SEEQUENT

UNEARTHED

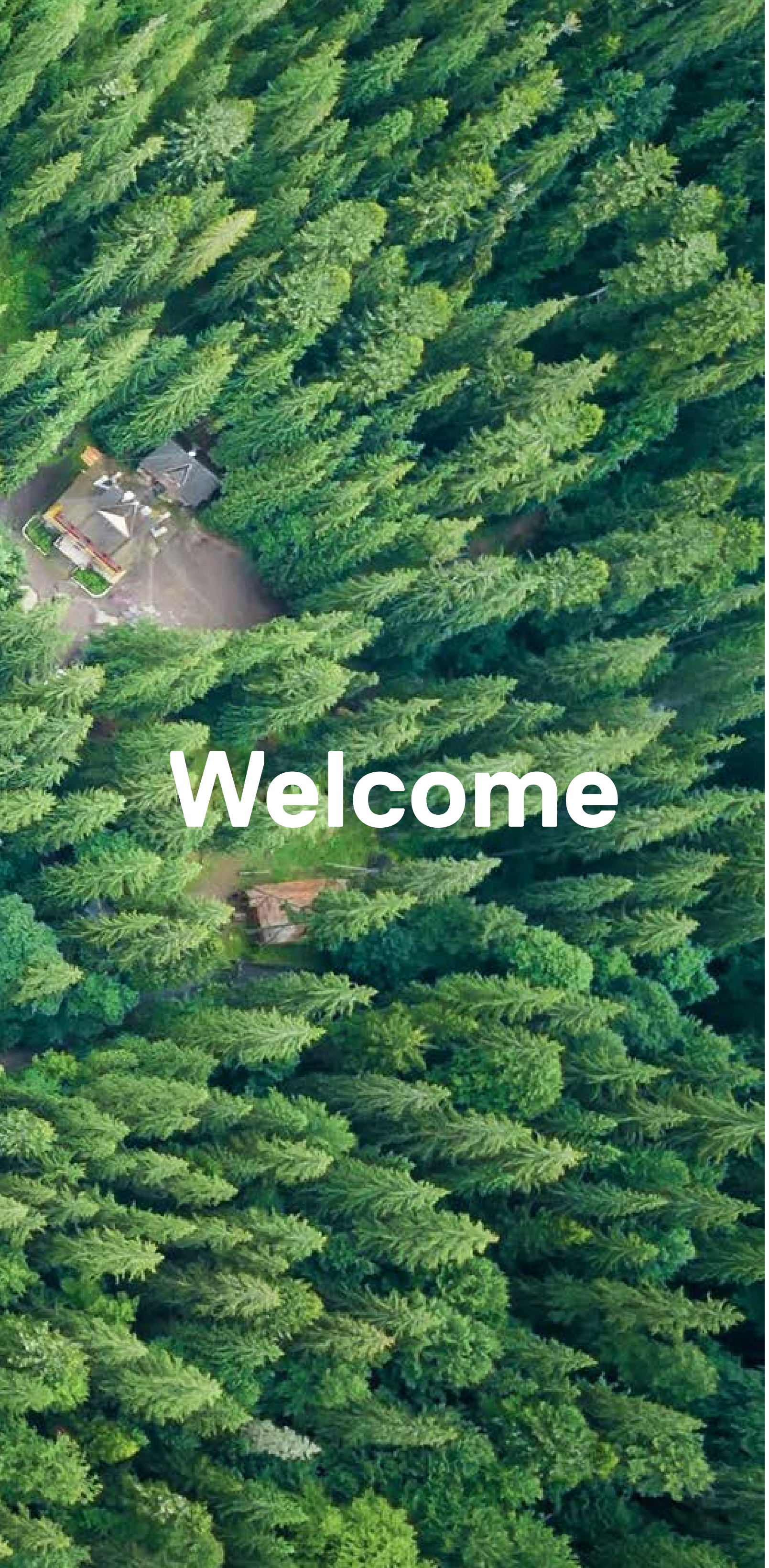
GEOSCIENCE FOR GOOD

THE UNEXPECTED WAYS GEOSCIENCE IS MAKING THE WORLD SAFER, SMARTER AND MORE SUSTAINABLE

ISSUE 5

Technology and innovation for the Civil Engineering and Environmental industries.

Brought to you by Seequent, developers of Leapfrog, Oasis montaj and GeoStudio.



Welcome

Geoscience is a remarkable, fascinating and all-encompassing discipline. We are lucky to work in a field with enormous breadth, which touches almost every part of our planet's physical characteristics; from earthquakes to raindrops and from floods to fossils. Don't believe me? I hope this issue of Unearthed will convince you otherwise.

Here at Seequent, we believe that geoscience has incredible power for good. Across the world, experts in geoscience are using their "geo" expertise - geological, geophysical, geotechnical, geostatistical, and geospatial (among others) to the benefit of our planet and the lives we live on it. And I'm proud to say we have many such people on our own team.

So we've dedicated this edition of Unearthed to looking at how geoscience is making the world safer, smarter and more sustainable – sometimes in remarkable and unexpected ways.

Geoscience can hold the key to stopping Arctic ice sheets from melting, it can prevent long-dormant WWII bombs from exploding, it can help deliver cleaner, greener energy, it can bring fresh water to beleaguered refugees.

This edition's expert contributors bring through their views on how the world is changing and how we can leverage geoscience for good across the globe. We hope you enjoy reading this edition. And to all who use their geoscience skills for good in your own way, thank you and we salute you!

Daniel Wallace
General Manager, Civil and Environmental Industries, Seequent

GEOSCIENCE AND THE ENVIRONMENT

THE ANTARCTIC SECRET THAT COULD SWAMP THE WORLD

> I think one of the remarkable things about this project was that before we started working on it, this was the largest unknown area of any continent on the Earth.

The journey from ice to water seems simple. It's a transformation even schoolchildren grasp. Yet apply it to polar ice and rising sea levels and the subject gains complexities and mysteries that stretch geoscientific research to its limits.

We talk to geophysicist Jamin Greenbaum about the exploration and analysis that plumbed the literal depths of Antarctica's melting ice sheet, and how geoscientific discoveries there are having increasing significance for all our futures.

The link between rising sea levels and melting Antarctic ice has rightly attracted increasing amounts of research and publicity in the last two decades, with the risks to life of rapid sea level rises coming into ever sharper focus.

Prior to 2008, most initiatives and studies were concentrated on West Antarctica, considered to have the more vulnerable glaciers and to be changing the most rapidly. In comparison East Antarctica was viewed as relatively stable and of less immediate concern.

However, the International Collaborative Exploration of the Cryosphere through Airborne Profiling (ICECAP) project that has seen welcome levels of collaboration between the US, UK, Australia, France, Italy, Korea and China, has cast doubt on that assumption. While East Antarctica may be melting less rapidly than West, the scale of the threat is far larger than anticipated as the ice contained by its glaciers holds the potential for truly dramatic rises in sea levels. The ice within just the single Totten Glacier could raise global sea levels by 3.5m on its own. That's greater than the impact all of West Antarctica's glaciers would have put together. Furthermore, not only is Totten the most rapidly thinning glacier in East Antarctica, but it's melting faster than it should, and no one was entirely sure why.

Geoscience has been integral to a new and clearer understanding of this climate change puzzle.

Interrogating ice on a colossal scale

Jamin Greenbaum, Research Associate at the University of Texas Institute for Geophysics, has played a key role in the Totten research and been involved in the airborne surveys tracking the shifting fate of the continent's ice sheets. In 2015 he and the project's international team authored a Nature Geoscience research paper that threw light on the unexpectedly rapid thinning of the glacier. Totten had been thought to be insulated from the effects of warm, deep ocean water by a shallow basement ridge. However, using airborne gravity and magnetic studies, Greenbaum revealed the existence of two deep seafloor valleys that could allow the warm water to reach the base of the glacier's floating section and accelerate melting.

"I think one of the remarkable things about this project was that before we started working on it, this was the largest unknown area of any continent on the Earth," recalls Greenbaum. "It was the last frontier of continental exploration, really.

"I've surveyed the glacier dozens of times now and I still can't wrap my head around how big it is. It flows from the South Pole to the North, and when it reaches the grounding line, that's when it becomes thin enough to float – and at that point it is 2km thick. The scale is just mind blowing. That's just amazing to me."

In presentations, Greenbaum brings this point home to audiences by illustrating how many Eiffel Towers would fit into such a depth. It's six...

Gathering the data and drawing new models

As part of the research, a BT-67 aircraft criss-crossed the glacier, packed with scientific equipment - from radar able to measure ice several kms thick, to lasers that could determine the shape and elevation of the ice surface. The flights set out to fix the 'pole of ignorance' that this area had become – the last major gap in Antarctic bed topography. The coastal part of the survey revealed that warm water flowing below the surface was likely melting the glacier, which would explain its rapid thinning.

