Mapping Groundwater with SkyTEM

SUMMARY

The ability to reveal the availability and movement of groundwater can be a huge asset for countries and regions with the need to responsibly and sustainably manage their aquifers.

The SkyTEM method, specifically developed to map buried aquifers, is widely accepted globally as the principal technique for mapping water resources. SkyTEM is an innovative and technologically advanced airborne geophysical system capable of mapping the top 500 metres of the Earth in fine detail and in 3 dimensions. SkyTEM was conceived and engineered in Denmark, a country with a reputation for environmental care and R&D. SkyTEM helps geological organizations and government water agencies on seven continents unearth a wealth of information about their aquifers and aids in their understanding of how geology and mankind can affect, and be affected by, groundwater resources. The SkyTEM method has mapped water resources on a Galapagos Island, important agricultural areas in the USA, Australia, Africa and India, islands in the Caribbean and Indian Ocean and even Antarctica. Recognized for its ability to quickly and accurately map geology in fine detail, the SkyTEM method is also employed globally for mineral and oil & gas exploration as well as environmental and engineering investigations.

This white paper provides results from recent global water exploration projects – from finding new fresh water sources to identifying groundwater recharge areas, saline water encroachment and more.

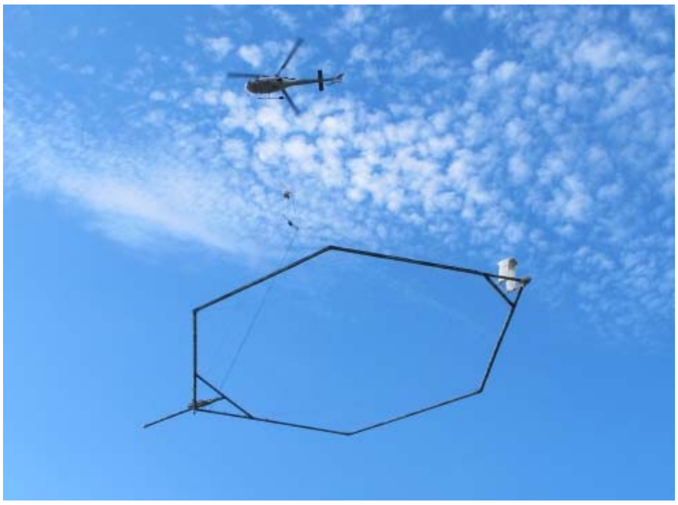

Figure 1: The SkyTEM system

INTRODUCTION

Water is essential for life on earth. Two thirds of Earth's surface is covered by water and oceans hold about 97% of all our water. In the remaining 3% of fresh, or non-saline water, groundwater provides us with 30% of all our drinking water while 68% is trapped in a frozen state. Less than 2% is available as surface water. This limited supply of available surface and groundwater is the main source of drinking water for the planet’s seven billion plus people. In recent decades as demand for water increases we witness falling water levels in almost all of the world’s wells, and many are beginning to run dry.

According to a recent NASA study one third of the Earth's largest groundwater basins are being over-exploited. Twenty-one of the world’s 37 largest aquifers, in locations from India and China to the United States and France have removed water quicker than it can be replaced by rain and snow and their sustainability is at a critical point. (see http://go.nasa.gov/1G3fLIV). Depletion of water resources is an immediate and growing concern and is creating overwhelming challenges for the next generations.

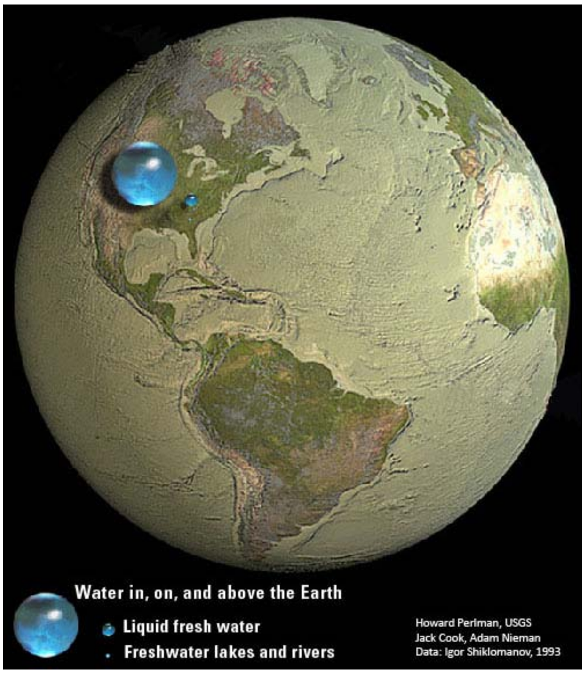

Figure 2: Global Freshwater Resources

A Holistic Approach (if you can't measure it then you can't manage it)

Since there is so much more groundwater than surface water on Earth and because it is an important part of the hydrological cycle, groundwater should be managed in an integrated way with other water resources. We must be careful in how we interact with groundwater as it takes only a few contaminants to damage them for generations. To deal with critical groundwater issues and begin to manage limited resources sustainably we must develop an informed understanding of the aquifers.

As our available fresh water becomes increasingly scarce and valuable many are calling groundwater the new oil. However, unlike the oil industry, few governments are mapping the resource in a systematic way. Airborne geophysical methods have been used for decades in oil exploration. SkyTEM advanced the technique and engineered an airborne method that now makes it possible to map water resources efficiently and effectively.

