SEEQUENT

CREATED BY SEEQUENT FOR ROAD AND RAIL
CONSULTANTS, CONTRACTORS AND OWNER OPERATORS

Ground control

Six ways transportation projects can meet their subsurface challenges to improve productivity, and reduce the risk to budgets, deadlines and operation

A PRACTICAL GUIDE TO

- Understanding and planning for complex ground conditions
- Using digital transformation to deliver better infrastructure faster
- Maintaining reliability across decades of change
- Reducing site investigation costs with agile technology

PLUS

9 key software solutions

To improve collaboration, keep stakeholders better informed, and deliver exceptional subsurface analysis

2022

Start >

CONTENTS

TWO SIDES TO EVERY STORY

Pat McLarin
Seequent Segment Director, Civil

Remember your vinyl record collection?

At the risk of showing my age (and for those growing up in the era of Spotify), a vinyl record has two sides. We might have bought that latest single for the A side, but we came to love, or hate, the B side.

It is a little like that in the world of transportation. Think of the A side as that long-awaited project to build a new road or bridge. It's something to get excited about and turn up the volume on. But there's a B side too, which is the ongoing relationship with that road or bridge; a critical piece of infrastructure that will need to perform day-in and day-out for many years to come.

In the world of transportation, you do not want the experience of a bad B side playing out on repeat. Yet in many respects, that is what we are all doing on our daily commutes.

In their 2022 bridge report, the American Road and Transportation Builders Association (ARTBA) highlights that there are **167.5 million crossings every day on 43,578 US bridges considered structurally deficient and in poor condition[1]**. Meanwhile, the American Society of Civil Engineers (ASCE) infrastructure report card rates America's infrastructure a poor C minus[2]. A similar story has played out in other nations over the past decade.

Addressing this global historic infrastructure gap has been a hot topic in the past 12 months. Now we are seeing the first of the stimulus funding starting to flow into the industry, triggering projects that have been languishing within the backlog of all those things we would like to do for our communities, but have lacked the resources to execute.

However, we should not expect that funding was the only missing piece of the puzzle, and that we can just pick up where we left off. In the same report, ARTBA points out that at the current rate it would take 30 years to fix those bridges. The reality is that we need a fundamentally different approach if we are to collectively modernise our transportation infrastructure and support a sustainable and resilient future.

One of the better kept secrets is how significant the impact of unforeseen ground conditions can be in terms of costs, claims and delays on transportation projects. A survey of 46 US Departments of Transportation[3] attributed the costs of these geotechnical issues averaged more than $10M per agency every year.

Here at Seequent we are all about a better understanding of the earth, and believe that better ground engineering can mean better transportation infrastructure for all.

We also take a long view of the value of data, advocating a structured approach to geotechnical data and model management, and employing the cloud to connect participants in the process. Given the challenges geotechnical engineers face in terms of **limited availability of subsurface data**, and the time and money spent on site investigations, it makes sense to take care of your data every step of the way. It's also vital to get the most leverage from it through more productive engineering geology interpretation, and to share your understanding with 3D visualisations that bring the subsurface uncertainties and engineering challenges to life for both technical and non-technical stakeholders.

> The reality is that we need a fundamentally different approach if we are to collectively modernise our transportation infrastructure and support a sustainable and resilient future.

Now part of Bentley Systems, together our solutions above and below ground bridge the gaps between geoscience, ground engineering, and infrastructure design and construction.
So it's a pleasure to bring together in this eBook some perceptive viewpoints from a team of experts around Seequent and Bentley; to share with you their insights, tips and inspiration to change things up a little in your approach to ground engineering for transportation.