But analysis of other geophysical data helped solve a further mystery. Previously, when looking back at the sea level rises indicated by geological records, physical models struggled to melt enough ice in the Antarctic to account for the increases. Solving that mismatch – as fresh analysis and a resulting paper has – is an important step. It helps buttress the argument that such increases are not just feasible, but far from extraordinary.

"There's nothing special about the sea levels we have now," says Greenbaum. "Six to nine metres above this level is what the Earth saw in the last interglacial period when average temperatures were about the same." Applying the paper's modelling to the future also shows a worst-case scenario eclipsing even the Paris climate change agreement's fretful prediction of a 5metre rise by 2500. Instead it's 13.6metres.

Meanwhile, separate research published by Climate Central in October indicates we may have underestimated the number of people at risk from rising sea levels in a more immediate timeline – the next 30 years. It puts the figure at 300 million, three times that originally thought to be in danger. The research re-examined a wide range of digital elevation modelling data and found a number of errors in the ground truth. These resulted in underestimates of the impact sea level rise will have on coastal areas. It also sought to address an alarming lack of accurate DEM data in various parts of the world, such as Asia, that are most likely to be affected.

International collaboration as a way forward

Using geoscience to investigate some of these major challenges for global society has been a constant driver in Greenbaum's career. "When I was younger I was really motivated by exploration, and originally, space exploration. When I decided to go into earth science I was looking for something that had that exploration component but also took on a societal role. Today I'm certainly motivated by collecting the data we need to better predict sea level rise, and it appears that Antarctica provides most of that sea level."

Greenbaum also confesses to an instant love affair with Antarctica from the moment of his first survey. "It was actually ground based, driving a snowmobile around for 12 hours a day, towing radar antennas, eating beef jerky, listening to my iPod, being freezing cold. It was great. Super extreme!"

But equally important as the mysteries geoscience unpicks, is the collaborative nature of the effort. "The main reason I stayed at the University of Texas after I completed my PhD was so that I could work on this project with China and the other collaborators;"

"I'm such a believer in this international approach to geophysical data acquisition. It's an example of what our nations will need to do in the next hundred years to react to climate change or other problems we encounter. It's inspiring to work in a field such as geoscience that transcends politics and allows us all to work on a subject as important as this one."


Kenn Borek Air Ltd.
AUSTRALIAN ANTARCTIC PROGRAM
C-GJKB

GEOSCIENCE AND ENERGY

NOT SO DEEP HEAT

> Shallow geothermal can be reached with a much smaller and less expensive drilling rig than high temperature geothermal needs. It's also less cumbersome and requires less complex and costly technology.

Shallow geothermal energy has been gaining traction as a clean energy source that avoids some of the challenges felt by other renewables. In geophysical terms, it's just below the surface – and that makes it practically on the doorstep for many urban areas across the world.

The traditional use for geothermal energy has been to generate electrical power, and that generally calls for very high temperature fluids to deliver the temperature differences necessary. Unfortunately, such applications are extremely geographically constrained; they only tend to operate in areas where there are volcanoes or very high/low temperatures, e.g. New Zealand, Indonesia and Iceland.

But what geothermal also affords is the ability to just provide heat. That can be useful at much lower temperatures, and this low temperature geothermal resource can be found in many more locations, without drilling so deeply. While this approach may not have the capacity to generate large amounts of electricity, it can play an important role in displacing the need to create electricity from another source.

"The greatest value of shallow geothermal energy is that it replaces baseload energy," says Jeremy O'Brien, Seequent's Energy Business Manager. "Around 40% of all the energy used in Europe is for heating and cooling, so if you were able to get half of that 40% from drilling some holes in the ground, that is an enormous benefit."

Geothermal also offers a particular advantage over other renewable sources. It's always there. "If the sun's not shining or the wind's not blowing it still works. It's 24/7 clean energy and it's not going away."

Jeremy O'Brien
Global Director - Energy, Seequent

Image Source: www.herrenknecht-vertical.com

Baseload is a key target for emissions controls

Much of the baseload energy our society relies on has come in the past from coal or gas generation, and those are the sources currently being curtailed by CO2 agreements. (In 2020 the world's use of coal fired electricity is on track for its biggest annual fall ever recorded, after four-decades of almost uninterrupted growth.)

While solar and wind energy also have a critical role to play in reducing our CO2 emissions, they are usually not focused on purely replacing baseload. Shallow geothermal doesn't need a battery to store the energy it creates. It just sits there in the ground, waiting to be tapped. The footprint of a geothermal plant will also typically be far smaller than that of a solar power array or windfarm as all the heavy lifting is going on underground.

All of this means that shallow geothermal – especially heat pump applications- has the ability to be highly 'local'. (A good example being the trend for supermarkets to extract heat from below their own stores and use heat exchangers to offset their refrigeration power.) Or it can be city-wide. Copenhagen is one of a number of European cities exploring the potential of shallow geothermal to support its district heating for residents.

"Often you're only looking for temperatures in the range of 50 to 80 degrees Celsius," says Jeremy O'Brien, "but in many cases that's all you need for baseload replacement." Neither is the idea actually that new. "Many people don't realise that Paris has had geothermal heating since the 1970s..."

Down in the not so depths

So how deep is shallow? "I suppose in our language we would say anything less than 1000 metres, whereas in a normal geothermal sense, the average depth of a well would be 2000 metres.

"What's important is that everything within those 1000 metres of the surface can be reached with a much smaller and less expensive drilling rig than high temperature geothermal needs. It's also less cumbersome and requires less complex and costly technology."

And in many instances, simple heat pumps can be effective at far less than that. London's Tate Modern gallery opted for a geothermal solution that goes just five metres down to a bed of river gravel. It uses the borehole to satisfy part of the building's heating demands in the winter, and cooling needs in the summer, keeping the invaluable collection of Picassos, Dalis, Rothkos and more at a comfy (and internationally required) 18 to 25 degrees.

Again in the UK, researchers are exploring how the country's legacy of abandoned coal mines could be used to create a second life of heat generation – this time using the slightly raised temperatures (around 30 degrees) of the miles of empty voids sitting there within the earth.

How shallow geothermal potential reveals itself

A key to making shallow geothermal work is locating the particular formations and stratigraphic units that have good temperature fluids in them, and which can be employed effectively. Surveys might include seismic, gravity, magnetic telluric data, but it can be invaluable to incorporate that with what's already known about the location, points out Jeremy O'Brien.

"Are there old oil and gas exploration wells or perhaps old groundwater wells where the data can be integrated with the geophysics? What are the flow rates from the existing wells? What does that tell you about the areas that might be most interesting to explore? Where are the highest temperatures and what's the geology?"

Good detective work can come in many forms. For example, a Google Earth tour of Almeria in south-east Spain reveals a glittering landscape of greenhouses covering almost the entire peninsula. It's the largest collection in Europe. When looking for areas of high geothermal potential, researchers reasoned that the farmers might perhaps know something they didn't.

"Just inland you can see the fault lines running through the topography, and the farmers were drilling for water up in these hills. The fault channels fluids deep down and back up again in a very efficient manner so they get hot relative to benign groundwater. It was no good for the plants as it had picked up too many salts, but for geothermal energy it was ideal...."

CASE STUDY - Assessing shallow geothermal potential in urban areas; Catalonia, Spain

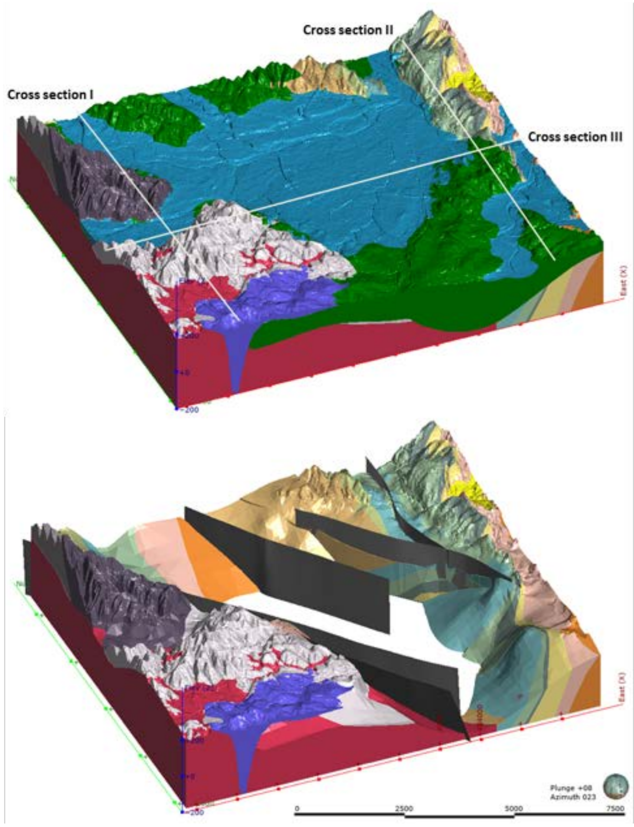
European urban areas are decarbonising, and the energy market is shifting towards renewables. The popularity of shallow geothermal energy is growing. Spain's Catalonia is one region exploring the possibilities, and is a case study for the MUSE project (Managing Urban Shallow-geothermal Energy). The urban area of Girona was chosen as the first pilot area – not without its challenges.