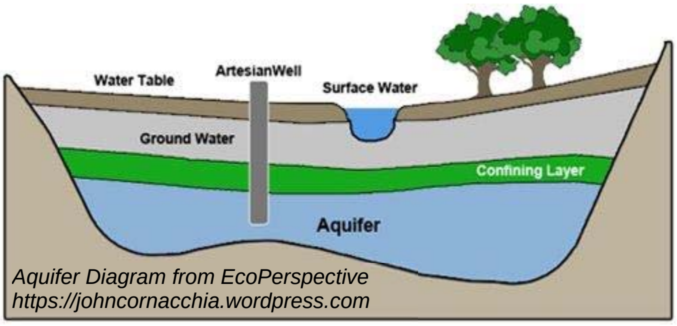

Figure 3: Aquifer Diagram from EcoPerspective

Hidden in aquifers, groundwater is a body of permeable and porous saturated rock and intricate networks of buried river channels through which water moves. Mapping and protecting this hidden resource is a challenging task. To begin to manage groundwater effectively and sustainably dependable, accurate, high-resolution subsurface data must be collected and used to monitor and manage:

- groundwater levels within groundwater basins
- groundwater quality degradation
- land surface subsidence
- changes in surface flow and surface water quality that directly affect groundwater levels or quality
- changes in surface flow and surface water quality that are caused by groundwater pumping

Denmark is one of the few countries to have conducted a countrywide groundwater mapping programme. This major initiative took over a decade to accomplish and required the development of unique tools and techniques. Buried aquifers are challenging to map because they are invisible to most existing exploration technologies. They can cover huge areas in the subsurface and range from those present in the near surface to several hundreds of metres depth. They can be connected to other aquifers via intricate networks of buried channels that meander in the subsurface as much as they do on the surface. Groundwater recharge can come from rain and snow and rivers and streams and are vulnerable to adverse human activities. Ground based methods of data collection such as boreholes or geophysical studies are conventional methods employed to map groundwater but these methods are slow, require ease of access to study areas and even a small area can require substantial financial resources to map in detail. Faced with these challenges and with a plan to map all of their principal aquifers, Danish scientists engineered a unique airborne geophysical method called SkyTEM.

THE DANISH GROUNDWATER MAPPING PROGRAMME

In Denmark, as in much of the world, the supply of drinking water is based entirely on groundwater resources. The Danish Environmental Protection Agency decided that before land could be slated for urban development it first had to first be examined to determine if aquifers were present in order to protect them from potentially harmful human activities. In an effort to make sound decisions on how and where to protect these critical resources it was important to base decisions on accurate and reliable information, in this case, spatially dense hydrogeological maps. In 1999, the Danish Government initiated the National Groundwater Mapping Programme aimed at obtaining a detailed description of Danish aquifers with respect to localisation, extension, distribution and interconnection as well as vulnerability against contaminants. The Mapping Programme covered approx. 40 percent of Denmark and following 15 years of work, the mapping of Denmark's groundwater is now complete. Denmark is one of a few countries in the world where the groundwater is so clean that consumers can enjoy a glass of water directly from the tap, without any need for added chlorine or other chemicals. See https://stateofgreen.com/en/news/15-years-of-groundwater-mapping-complete.

Drilling boreholes is not enough

In most parts of the world groundwater mapping is based on only one data source - drilling information. Consider however that a 6 inch borehole represents less than 1/millionth of one acre. A borehole will provide precise information about geology in the immediate vicinity of the borehole but any inferences made about the surrounding geology is a leap of faith or at best a guess. Boreholes are expensive and sometimes difficult to drill in certain locations and the result is often scattered information with low borehole density and few drillings extending to sufficient depths. Inadequate drilling information can lead to uncertainties and low confidence levels in geological interpretations and hydrogeological models.

Ground based geophysical methods produce highly accurate three dimensional data sets, but are slow and difficult to employ in hilly terrain or populated areas. In the late 1990s when Denmark was researching groundwater mapping methods they determined that available airborne systems, while able to collect data in rugged or inaccessible terrain, were not able to detect the subtle variations in geological layers required to accurately map buried aquifers. Conventional airborne systems were designed as "bump detectors for mineral exploration" and could provide either near surface or deep images – but not both. In order to quickly and economically map aquifers from near surface to depth in one pass, a new airborne method was required. A Danish R&D team of leading geophysicists, hydrologists and scientists within government and universities set out to develop a method capable of mapping the near surface concurrently with mapping to depths of about 350 m – the interval wherein the aquifers resided. They also set out to collect highly accurate noise free data that was robust enough to create advanced mapping products within a few days of being acquired

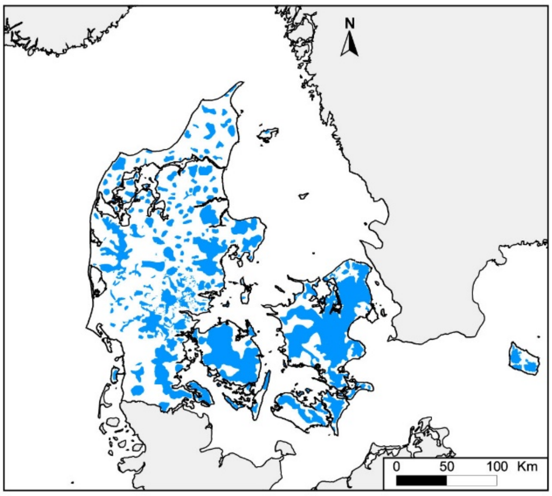

Figure 4: Aquifers in Denmark:
http://www.geus.dk/gerda/groundwater_mapping-uk.htm

With these specific aims in mind SkyTEM, a high-resolution helicopter-borne electromagnetic (AEM) system was developed. With the new SkyTEM system up to 1,100 line kilometer data can be collected daily covering 200-250 km2 to a depth of 500 or more metres.