THE STATE OF PLAY

On the road ahead

The next 5 years will see enough planned road and rail projects to circle the earth

2.5x
every year

BUT

50%
of them could be impacted by geotechnical issues*

TYPICAL UNFORESEEN PROBLEMS THAT DRIVE COSTS INCLUDE*

SEEPAGE PROBLEMS
MISCLASSIFIED OR MISCHARACTERISED SUBGRADE
GROUNDWATER SHALLOWER THAN EXPECTED
UNANTICIPATED
ROCK EXCAVATION
MISCHARACTERISED ROCK FOR DRILLED SHAFT CONSTRUCTION
DEWATERING
PILE OVERRUNS

The subsurface is always uncertain

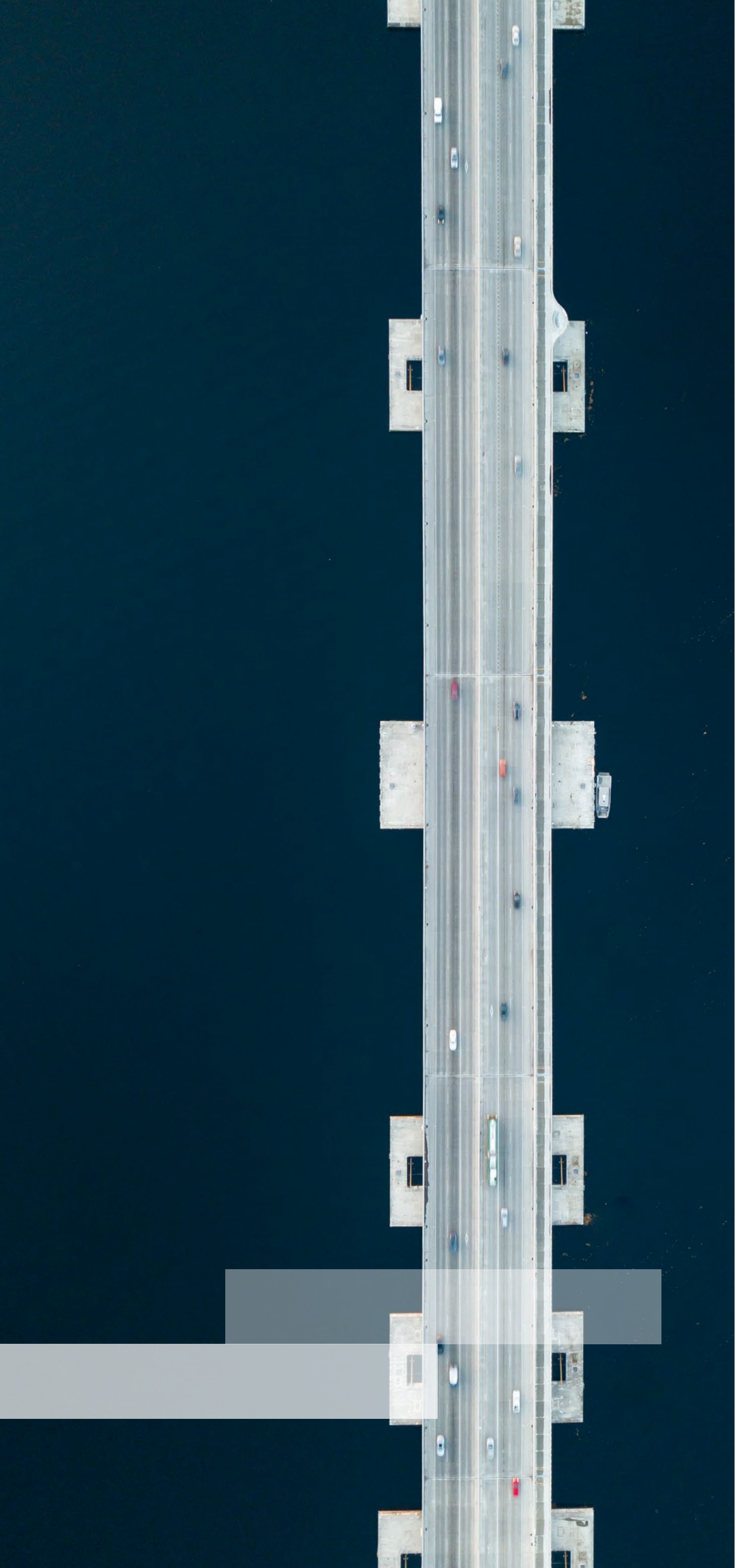
But we can help bring clarity so that

CONSULTANTS AND CONTRACTORS CAN:	OWNER OPERATORS CAN:
Demonstrate expertise and excellence	Be data ready for whole life operation
Connect workflows with a single source of truth	Enable transparent delivery
See less downtime and more productivity	Collaborate more effectively
Shorten site investigation to design times	Improve safety and reliability
Reinforce client relationships through strong data control	Control costs and timelines
	Share 3D visualisations with community stakeholders