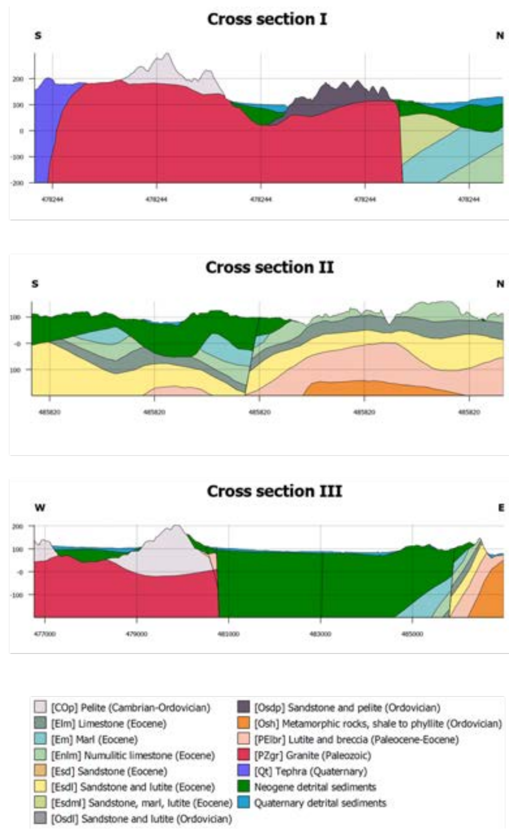
It's the thermal properties of the subsoil that determine how much energy can be extracted via heat exchangers, and around Girona the geological and hydrogeological properties of each stratigraphic unit are complex and vary significantly. A detailed 3D model was needed, and Leapfrog software was used to prepare that model from all the available data, which was substantial.

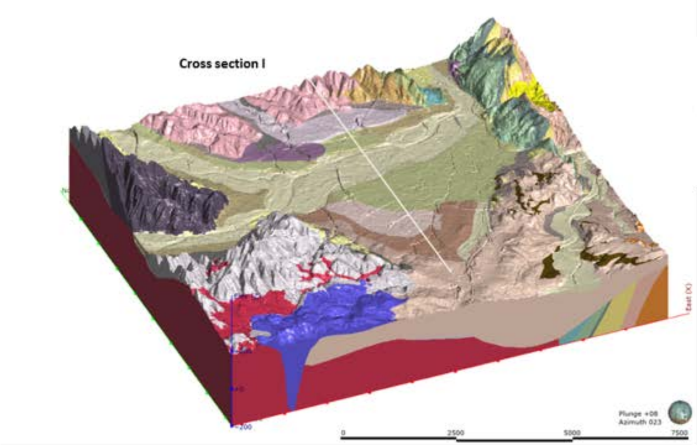
All in all, around 1400 drillholes, 4 geological maps scale 1:25000, 5 geological maps scale 1:5000, 2 hydrogeological maps scale 1:25000 and a wealth of geophysical data were used to prepare a detailed geological model of an area 10km wide, 9km long and 300m deep. A total model volume of 29km3. Average ground water temperatures were also monitored.

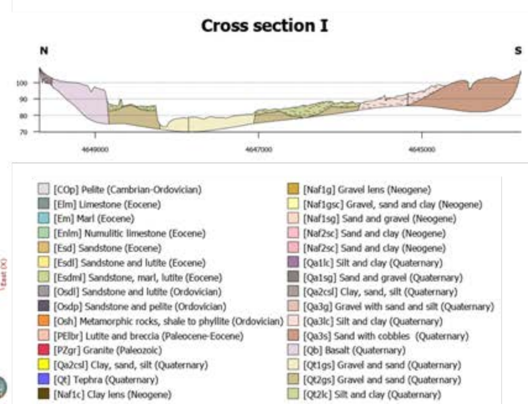
In order to interpret and present subsoil geology in the best way possible, it was necessary to build a base model defining the Paleogene-Palaeozoic, Neogene and Quaternary periods. In fact 31 geological units were modelled in total, between Ordovician and Quaternary. The focus was on determining the depth and spatial expansion of Girona's La Selva sedimentary basin (the basin's sedimentary fill is likely to be the principle medium through which to utilise geothermal resources).

The research is ongoing and will ultimately contribute to the GeoEnergy SGE Project that will provide a platform to assess geothermal potential at a regional and local scale and help Girona decide which areas are the most feasible for installing open and closed loop heating systems.









Using Leapfrog to chase the heat

Increasingly governments are looking to screen and sift all the data they've gathered in areas, like Almeria, where they suspect there could be useable heat gradients due to faulting or pressured sedimentary aquifers, etc.

"I think Leapfrog can make a real contribution to that," considers Jeremy O'Brien. "It's a very intuitive tool for combining all those different data sets together in one place. You can build a picture of the subsurface that will identify potential spots that might not have been intuitive otherwise.

"If you're starting a project, you might have an old geological cross section that covers a massive region and you need to integrate all that data into one place. Leapfrog can speed that up enormously, quickly building a picture and generating visualisations. In comparison it might take you days to explicitly draw temperature contours by hand or by using another package.

"Screening a lot of data quickly makes it a powerful tool in identifying areas with potential for shallow geothermal. Then, once the drilling campaign is planned, the fresh data can be input to update the model and show what's happening in the subsurface. Because Leapfrog connects with other simulation software you can also look at the flow of water in the ground or changes in temperature. The software can guide teams on where drilling should occur, and then go on to help understand and manage the resource with time.

"It means that Leapfrog can support a project from beginning to end, throughout the value chain."

GEOSCIENCE AND UNEXPLODED ORDNANCE

LIBERATING THE WORLD FROM AN EXPLOSIVE LEGACY

The role of geoscience in locating the unexploded bombs that claim lives, endanger workers and threaten construction across the world.

UXO – unexploded ordnance – is a small acronym for a big problem. Exactly how many unexploded bombs and mines are scattered across the globe is almost impossible to tell. This is an issue where, by its nature, we don't know what we don't know.

We do know that 78 countries around the world live with a legacy of landmines and they kill between 15,000 and 20,000 people every year, 80% of them civilians. Even on military training grounds, where elaborate precautions are taken to clear firing ranges of unexploded munitions, they have still been known to claim the lives of military personnel.

While the threat to life and limb is plainly the most pressing concern, dormant munitions have other victims too. As materials leak they can contaminate soil and groundwater. Forest fires have been known to worsen as they detonate explosives.

Then there is the challenge of submerged ordnance which comes with its own set of hazards. They threaten shipping; droughts can cause water levels to drop, revealing unexploded bombs and making them more dangerous; and undersea work on cables, windfarms, offshore platforms and more are all made more dangerous by the risk of unidentified ordnance lying just feet below the seabed.

The ever-present threat of the SS Montgomery

One of the most perilous seaborne caches of explosives lies in the hull of the SS Richard Montgomery, which sunk 8km offshore from the British coastal town of Sheerness in 1944. It was carrying 1500 tons (1.36m kg) of munitions, all of which remain onboard only 15metres below the waves. When the UK's Protection of Wrecks Act was passed in 1973, the Montgomery's name was at the top of the list (it holds the dubious honour of being the first such listed ship). In 1967 a much smaller and deeper load aboard the wreck of the Kielce exploded. Nonetheless, it registered 4.5 on the Richter scale. The Montgomery is constantly monitored by the Maritime and Coastguard Agency with an exclusion zone for shipping. The task of removing the munitions is considered just too complex and dangerous to undertake.

WHY OFFSHORE WINDFARMS FEAR WHAT LIES ON THE SEABED

Matt Grove,
Strategic Account Executive,
Seequent

> "What we thought were tightly defined areas of risk have turned out to be entire corridors of risk, with ordnance ranging from high explosive to chemical."

Undersea UXO are a risk to windfarm construction in the UK's North Sea, with a historical twist that makes detecting them more complex than it should be. Seequent's Strategic Account Executive Matt Grove explains how geophysics helps this branch of the clean energy sector build more confidently and efficiently.

Windfarms are an important source of clean energy, and around the UK, the North Sea is an ideal place to put them. Lots of wind, so lots of energy, and not an eyesore for anyone. But they face a problem in that these huge turbines need to be built in locations where there's a risk of unexploded munitions right below them. What we try to do is mitigate that risk.

Why should that be the case? Well, post World War II there was a real urgency to dispose of unused ordnance. The plan was to drop them far out into the North Sea, well away from shipping lanes or infrastructure. However, the commercial vehicles commissioned to dump them in these carefully selected and marked off polygons on the map, were paid by the load. As soon as they left port and were out of sight, many just ditched the munitions over the side and came back to load up again.