The geophysical data collected does not replace, but complements existing borehole data, thereby reinforcing the geological interpretation, which in turn leads to greater certainty of identified economical and productive drill targets. Once the area has been mapped with SkyTEM, the data can be interpreted for other targets as well, including location and extent of salt water encroachment, groundwater recharge areas, surface and groundwater connections, contaminant plumes and inputs for geotechnical and environmental engineering studies such as mine tailing site selection.

SkyTEM is a major technological breakthrough – one that changes how aquifers are mapped. It is the first system engineered with a Dual Moment transmitter design that allows for the collection of accurate images from both shallow and deep geology (see Figure 5). The advanced engineering includes a low-noise receiver for detecting subtle geological changes, the ability to stay calibrated throughout acquisition so that depth to, and depth of the groundwater can be calculated accurately. The SkyTEM frame is rigid enough to place an array of ancillary sensors including a magnetometer, laser altimeters, video cameras and GPS equipment.

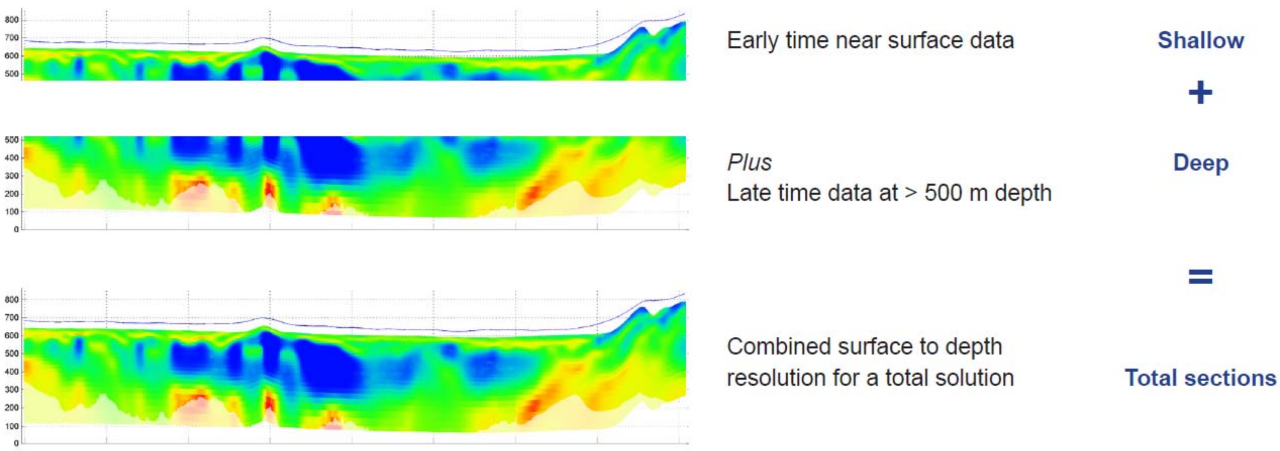

Figure 5: Data acquired from the SkyTEM508 system

The first commercial SkyTEM survey was performed in 2003 and SkyTEM Surveys ApS was officially launched in April 2004. Since then government scientific agencies, consulting firms and the agriculture sector have used SkyTEM to collect the subsurface geophysical data they need to understand and sustain their groundwater resources. This White Paper describes some of this work.

Let's Get Geophysical (From Wikipedia)

Exploration Geophysics uses physical methods (e.g., seismic, gravitational, magnetic, electrical and electromagnetic) at the surface of the Earth to measure the physical properties, that is, the relative electrical resistivity or conductivity of various earth materials along with anomalies in those properties. The figure below provides typical resistivity/conductivity values of various earth materials. Geophysics is most often used to detect or infer the presence and position of economically useful geological deposits, such as ore minerals; fossil fuels; geothermal reservoirs; and groundwater reservoirs. Geophysical techniques can be compared to computed tomography (CT) scans performed on the human body as they are noninvasive ways to diagnose or flesh out geological features and conditions. Geological features can be located, mapped, and characterized in three dimensions by detecting variations, or anomalies, and airborne geophysics has been an integral part of mineral and petroleum exploration programs since the 1950s.

Electromagnetic methods are particularly useful among the geophysical methods since there are strong correlations between both the measured resistivity and the lithology of the subsurface, and between the resistivity values and water salinity.

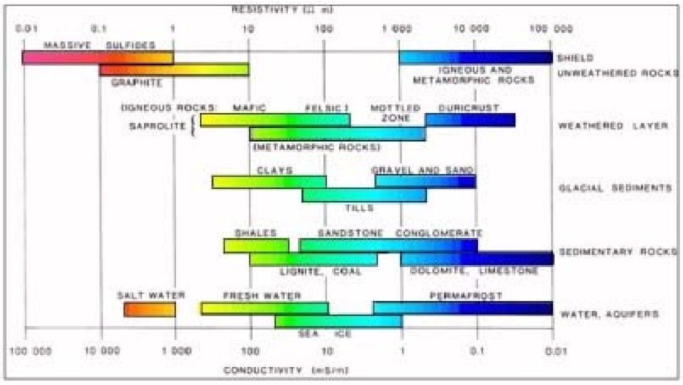

Figure 6: Representative chart (adapted from Palacky, 1987) illustrates very generally how the resistivities of important rock groups compare to each other. This type of figure is given in most texts on applied geophysics

CASE STUDIES

Hydrogeological Mapping in Northeastern British Columbia

In 2015 Geoscience BC (GBC) launched the Peace Project – a subsurface mapping project designed to collect new information about groundwater within an 8,000 square kilometer area in northeast BC, Canada. This region of the province has been a focus of petroleum exploration and development since 1952 and participating partner companies included the BC Oil and Gas Commission, ConocoPhillips and Progress Energy as well as several Treaty 8 First Nations.

