system using a Digital Wall Mapper (Arnold, 1999; am Ende, 1998).

The expedition divers also Brian Pease's underwater radio-location beacons. This article will concentrate on the beacons and, hopefully, we will report on the Digital Wall Mapper navigation in a future issue. The radio-location equipment has been used to a depth of one hundred metres in water.

Brian with the Receiver and Search Coil

Geology

The geology of the area is simple with flat lying limestone from the surface to well below the flooded cave passages, with the water table just below the surface. The passages at Wakulla are formed in the soft and porous upper Suwannee limestone.

What We Did

Divers set up 38 beacon transmitters to provide "precision points" for accurate location from the surface. A full description of the beacon transmitter can be found in *CREG Journal* (Pease 1996a).

We also measured the conductivity of the limestone in an effort to enhance our understanding of the cave system and its geology.

The beacons transmitted to surface receivers, a full description of which can be found in *CREG Journal* (Pease 1996b, 1997b).

We found it advisable, if possible, to do the searching between 9am and 3pm local time, which was the quietest period for atmospheric noise.

Observations

We measured a 600m ultimate range for the radio-location equipment in a quiet location with a beacon at 90m depth. This was during a very quiet morning in winter. A 300 – 400m range was more usual. Power-line interference was a significant problem.

While doing the ground-zero locations, it was observed that some lines of position (LOP) gave much sharper nulls than others. The same effect was observed during the conductivity measurements with both loops on the surface, although conductivity in different directions seemed to be the same. The deepest null always seemed to occur at right angles to the poorest null. The cause of the asymmetric behaviour (called anisotropy) is not known, but has been observed elsewhere and could be related to vertical jointing in the rock.

Anisotropy was observed at most locations, sometimes completely filling in the null at long ranges. At every location, there was always one direction (LOP) with a sharp null, with the poorest null on an LOP 90° away. The field caused by the anisotropy is a horizontal magnetic field perpendicular to the LOP, just like the far (radiated) field, which it probably is. At maximum range it is the *only* field that can be heard!

Electrostatic shielding on the receiver loop antennas gave slightly better results by eliminating any electric field pickup.

The precision points installed in the cave with the radio-location gear proved essential for correcting the drift of the Digital Wall Mapper.

Accuracy

There was essentially no error in the calibration of the bubble level on the underwater beacon loop.

Likewise, there was essentially no error in the receiver loop if the loop was flipped 180° (and 90°) to create a box around ground-zero (four measurements). In practice, the box size varied from less than 100mm up to 500mm even in quiet conditions as the bubble level of the receiver loop tended to get slightly out of adjustment while we were carrying it through the woods. One could, however, still place ground-zero at the correct spot in the centre of the box.

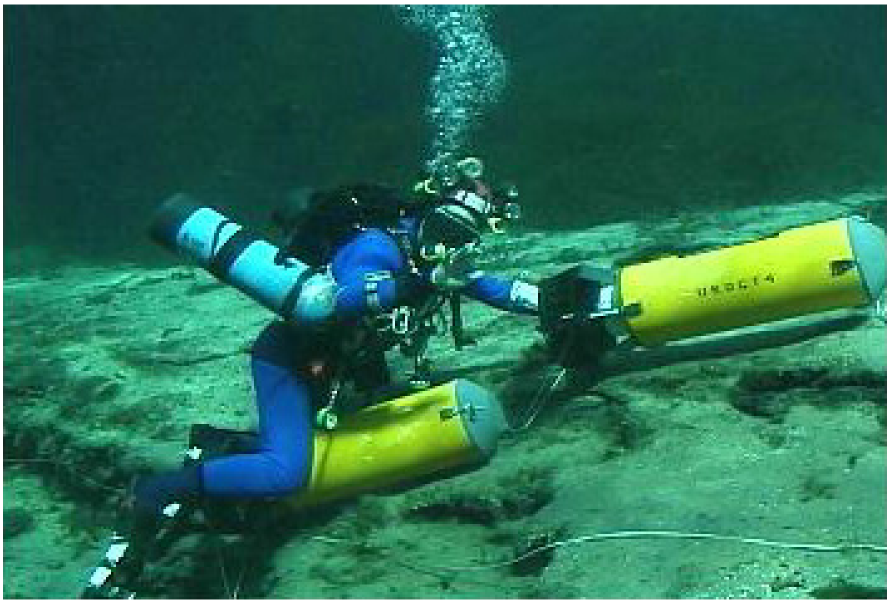
If the bubble is split in the centre by the circular mark on the level, the loop tilt is 1°, the beacon levelling error was 500mm in ground-zero at 90m depth in the worst case.

At a depth of 90m the ground-zero location error varied from 100mm in the best conditions (no power line or atmospheric noise) to about 1m in the worst conditions. See the earlier comment on anisotropy.

It was not possible to do underwater surveying to centimetre accuracy, but the rock should have little effect on ground zero location accuracy, being flat-lying and saturated nearly to the surface with water of similar conductivity.

Surface survey errors were about 10 – 20mm, which seemed negligible compared with other errors.

The r.m.s. value of errors in beacon levelling and ground-zero location was 1.03m in the absolute worst case. The main known source of error was ground-zero location.



Team Members John Buxton (top) and Mark Meadows (bottom) in Wakulla

Rock Conductivity

We estimated the conductivity of the limestone at various depths by using a beacon on the surface and measuring the relative strengths of the primary and secondary magnetic fields at measured distances from the beacon corresponding to the depth for which we wished to know the conductivity – see (Pease, 1991). Measurements gave about 0.01S/m down to about 10m and 0.014S/m from 20 – 100m. We are not surprised to see the high measured conductivity, as this soft limestone is saturated with water. For comparison, measurements over typical dry caves in the US have yielded conductivities of 0.003 – 0.005S/m.

To derive a bulk conductivity for the limestone both above and below the cave passages, we measured the signal strength with the beacon on the passage floor at a depth of about 75m and analysed it to yield an average conductivity of 0.0036S/m. This lower conductivity was to be expected, given the denser lower Suwannee and Ocala limestones which underlie the passages.

Using the known depth of the beacons and the absolute signal strength at ground zero, we calculated an average bulk conductivity of 0.019S/m. In my experience, typical dry cave limestone conductivity is five times less at about 0.004S/m.

The average of the Ratiometric and Absolute methods gave depths within a few feet of actual (Pease, 1997a).

Problems

At depths of the order of 100m, even double O-rings (on the underwater beacon/battery cases) can leak. We fixed this by shimming the clips so they clamped tighter, and putting a hose clamp around the top of the case at the radial O-ring.

Rubber-covered toggle switches can also turn themselves off underwater *if* first turned on at depth.

Twice as many beacon/battery cases as loop antennas were needed because the 12V/7Ah batteries had to be recharged on the surface before the next use. The loop antennas remained underwater throughout the project, often stuck for days with a dead beacon/battery case.

Conclusions

This project was perfect for testing our ability to measure the depth of the beacons.

Our 3496Hz gear was adequate for the task, despite the 90m depth and very high electrical conductivity of the soft, water-saturated limestone.

Built-in beacon self-tests, used both on the surface and by the divers, proved very useful. Most of the beacons had a delayed turn-on. This was generally a 20 hour delay so that the beacons turned on at the quietest time the next day (9am – 1pm local time).

More poles of filtering in the receiver might help to reduce power-line interference.

The detailed results of the survey are currently being processed. For further details keep an eye on the Wakulla2 Web site at **http://www.wakulla2.org/** .

References

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Note that updated versions of (Pease, 1996a – 1997b) can be found at **http://www.uconect.net/~bpease/CREG/HomePage.htm**

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