Consequently there is unexploded ordnance peppered all over the place, and often in areas closer to shore where windfarms like to be.

Add to that the complication of the North Sea being a very mobile environment. Sand waves are moving and migrating on a daily basis, shifting these munitions with them. One day they might have a dune over them, the next they're lying exposed on the seabed.

Never underestimate what sits on the seafloor

What we thought were tightly defined areas of risk have turned out to be entire corridors of risk, with ordnance ranging from high explosive to chemical. It's never a good idea to underestimate what might be on the seabed. For example, there was once a practice flight with a live nuclear bomb on board that ran into trouble and had to ditch the bomb in the sea. That's still not been found to this day....

Therefore surveys of these areas not only face a number of challenges, but have a limited lifespan as the seafloor conditions change. It's impossible to have any confidence in the old maps and charts, so it's often simpler and cheaper to survey the entire area of a windfarm and deem it safe than make a guess of where you should look for UXO.

Ten years ago, surveying such a wide area might have been impossible. You would have been towing a single magnetometer at maybe 30 or 50 metre line spacing, and ending up with barely any data to work with. Now it's possible to mount 10 magnetometers on a frame and be towing four or five frames at a time, and arrive at very dense data with few gaps in your coverage. It's known as gradiometry.

It's true that there are other industries operating in the North Sea that have traditionally exhibited less concern about the potential presence of UXO, and in fairness, incidents have been rare. But that attitude is changing. The windfarm sector is something of a pioneer in this area. I think that's because it's an industry trying to do 'the right thing' about energy and demonstrate where we should be going in the future, so they've decided to set a precedent on this.

Remnants of an earth-shattering air raid
This September one of the biggest bombs ever dropped during WW2 was found, unexploded, in a major Polish shipping channel. The 5,400 kg (12,000lb) "Tallboy" seismic bomb had been developed to attack underground targets. It had been dropped on April 16, 1945 by the Dambuster Squadron, which was carrying out a raid on the German cruiser Lützow, anchored in the Piast Channel. The unexploded shell was discovered by workers deepening the channel, with naval divers quickly called in to establish the risk. It's currently marked by a buoy and, as we went to press, authorities were still deciding on the best course of action to take.

USING UXO MARINE TO PINPOINT ANOMALIES

Searching for seafloor ordnance by sending out a vessel with divers and equipment is very expensive, so companies are trying as much as possible to employ geophysics to provide a solution and lessen the human involvement. Typically they'll use Seequent's Oasis montaj with the UXO Marine extension to pull together the vast amount of data gathered by the surveys.

Not only can this software configuration do all the processing, visualisation and target generation, but it can also bring in all the other data sets that might be available – sidescan, profiler, multibeam and so on.

You can start to layer up an interpretation of what your survey area is looking like, then bring in your bathymetry and all your other geophysics methods underneath, to get a better understanding of what that anomaly is down on the seabed. Is it an anchor, a spooled-up chain, some debris a fisherman has thrown over the side, or might it potentially be a UXO? All of that will be displayed on a colourful map with nice clear blobs for where the anomalies are.

Making sense of the iron harvest

Magnetics, as a science, will help you detect anything with a ferrous content, and because of the ages of these munitions, most will have been cast from iron. The big challenge is trying to decipher between each of these ferrous items and make sure the client can focus on the real risks rather than having to check every single piece of scrap on the seabed.

Once you know how deep the object is buried, its size and its orientation within the seabed, analysis of that data can sift out the anomalies most likely to be worth studying more closely. You can give the client a GPS location, then they can investigate further with an underwater ROV (Remotely Operated Vehicle) directed by a pilot on a nearby vessel, or even back on land. That ROV will have a geophysics instrument on the front, or a sub-bottom imager, and will gain a deeper understanding of what that anomaly is.

And if it is a bomb? In fact it rarely makes sense to remove what's found, or blow everything up on site. It's easier to leave it where it sits and put your windfarm somewhere else. Ultimately that means the windfarm can be redesigned slightly to avoid the problem, or maybe moved altogether if there's a dump or a huge munition in the area. The risk is reduced, and the project can move ahead.

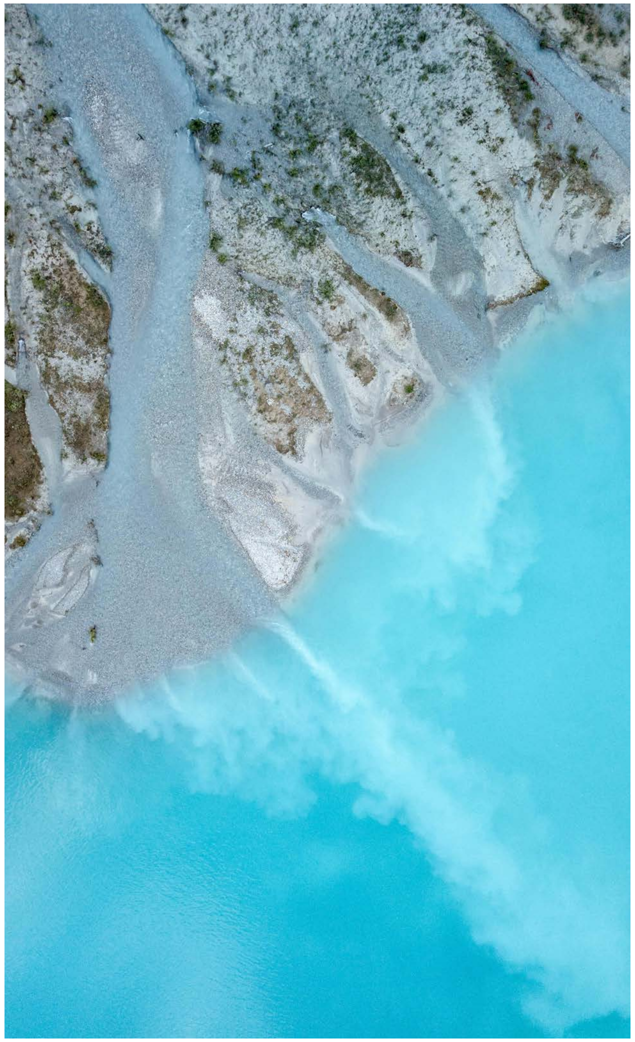
THE NEXT STEP FOR SEAFLOOR SURVEYING

We've learned there is plenty of UXO on the seafloor – really, a lot – and in the future there will be an increasing requirement from contractors in this sector to narrow down the target list to the anomalies that are genuinely important.

Because of the way contracts are drafted, there has been a tendency for contractors to err on the side of safety and present a target list that could run into the thousands for further investigation. For example, there are certain parts of the North Sea that have boulder fields with a slight magnetic signature, and some companies will recommend checking every single boulder. Thousands and thousands of them... But that's becoming unacceptable. The pressure is on to bring those numbers down.

There are a couple of interesting directions the technology could go in to address that. You could introduce electromagnetics. It's rare in the industry at present, but has the capability to classify the munition more accurately.

There are possibilities for machine learning, using AI to rattle through the data and identify signatures for you. There are multiple ways this could go, and better classification is definitely something the industry would welcome. If it helps make the creation of clean energy easier, more cost efficient, and with less risk, that will be an important and valuable contribution.



UXO IN STRANGE PLACES

SAFEGUARDING THE RIVER OF A MAJOR CAPITAL CITY

Oasis montaj and UXO software were also the chosen tools of SAND Geophysics who were called in by the Port of London Authority Hydrographic Service when a 50kg (111lb) unexploded WW2 bomb was found in the Thames riverbed in 2017, not far from the Houses of Parliament.

SAND uses a combination of multibeam and sidescan imagery, magnetic gradiometry and GeoChirp 3D surveys to identify such underwater UXOs. (GeoChirp 3D is an acoustic imaging system developed by the University of Southampton and Kongsberg GeoAcoustics to provide high resolution imagery of the top ten metres of sediment.)

For this project, the PLA provided a survey platform and a high resolution multi-beam echosounder.

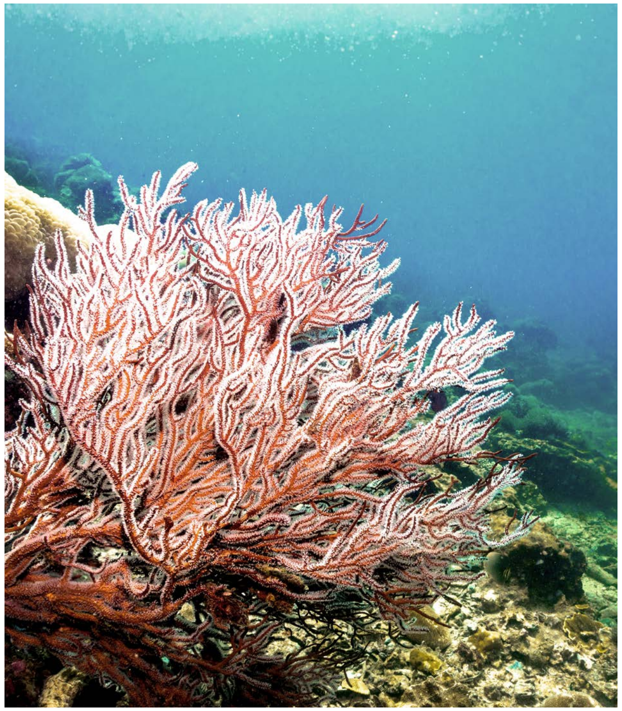
“The Thames is a notoriously difficult area to survey with traditional magnetic techniques because of its busy nature and high level of construction,” said Richard Hamilton, one of SAND’s founders. Vessel traffic and ferrous structures create false anomalies while changing tides disturb buoyed sensors. The software was able to find and remove those false anomalies and correct for the buoys’ movements, successfully confirming there were no other UXOs in the vicinity.