The main priority of the project, comprising of the collection 21,000 line kilometers of SkyTEM data, was to map aquifers in the area to a depth of at least 300 meters. A secondary priority was to complete the airborne data acquisition before hunting and trapping season began. This required that all data collection be completed within seven (7) weeks from start up. SkyTEM312^{FAST} was selected for the data acquisition. The system operates at speeds of 120-150 km/h, and all data was acquired in only forty-three (43) days.

The figure below (Figure 7) shows SkyTEM airborne results (left) and gamma log borehole results (right). The paleochannel in the area lies at about 10 meters depth and is about 50 meters deep as mapped by SkyTEM. The gamma results show the depth to bedrock at each well (numbers near red and yellow dots – yellow dots indicate sand/gravel). Note the outline of the paleochannel as interpreted from the borehole data and how it matches the airborne electromagnetic (AEM) results. These two data sets were done independently and neither processing group saw the other's results. Conclusions from the comparison of airborne and ground geophysical data are:

- the airborne data is in good agreement with the drilling data;

- many holes were drilled at various depths to delineate the aquifer. Several were far from the paleochannel;
- the airborne data was collected in a few minutes whereas the drilling required many months;
- no dollar figures for the drill program are available but given the time and money required to drill approximately 24 holes it is expected the airborne data was significantly less expensive to obtain;
- to save time and money and increase the chances of striking water, it is highly recommended that SkyTEM data is collected in order to select and optimize drill targets. This drill data can then be used for verification and further refinement of the airborne data interpretation model.

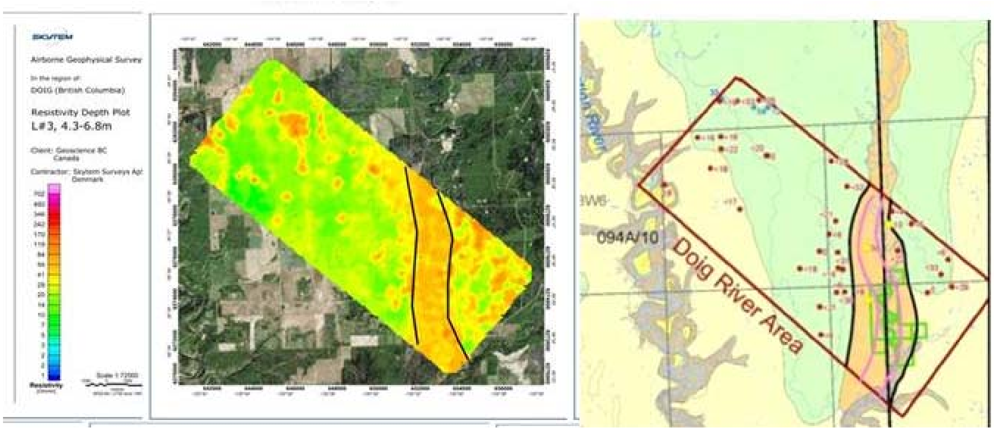

Figure 7: EM (left) and Gamma log (right) results

Carlos Salas (Vice-President Geoscience BC) said:

"SkyTEM312*FAST* is an incredibly efficient system, and we are impressed by the great results we have achieved so far. Not only does the SkyTEM system map the near surface aquifers we were looking for, it now seems the system has a much greater depth of penetration than we expected for resolving much deeper geology. The ability to review high quality data several times a week was also of benefit to our program."

Airborne Survey Increases Odds of Finding Water

SkyTEM data was recently used successfully to optimize drilling programs in a water well field in the Lower Gascoyne River in Western Australia for the Department of Agriculture and Food, Western Australia (DAFWA). DAFWA used SkyTEM to improve the success rate of finding quality water supplies in the Gascoyne as part of the region-changing Gascoyne Food Bowl Initiative. The results so far have increased irrigated agricultural production in the Gascoyne by 400 hectares.

To provide this water DAFWA selected water-drilling sites likely to contain water of sufficient quality and yield based on SkyTEM's airborne data. DAFWA principal research scientist Richard George says "previous drilling involved a hit-and-miss technique in which there was just a one-in-five chance of finding water and even less chance of finding water of suitable quality but the airborne electromagnetic surveying has doubled the odds of striking it lucky".

The data was processed to reveal targets that were mapped for exploratory drilling. Of the seventy (70) targets identified, DAFWA has already located more than thirty (30) sites suitable for production bores and 17 of these have been equipped. "We're running better than a one-in-three success rate of finding sufficient water-bearing sands, though we're still only half way through the program" Dr. George says. "By finding sites with high yield we can save on energy as we don't have to pump from such a long way down."

Gascoyne growers worried by an increasingly dry Gascoyne River are already seeing the benefits of the water, using it to bolster declining traditional sources. "Testing has also been prioritized on four (4) new production bores installed at the end of the new power line," Dr. George says. "These and another five (5) potential exploration sites located using the AEM may be able to make available more water to assist industry in the short-term."

Figure 8: Installing water production bores at Carnavon.
Credit: DAFWA

Conclusions from this study are:

- collecting high resolution SkyTEM data resulted in drilling significantly fewer exploratory holes;
- SkyTEM data contributes to the success of drilling programs and can often be collected for less than the cost of a single borehole.

Groundwater Mapping in Botswana

The International Water Management Institute (IWMI) published an article about their SkyTEM groundwater mapping project over the Ramotswa Aquifer on the border between South Africa and Botswana). The aim of the project, carried out in conjunction with consulting firm XRI Blue, was to generate new information about groundwater to facilitate sustainable management and support water security and resilience for the two countries. Read more here: http://www.iwmi.cgiar.org/2016/02/exploring-underground-by-helicopter/

"This is tremendously useful for us," said IWMI's Karen Villholth who leads the initiative. "By digitally mapping the subsurface in this way we can work out where the important aquifers are located, how large and deep they are, how they are delimited by other geologic formations. From this we can determine where it would make sense to further explore the aquifer through traditional means to identify good sites for drilling and managed aquifer recharge."

Figure 9: International Water Management Institute (IWMI) and XRI team on the survey site with SkyTEM system

Read see the entire article http://www.iwmi.cgiar.org/2016/02/exploring-underground-by-helicopter/

Measuring Volumes of Water

SkyTEM was employed to collect data over a ninety-nine (99) square mile area of northwestern Nebraska. The area is designated as a Special Management Area by the Natural Resources District (NRD) in response to seasonal water level declines. The State of Nebraska webpage states "…as hoped, the electromagnetic survey provided extensive information about the area's geology, aquifer characteristics and water in storage. The NRD's use of the data is on-going. This summary is intended to help landowners in the project area access data showing the depth to aquifer material, the thickness of the aquifer and other basic information."

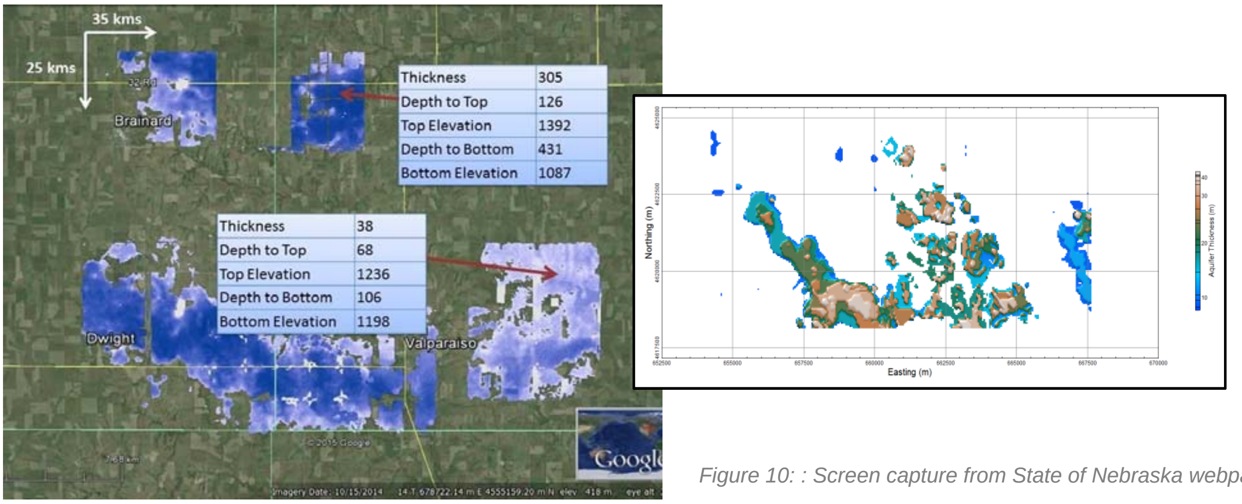

Figure 10: : Screen capture from State of Nebraska webpage

Once the State was able to confidently calculate volumes of available water they were able to identify:

- why many domestic wells had been reduced or had no ability to pump water
- potential water shortages and state of municipal wells
- Locations for new test holes
- why a new hydrogeological framework was required

Conclusions from the survey include:

- limited groundwater exists in the study area;
- aquifers are discontinuous and limited in size;
- once an aquifer has been identified monitoring wells can be placed in critical areas for continuous and year round verifications and checks of available water;
- approximately 131.5 million cubic meters (106,608 acre-foot) of recoverable groundwater (when saturated) have been identified;
- nature of the mapped aquifers combined with the assumed increase in pumpage due to drought led to the previous declines;
- potential for new supplies in bedrock have been identified;
- AEM is the best possible tool to improve understanding of the hydrogeological framework.

Mapping Brackish Water for Desalinization and Industrial Purposes

In April, 2011, Geoscience BC employed SkyTEM to collect approximately 2,400 line km of data over four separate areas in the Horn River Basin, British Columbia. The survey was flown with the objective of using AEM data and models to better understand the near surface groundwater resources in areas managed by EOG Resources Canada, Imperial Oil

Resources, Quicksilver and Stone Mountain Resources. The data are publically available on the Geoscience BC website http://www.geosciencebc.com/s/Report2012-04.asp.

Results from two of the areas are described below. Figure 11 shows a paleochannel mapped to a depth of approximately 150 m. This feature was more conductive then the surrounding earth and it was concluded that water in the channel is most likely brackish. The shape of the buried feature can also lead one to believe that the feature is a buried river system. For drinking water, brackish water can be treated through reverse osmosis or other desalination processes. Brackish groundwater is also used for purposes such as cooling water for power generation, aquaculture, and for a variety of uses in the oil and gas industry such as drilling, enhancing recovery, and hydraulic fracturing.