Bridges and roads were closed, and engineering work halted while the Royal Navy removed and later safely detonated the device.

SHALLOW WATERS CAN BE JUST AS CHALLENGING AS DEEP ONES

Occasionally underwater UXO will materialise in places that broader geophysical surveys cannot access. One example is the Caribbean where target practice by the US Navy has left unexploded shells in 200 acres (81 hectares) of shallow coral reefs. The reefs cannot be surveyed in normal ways for fear of damaging the coral. (The entire 1000-acre range was on the receiving end of aerial bombs, rockets, missiles, mortars and navy projectiles from 1903 to 1975.)

The solution was to mount a near zero-draft EM sensor array on a hovercraft that sits just inches above the delicate coral but never touches it. The hovercraft was modified to have a thrust system that allowed the pilot to finely control the position of the craft while the sensors did their job.



FINDING THE TRUTH WHEN THE GROUND TELLS LIES

Soils with different degrees of conductivity can easily complicate the search for unexploded ordnance. For example the Ho Chi Minh Trail that links north and south Vietnam was seeded with colossal amounts of ordnance during the Vietnam War – 3 million tons around Laos alone.

However the country’s soil, which is rich in aluminium, can mean that a 114kg (250lb) bomb sits only a metre below the surface, yet its EM signal will still be lost in the background noise. Survey teams have responded by recording multiple time gates with EM63 time-domain electromagnetic detectors to map subtle changes in background conductivity, enabling the spatial refinement of target locations.

Research facilities will also assess detectors by laying out lanes of soil - from clean sand to metal-rich laterite – and putting them through their paces against a range of UXO risks, from antipersonnel mines planted 10cm deep to 340kg (750lb) bombs four metres down. Targets are raised, lowered and moved to map the effectiveness of various sensors, then that database is used to produce 3D models of UXO responses for a wide range of munitions.

SIFTING A MASS OF DATA FOR THE FEW SIGNALS THAT MATTER

Sometimes the list of potential targets is so large that UXO specialists barely know where to start. For example, when a team from geophysical surveyors Aqua Survey checked a single mile of road in southern Laos, it found more than 700 dense metallic objects, the vast majority of which would be metallic debris rather than bombs. But which ones? Using a combination of techniques that isolated larger and higher conductance targets, they were able to narrow that 700 down to 29, enabling the UXO disposal experts to focus their efforts and improve their chances of success.

They also tackled the problem of the Sepong copper mine where large bombs are found on a regular basis amidst some of the most conductive soil in the world. Reconfiguring their equipment and software allowed the team to distinguish between responses from the ground and the bombs. This dramatically sped up the detection of unexploded ordnance which enabled the mine to work faster and more efficiently, supporting a country where mining makes up more than 10% of the economy.

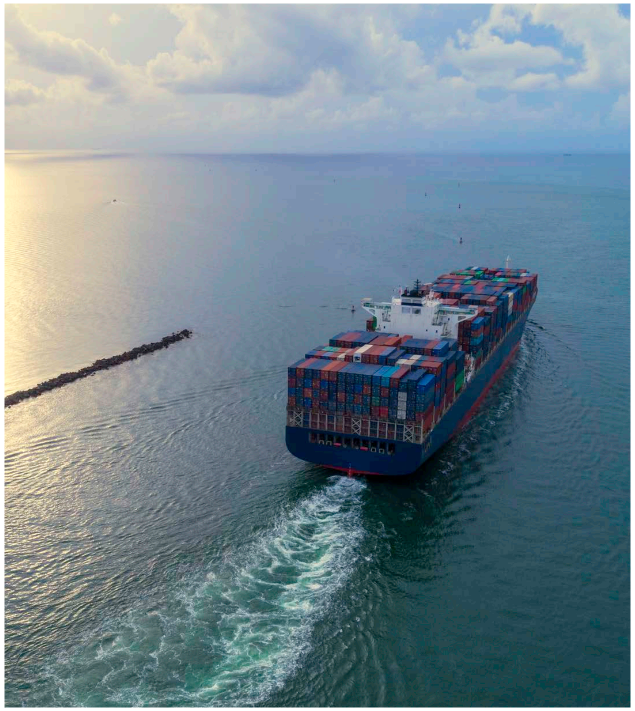
THE LARGEST UNEXPLODED BOMB ON THE PLANET?

The detonation of more than 900 million kgs (1 million tons) of TNT during the Battle of Messines in World War I is one of the largest human-made explosions before the nuclear age. Nineteen mines, buried beneath the German trenches over two years, were set off on June 7, 1917, all within 30 seconds of each other. The resulting explosion was heard in London. In Switzerland it was recorded as an earthquake. General Sir Charles Harington, Chief of Staff of the Second Army, famously remarked on the eve of the battle: “Gentlemen, I don’t know whether we are going to make history tomorrow, but at any rate we shall change geography”.

However, 25 mines were actually laid… Four were never used as the southern flank fell so quickly they were not required. (One exploded in 1955 when electricity struck a pylon. The three others are thought to survive nearby.) The fifth was lost when a tunnel collapsed and the sixth, one of the biggest, sits to this day, 25 metres beneath a barn on La Petite Douve farm, owned by the Mahieu family. At 20,000 kg (22 tons) it is potentially the largest single, unexploded bomb in the world. With admirable Gallic insouciance, the Mahieus declare themselves largely unperturbed.

REMNANTS OF AN EARTH-SHATTERING AIR RAID

This September one of the biggest bombs ever dropped during WW2 was found, unexploded, in a major Polish shipping channel. The 5,400 kg (12,000lb) “Tallboy” seismic bomb had been developed to attack underground targets. It had been dropped on April 16, 1945 by the Dambuster Squadron, which was carrying out a raid on the German cruiser Lützow, anchored in the Piast Channel. The unexploded shell was discovered by workers deepening the channel, with naval divers quickly called in to establish the risk. It’s currently marked by a buoy and, as we went to press, authorities were still deciding on the best course of action to take.



GEOSCIENCE AND THE WORLD

SHIPS, SCROLLS AND SPEEDING ICE

Five ways geoscience and geophysical surveys are unlocking secrets around the world

1) FINDING LOST SHIPS

In search of historic wrecks consumed by sand

In 1776 the 450-ton Dutch slave ship Meermin ran aground off Africa's Cape Agulhas after the 140 slaves on board revolted in a bid for freedom. The Meermin was lost in sand banks, and to history, but remains a significant moment in South Africa's past.

Traditional efforts to locate the wreck have proved fruitless, but an airborne magnetometer survey was able to identify 22 potential locations (anchors, cannon and iron fastenings give distinctive signatures). Further analysis of the data revealed anomalies such as a ship's keel, helping to identify the six sites most worthy of investigation.

After more work was done to determine the depth of sand deposits over the targets, those sites were excavated and… not one turned out to be the Meermin. Yet such was the accuracy of the interpretation that every one of the six revealed a previously unknown wreck ranging from the late 18th to late 19th century. The final resting place of the Meermin remains elusive, but geoscience may yet track her down.

2) UNEARTHING ANCIENT SCROLLS

Mapping earthquake shattered caves to throw light on an old mystery

In Israel, the Cave of Letters achieved fame in 1960 when a horde of papyrus scrolls were discovered, dating to 153AD. But further discoveries have been hindered by the condition of the cave floor, which is littered with boulders dislodged by earthquakes. Using an Electrical Resistivity Tomography (ERT) scan, it recently became possible to finally determine where the original cave floor lay and continue the exploration. The use of ERT in the area has also revealed a city beneath a city – the Iron Age remains of a settlement below the first century AD city of Beithsaida. And further geophysical surveys have located two burial sites that could offer important clues about the authors of the region's famous Dead Sea Scrolls, long a question of debate.

3) WATER FOR REFUGEES

Hunting new sources of water free of volcanic contamination

The UN's Kakuma refugee camp in Kenya was relying on just a dozen wells to serve 163,000 people. Not only was the supply inadequate but it had heavy fluoride concentrations. Geophysicist Paul Bauman concluded that the UN's practice of using one dimensional electric soundings to spot fractures in the underlaying volcanics and sink wells was contributing to the unacceptable fluoridation levels. Tracking down water in the thick overburden gravels would be a better alternative, he believed.

However, the complex geology and hydrogeology of the area called for a more modern geoscientific approach to locate the sand and gravel aquifers most likely to produce clean, fresh water. Bauman and his team ran the equivalent of 11.4km lines of ERT to differentiate fine materials from coarse and fresh water from saline. A simultaneous seismic refraction survey totalling 5.8km lines helped to determine the top of the bedrock and the thickness of the overburden. Compiling data in Seequent's Oasis montaj identified high priority targets for drilling. The work produced sustainable water yields of 29-45 cubic metres per hour – enough to supply 57,000 refugees with 20 litres of good water every day.

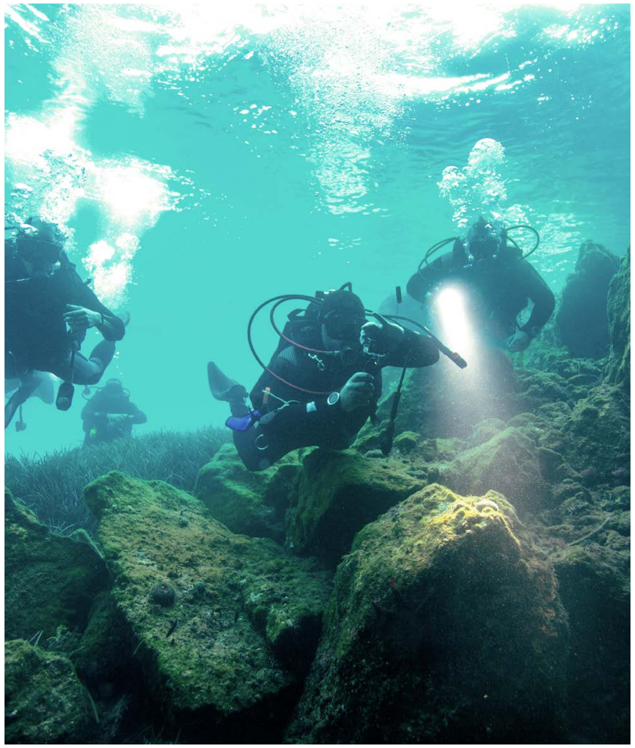
4) PATROLLING UNDERWATER CAVES

Keeping tourism and local welfare in balance

The cenotes – natural sinkholes – of Mexico's Yucatán Peninsula lead to the longest underwater cave system in the world. They're a constant draw for tourists, but are also inextricably linked to the welfare of the local people as the aquifer is the sole source of fresh water in the region. While tourism supports the local economy, it also presents two simultaneous threats: an increase in the extraction of water by hotels and higher levels of sewage.

To understand and address these issues, an airborne EM survey was commissioned to map the flow of fresh water through the sinkholes. However, the project was also made possible by hundreds of tourists working as amateur geoscientists, without knowing it.

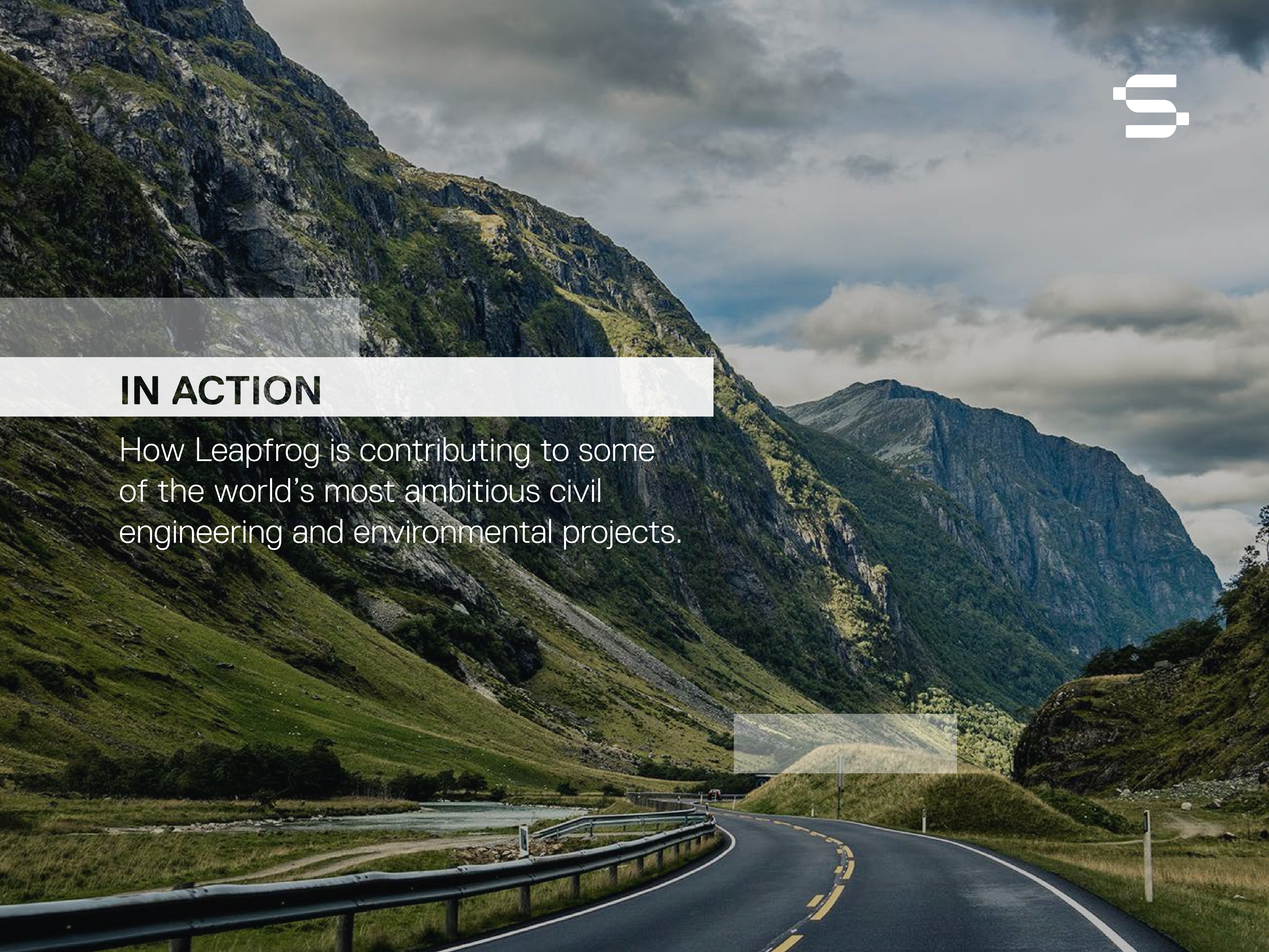
Over the decades, divers had mapped 262 underwater caves and 1140km of underwater passages. Along the way, many had also made biological, archaeological and environmental observations, and even taken water chemistry samples. Overlaying their records on the airborne data and bringing it all together enabled an objective assessment to be made of two totally independent data sets. This contributed to a far more comprehensive understanding of the hydrogeology. Monitoring this vast system with greater accuracy will be invaluable in ensuring the region can continue to attract tourists while reducing the impact on groundwater quality and availability.



5) MEASURING ICE MOVEMENTS

Tracking ice velocity to understand melting glaciers

Researchers from University of California, Irvine and NASA's Jet Propulsion Laboratory have been using SAR phase interferometry to map the speed of ice movements in the Antarctic. Surface ice velocity can reveal a lot about how glaciers and ice sheets are changing, and the resulting impacts on sea level rises. Previous maps have only been able to cover around 20% of the continent, but the new SAR research, published in July this year, boosted that to 80% with ten times more accuracy than previously possible. The team combined inputs from six different satellite missions from 1994 to today and used it to track details such as visible patches of dirt on the ice surface.



IN ACTION

How Leapfrog is contributing to some of the world's most ambitious civil engineering and environmental projects.

BUILDING HOMES FASTER WITH DIGITAL TRANSFORMATION

While Leapfrog Works is used in a number of major engineering projects, it also has a role to play in smaller scale schemes - especially those trying to avoid the expense, complexity and skill-set demands of traditional modelling solutions.

This year in Hamburg, the pressing need for more living space prompted developers to propose housing plans for a former school and a disused landfill site next to it. Demolishing the buildings and reutilising the land could create more than 200 flats. However, the potential contamination called for a detailed environmental investigation to assess the subsoil, and make recommendations for safe foundations (including settlement and ground seepage calculations) drainage systems, excavation pit construction and more.

The Lieberman Engineering Company, contracted to carry out the survey, also saw another opportunity within the commission – a chance to advance their own digitisation in preparation for Industry 4.0 (a future, high-tech vision of the German government).