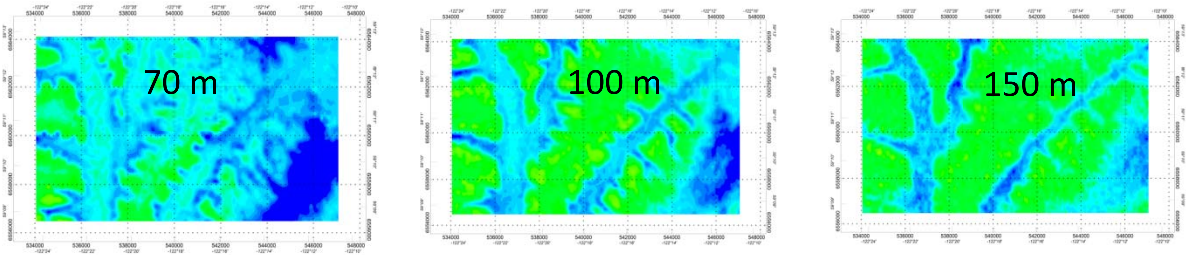

Figure 11: Data from Horn River Basin survey showing a paleochannel at various depths

Conclusions drawn from this study include:

- Borehole placement can be targeted to collect geological information used to interpret the airborne data and adjust depth calculations

During the post data acquisition interpretation phase and due to the high quality of the data and resulting resistivity models, other important discoveries and applications were developed aside from aquifer mapping. These are described next and in more detail in a paper found here: http://skytem.com/wp-content/uploads/2014/12/SkyTEM-Horn-River-Basin.pdf?9c6367.

Artesian well explained – recharge areas identified

In a second area of the Horn River Basin the SkyTEM data resolved an area where the groundwater was under pressure explaining an artesian well. In Figure12 we see the ground (moderately resistive green/yellow colours) below the clay cap (conductive orange/red) interpreted to represent water charged paleochannels overlying a thicker clay layer below. The water filled paleochannel produces natural artesian water flow from the overburden at surface (represented by blue colours). These blue coloured areas in the very near surface have high resistivity values suggesting aggregate material (sand and gravel) and these could be areas of aquifer recharge. Also, this study was carried out in an active gas producing area and in adjacent areas clay caps could trap significant accumulations of shallow gas and present a potential drilling hazard.

Further interpretation of the SkyTEM data can provide a number of verifiable predictions: prediction for the location of ground water resources, prediction for the location of artesian water flow from the quaternary, prediction for the presence (absence) of shallow gas on the property, and a prediction for locations of near surface coarse materials for engineering applications.

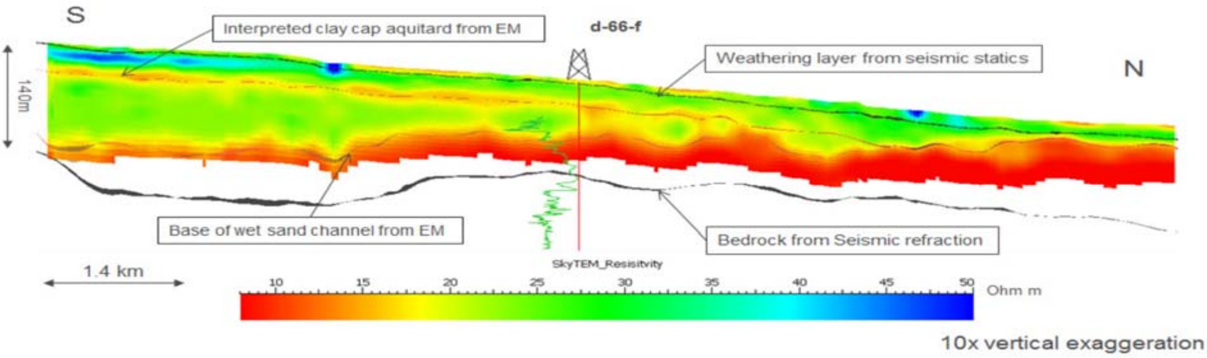

Figure 12: Layered earth represented in the AEM resistivity model

SALT WATER ENCROACHMENT

In the Pilbara region of Western Australia, a major water management scheme on the fringe of a large hypersaline lake system (the Fortescue Marsh) has been operating since 2008. The scheme supports the Cloudbreak iron ore mining operations, and has the Indigenous name of Papa Warringka. A key input for water management decisions on the fringes of the Fortescue Marsh is hydrogeological drilling data; however, due to the heterogeneity of the aquifer and the salt-interface, it has been a challenge to model aquifer processes using borehole data alone. To address this challenge, recently acquired SkyTEM data has been successfully employed to map saline-interface processes. For more information on this study see http://www.swim-site.nl/pdf/swim21/pages_061_064.pdf

In 2014 The National Science Foundation (NSF) and an international team of scientists applied the SkyTEM method in Antarctica to map the hidden distribution of groundwater and ice in the McMurdo Dry Valleys region to enable researchers to study microbial ecosystems in sub-glacial environments.

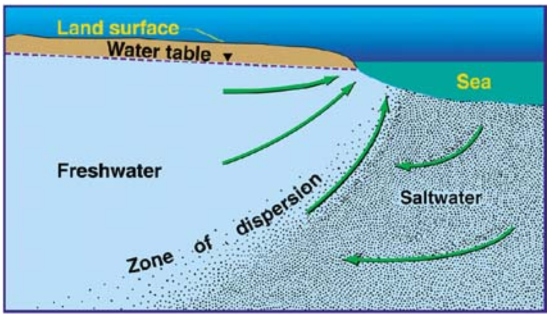

Figure 13: Conceptual saltwater intrusion setting

See http://www.nature.com/ncomms/2015/150428/ncomms7831/full/ncomms7831.html for a paper on this study.