They seized the moment to diverge from a traditional CAD-based modelling approach – and its high-level skill demands – and connect their teams with the easier to understand functionality of Leapfrog. The resulting 3D models would help a multitude of stakeholders understand the issues more easily and drive the project forwards. But the experiment would also invest Lieberman's own people with a set of valuable, future-proofed abilities and experience.

The Challenge

To minimise remediation costs the investigation needed to establish the exact volumes of overburden and different contamination levels to arrive at a safe and economic disposal concept. This clarification would determine which areas and volumes were to be excavated for the new buildings and which areas would need to be disposed of.

However, most BIM-capable products used for such geological and geotechnical applications require extensive CAD knowledge. This can make them prohibitively expensive for small or even mid-sized projects as this one. Leapfrog Works was able to offer Lieberman more approachable and affordable digitisation of data, yet still in accordance with the requirements of the BIM working method.

“Due to Leapfrog's intuitive functionality, geologists or geotechnical engineers are able to work on models themselves, rather than employing a CAD specialist as we've had to with other modelling solutions,” said Tobias Querfurth M.Sc., Geological Engineer for Lieberman. “This means we can use Leapfrog for even small projects and can integrate it into a consistent digitised workflow that can become standard for all of our geotechnical and geological projects.”

Getting the attention of stakeholders early on

Such projects also attract a further challenge around communication, explains Querfurth. It's one that may be familiar to many. "We often see that our geotechnical results, which are important in the early stages of a project, only receive full attention in late planning phases. If further investigations or changes to plans have to be undertaken in these phases, costly project delays can quickly occur."

Leapfrog Works took on the role of a central communication platform for stakeholders at this early phase, enabling smooth and transparent communication. As Leapfrog models are also built directly from data, they could be readily updated as new project information was added, supporting better decision making throughout the project's lifecycle.

The Outcome

"To test the effectiveness of the Leapfrog solution, and its digitisation potential going forward, Lieberman also ran their existing 2D method in parallel to form an early appraisal. Leapfrog Work's 3D approach was not only twice as fast as 2D, but it gave us much more clarity from the start of the project," said Tobias Querfurth. "It's also easier to share with non-technical stakeholders, as we all tend to imagine in 3D."

- Performing a mass calculation using the solids from the 3D model enabled Lieberman to significantly reduce the expected disposal costs.
- The ability to rapidly update data and models meant that areas requiring deeper investigation could be identified quickly, speeding the project along. Information gaps could also be spotted earlier, further reducing costs.
- With the disposal concept completed, it should now be easy to update it with further refinements around soil categorisations and additional data as it comes in, for example, on the vast number of chemical substances present - lead, copper, polycarbonate and more.

The Future

And as for the learning experience? A success, confirms Tobias Querfurth. "In fact it is our hope that this project will create a digital standard for Lieberman Engineering, and will lead us to favour digital processes going forward. Visualisation of the abstract data provided us with a better project overview. Sharing visualisations early in the project reduced the risk of time consuming and costly supplements that could be needed later on. And as we're easily able to import and visualise new data, decisions could be made faster."

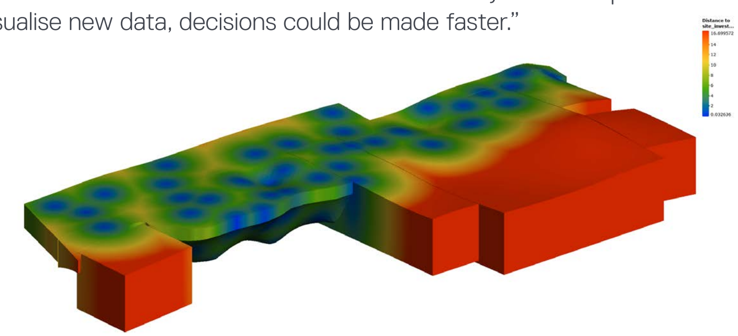
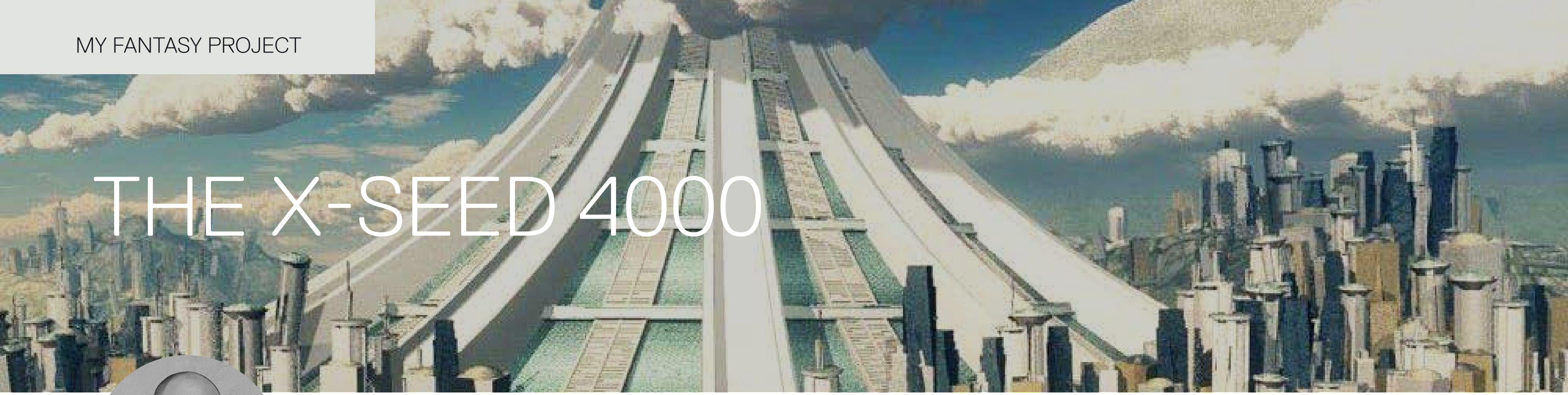


Figure 1 - Conveying uncertainty: Visualising the distance to landfill investigation data makes it clear where further investigation may be needed.



THE X-SEED 4000

Adam North,
Seequent Regional BDM - APAC - Civil and Environmental

4,000m
in height

6km
in diameter at the base

800
floors

Looking like the cover of a sci-fi novel, the X-Seed 4000 is a futuristic concept building designed to tower 4,000m over the Tokyo skyline. The visionary skyscraper (or "skypenetrator") was conceived in the mid 1990's by Taisei Corporation. Capable of accommodating up to one million inhabitants, it combines ultra-modern living with emerging transport methods and interaction with nature. It's a structure that epitomises the futuristic vision of the engineering community and the evolution of humankind.

Why it fascinates me

When I was young, I spent countless hours scouring encyclopedias, books and magazines for content of interest, and I would often find myself gravitating towards articles of a more technical or futuristic nature. In many of these books, we had permanently occupied bases on Earth's Moon or Mars; we all travelled around in flying cars; and we communicated with each other via wrist worn devices. In 2020, the reality is that we are far from achieving some of these lofty aspirations, but technological advancements over the last few decades alone have realised some technology previously in the domain of science fiction.

As the global population continues to grow, an ever-increasing percentage of people are living in urban centres, shifting our historically dispersed geographical existence into highly concentrated areas. The demand for space in these locations is necessitating the construction of larger buildings to house, entertain and provide for significantly more people than these city areas were originally designed for.

In my lifetime, there have been 14 buildings completed that are taller than the tallest building when I was born, with a further 16 currently under construction. The tallest of those is the Jeddah Tower (formerly the Kingdom Tower), which will stand over 1km tall if it is completed, and begs the question; how big can and will we build?

How it works

X-Seed 4,000 is essentially a self-contained city in a building. A 4km (2.5mi) high, eco-utopian environment comprising over 800 floors in the open framework of a concave cone shape, aesthetically resembling Mt Fuji. With residential, commercial and urban space spread throughout the building, residents need never leave. Since the structure is so tall, special consideration is needed to manage the variations in air pressure throughout the building to avoid altitude sickness. Renewable energy generators would be spread throughout the structure to provide the bulk of the power requirements while reducing the overall weight of power cables.

The base is 6km (3.7mi) in diameter to support the massive weight with the concave cone providing stability to the structure at height. The open structure of the tower enables some air to flow through the perimeter of the building and lightens the load on the foundations and lower levels while also providing a path for natural light.

What it offers

Despite X-Seed 4000 holding the title for being the largest building to ever be "fully designed", it is unlikely to ever be built. What it does provide, however, is the impetus to drive not only innovations, but also inventions as we conceive the material, environmental, social and design requirements of a structure so massive.