Slawek Tulacyk of the University of California at Santa Cruz said “In a matter of a few weeks, SkyTEM revealed more about deep hydrological systems in the McMurdo Dry Valleys than what has been gleaned from a long series of heroic drilling and geophysical campaigns since the 1970s."

Regional scale zones of low subsurface resistivity were detected that are inconsistent with the high resistivity of glacier ice or dry permafrost in the region. Figure 14 shows (a) a photograph of the lower 2 km of Taylor Glacier showing its contact with Lake Bonney. Blood Falls is marked by the orange staining of ice caused by the release and oxidation of subglacial brine.

Panel (b) is a 3D image of the SkyTEM data showing highly resistive glacier ice and permafrost with conductive subglacial brine.

Panel (c) is a 3D image of the Taylor Glacier with resistivities above 100m removed to show the spatial extent of conductive brine-saturated sediments below glacial ice.

The results are interpreted as an indication that liquid, with sufficiently high solute content, exists at temperatures well below freezing and considered within the range suitable for microbial life. These inferred brines are widespread within permafrost and extend below glaciers and lakes. One system emanates from below Taylor Glacier into Lake Bonney and a second system connects the ocean with the eastern 18 km of the valley.
More information on this study can be found at:
http://www.hgg.geo.au.dk/ref_manager/MIKUCKI2015.pdf

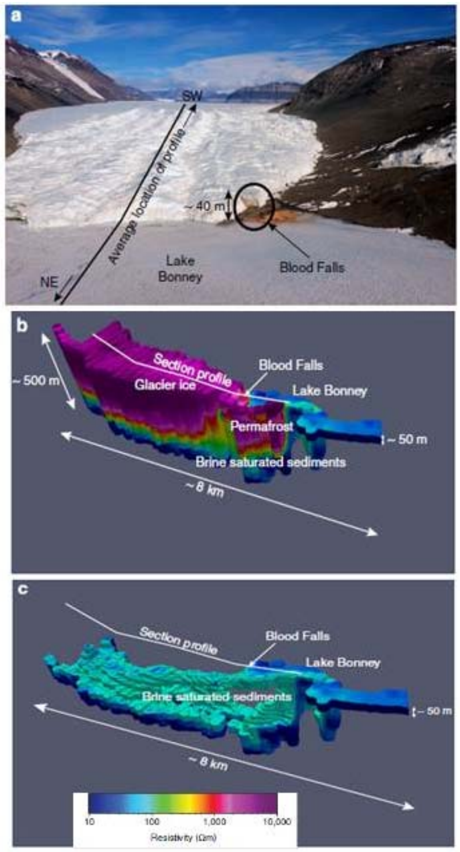

Figure 14: Resistivity maps from the Taylor Glacier and Bonney Basin Survey

SKYTEM PROVIDES A WIDE RANGE OF SUBSURFACE MAPPING SOLUTIONS

Hydrogeology divisions of governments worldwide routinely select SkyTEM technology over all others to map their water resources. Clients include:

- The United States Geological Survey
- CSIRO (Australia)
- Aqua Geo Frameworks
- BRGM (Geological Survey of France)
- Geoscience BC
- World Bank in India
- Central Groundwater Board India
- Lower Platte South Natural Resource District, Nebraska
- Western Australia for the Department of Agriculture and Food
- The International Water Management Institute (IWMI)
- Stanford University
- Geoscience Australia
- Geological Survey of Sweden
- U.S. Bureau of Reclamation
- India for the National Geophysical Research Institute (NGRI)

Figure 15: SkyTEM airborne system

There are many other applications for this technology

SkyTEM was initially developed to map the aquifers of Denmark but other market sectors now use the method for a multitude of applications. SkyTEM's ability to deliver accurate high resolution maps of the subsurface from the very near surface to depths over 500 metres is of tremendous benefit for resource exploration, environmental and engineering studies. SkyTEM provides solutions for:

- mineral deposits
- soil contamination
- aggregates
- fractures and faults
- landfills
- water depths (bathymetry)
- oil and gas
- site characterization
- landslide investigations
- pre-construction planning

A significant portion of SkyTEM's projects are in the mineral exploration sector. Clients include BHP Billiton, Rio Tinto, DeBeers, Anglo American and Boliden. Geotechnical solutions have been provided to the Norwegian Geotechnical Institute, Golder Associates and First Quantum Minerals,

The superior mapping capabilities of SkyTEM are well documented in papers and case studies authored by our clients and the scientific community. Please visit our website at www.skytem.com to read some of these papers and for other information about the SkyTEM method.

A SYSTEM FOR EVERY PURPOSE AND TARGET

To meet the various subsurface mapping needs of all the different markets sectors and clients served SkyTEM offers a variety of systems that can be customized to each project to maximize the results. Not unlike Lego bricks, also a Danish invention, SkyTEM is engineered to be quickly reconfigured and rebuilt in the field to adjust for depth of penetration, near surface resolution and other parameters in order to maximize the value of the delivered data.

A recent SkyTEM development is SkyTEM312^{FAST}. For budgetary reasons alone, large-scale airborne surveys have traditionally employed fixed-wing aircraft platforms. This, however, has often been at the expense of near-surface resolution due to the separation between the transmitter and receiver of fixed wing systems and the requirement to fly at higher altitudes and faster speeds than helicopter-borne systems. As a result ground geophysical surveys are often required to follow-up the targets detected by fixed wing systems. Helicopter geophysical surveys benefit from the ability to operate from remote locations with no requirement for a landing strip or airport as there is for fixed wing operations.