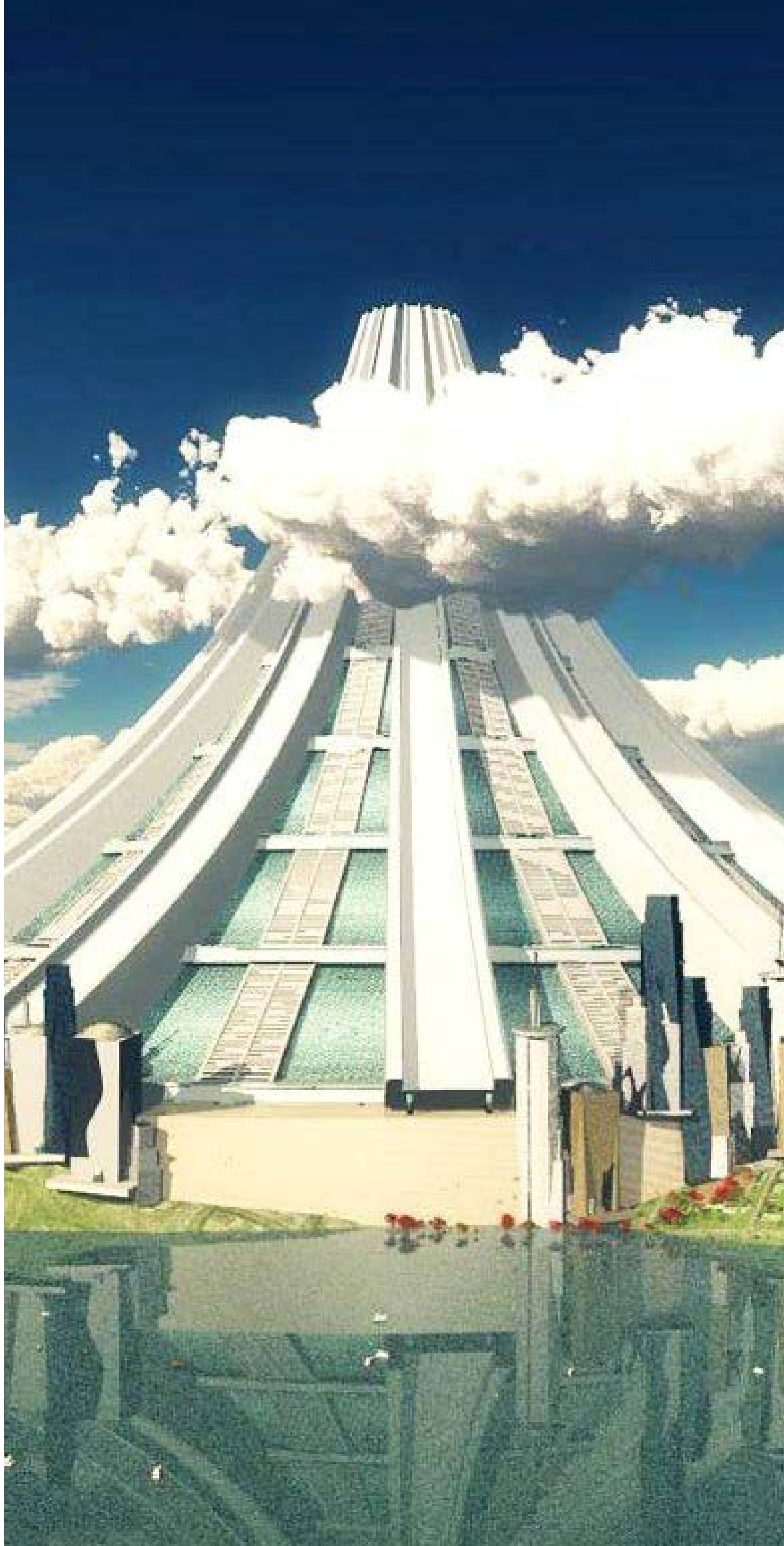
Advancements in design technology, modelling and simulation have enabled the rapid evolution of engineering structures and the materials used to create them by combining advanced numerical simulations to rapidly generate and assess design models without the historic need for extensive prototyping. The higher levels of confidence that are gained through these processes also reduce risk and subsequent overengineering, enabling engineers to push boundaries with a greater degree of confidence.

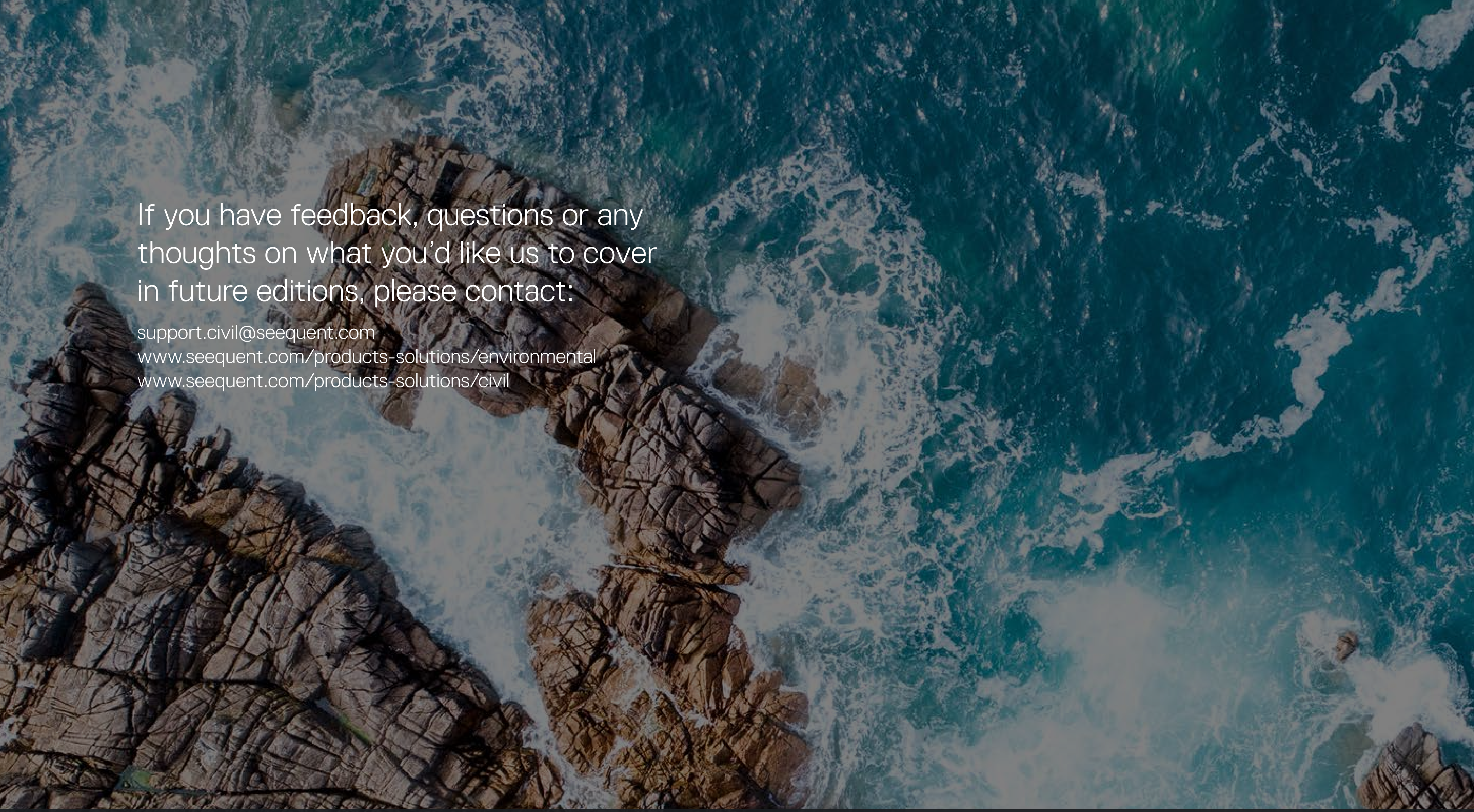
As the world evolves and we look for new ways to inhabit the planet, we are starting to realise that everything that we put in, take out, or change to the Earth has potentially far-reaching effects, and no infrastructure decision should be taken without appropriate and thorough consideration.

Geology's role in future infrastructure

Often hidden from view, it is easy to overlook the significance that geology plays in all infrastructure projects. The subsurface can be directly impacted through mechanical means such as supporting foundations, excavations or tunnels, or further afield by alteration to the water table or contamination of groundwater. Geology is a complex topic as there are many variables that need to be managed in parallel in order to gain a more complete picture of the subsurface conditions. Understanding these variables and being able to put them into context is the first step in addressing the risks of any project and formulating appropriate measures to minimise the impact it will have.

I think Leapfrog Works provides an ideal platform to collate these geological variables in order to put them into context, to visualise and communicate their significance, and to provide the necessary inputs for numerical analysis. As we continue to build bigger, taller and more massive buildings, our potential impact on the environment also grows. Through the diligence of the geoscience community, armed with the knowledge and tools to make a difference, we can ensure that these mega structures of the future… tread lightly.





If you have feedback, questions or any thoughts on what you'd like us to cover in future editions, please contact:

support.civil@seequent.com
www.seequent.com/products-solutions/environmental
www.seequent.com/products-solutions/civil