In order to address these shortfalls, SkyTEM engineered a new type of system – SkyTEM312^{FAST}. SkyTEM312^{FAST} is a radical cost efficient departure from all other existing helicopter HTEM systems. The system can be flown at 150 kilometers per hour close to the ground and is built on an exceptionally rigid and aerodynamic carrier frame that maintains the low noise levels necessary to provide fine discrimination in the near surface data while retaining the ability to detect weak conductors at depth. SkyTEM312^{FAST} is able to acquire over 1,000 kilometers of data per day and is ideal for both mineral exploration and groundwater mapping purposes.

As with all SkyTEM systems, SkyTEM312^{FAST} is highly efficient and robust with little to no downtime, a critical precondition for rapid survey execution. Each SkyTEM system, regardless of model or application offers the same basic SkyTEM benefits including:

- **Resolution** – All SkyTEM systems employ dual-moment technology where a current waveform composed of low and high dipole-moments is used enabling discrimination between weak geological contrasts in the top layers concurrently with those at depth.

- Low moment (LM) mode with low current, high base frequency and fast turn off provides early-time data and high spatial sampling for shallow imaging.
- High moment (HM) mode with high current and low base frequency provides high quality late-time data for deep imaging.

- **Calibrated** - The SkyTEM system is one-time calibrated allowing for direct comparison with ground based or borehole EM datasets together with complete traceability back to the established TEM reference model. This also ensures that data from repeat or contiguous SkyTEM surveys can be seamlessly and confidently processed and combined.

- **Rigid carrier frame** - All sensors, including the magnetometer, are mounted on the rigid carrier frame and flown at low altitude ensuring that all measurements are recorded in a fixed geometric setup and as close to the ground as is achievable from an airborne geophysical platform.

- **Magnetic system** – The rigid platform's position and orientation is continuously monitored and together with its separation from the aircraft means that magnetic data is not being corrected with lower frequency response fluxgate data in the compensation calculations. Corrections regarding frame geometry are actual and not approximated. Magnetic data is also used to map geological features such as fractures and faults,

- **Robust** - The system is very robust and can fly in challenging weather and terrain conditions and without and onboard operator.

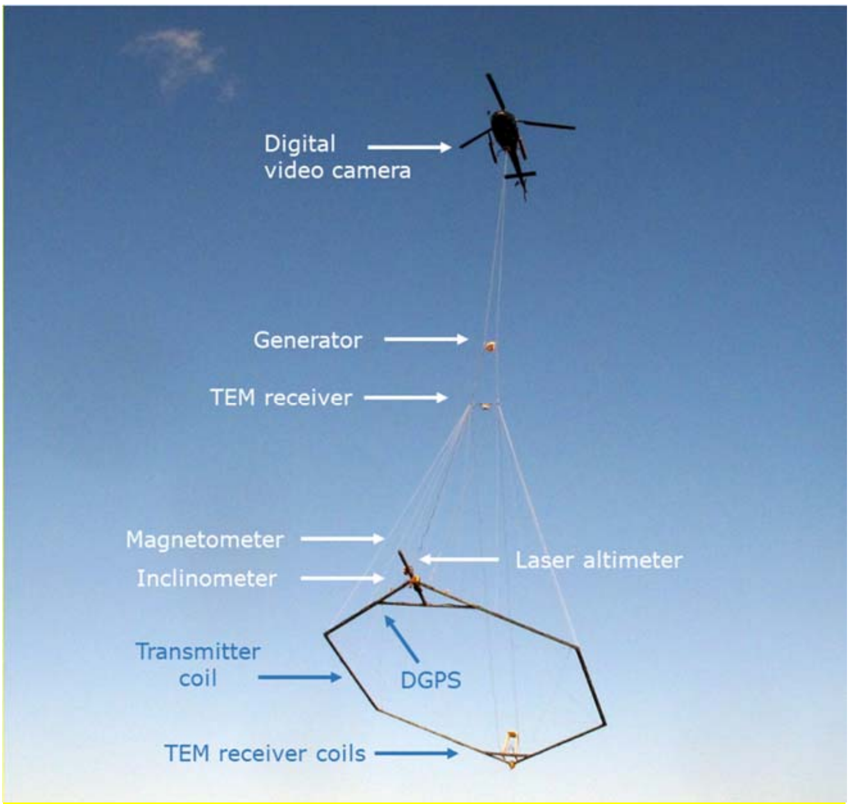

Figure 16: SkyTEM system components

GLOBAL SCOPE

Our diverse and highly skilled workforce of geophysicist, engineers, technicians and project managers have managed and completed projects on all seven continents and are experienced in all aspects of geophysical data collection and safe operations. Our global coverage is complemented via partner companies that are strategically located to ensure availability of our technology and services.

TECHNOLOGY AND EMERGING NEEDS

The SkyTEM Method is not based on what others have done – and are still doing – rather, we engineered a truly innovative and unique technology capable of delivering accurate and finely detailed images from the very near surface to depth using airborne geophysical surveys. We focus on improving your ability to find, manage and develop resources and your ability to make timely decisions with confidence. We continue to develop the next generation of TDEM sensors, including the achievement of even greater depths of penetration and increasing our already high S/N ratio, via our on-going investment in R&D.

ENVIRONMENT AND SAFETY

We take great pride both as a company and as individuals in our contribution to the communities where we live and work. We operate always with great care for the environment and are proud of the many ways that our employees work to safeguard it.

OUR WORK

We recognize that the world needs all the water, energy and mineral resources we can develop and we work continuously to develop ways to map and manage these resources.

Figure 17: SkyTEM HQ in Denmark