Read on for the biggest geotechnical challenges facing transportation infrastructure teams today

the new technology and thinking that can help them

and the solutions that will reduce costs and risks, and boost transparency and productivity.



OUR EXPERTS

Paul Grunau
Senior Vice President,
Geotechnical Solutions, Seequent

Leads the geotechnical analysis group with a focus on driving growth and building high performance teams to connect innovation with customer needs. More than 30 years of software expertise.

Janina Elliott
Global Central Technical Lead, Seequent

Works closely with clients worldwide to help them gain the maximum advantage from Seequent's Central data management system, and create workflows that drive efficiency, productivity and profitability across a range of sectors.

Penny Swords
Director, Seequent Evo, Seequent

Head of Seequent's rapidly expanding Evo ecosystem that connects Seequent's desktop and cloud applications, and APIs, to bring additional functionality to existing and future solutions.

Roger Chandler
Director, Geotechnical Information Management, Bentley Systems

Supports DoTs, consultants, laboratories and field teams to be more efficient with their geotechnical data collection, management and reporting. This allows them to focus on higher quality geotechnical engineering, saving time and money.

Joshua Johnson
Senior Product Manager, Transportation, Bentley Systems

Closely involved in the creation of Bentley's software solutions for the management of transportation infrastructure assets, helping to identify industry needs, and producing requirements, functional specifications and use cases.

Francisco Diego
Director, Product Management, Geotechnical, Bentley Systems

Background in structural engineering and software production. Supports owner operators, engineers and construction companies worldwide to use Bentley Systems software solutions to sustain existing and planned infrastructure.

1: UNDERSTANDING GROUND CONDITIONS

Paul Grunau
Senior Vice President,
Geotechnical Solutions, Seequent

THE CHALLENGE

Can a digital mindset address the uncertainties that ground conditions impose on transportation projects?

THE DOUBT

The complex interaction of infrastructure and subsurface conditions can present transportation projects with a rollercoaster of complications

Ground conditions will impact plans of many new pieces of infrastructure, but the level of uncertainty they introduce to transportation projects creates an exceptional number of challenges – what you know that might go wrong, plus what you don't know that will go wrong; and that you will somehow need to respond to...

The linear extension of road and rail projects - **the sheer distance they cover** – means they will encounter wide variabilities in geology and ground conditions, both at and below the surface. Tunnelling will unlock stresses that have built up over millions of years, and the results may be hard to predict. Cutting into slopes can increase the risk of landslides. Changing ground water levels may affect the shear strength of the soil on which you are building. Understanding potential ground deformation can change the planned routes and avoid project costs. Bridge piers and foundations require subsurface knowledge to ensure the bridge structure can withstand loads, floods, and even earthquakes.

All of these elements can come together in a single transportation project, creating a demanding assortment of ground engineering issues. This frequently sets transport enterprises apart, both in the degree of complexity they face and the multi-layered nature of the ground condition hazards they confront; both the pre-existing hazards and the new ones induced by construction activities.

A BETTER UNDERSTANDING

Geotechnical engineers need to provide clarity for project stakeholders, but they can't do it from a position of isolation

Managing that ground condition uncertainty and providing an understanding of it to the rest of the project's stakeholders is the domain of the geotechnical engineer.

Geotechnical engineers often work in a silo from the rest of the project. Transportation or structural engineers pass their designs 'over the wall', and geotechnical engineers come back with a report outlining the geotechnical risks and recommendations. However, the two parties may not interact again.

> Geotechnical engineers need to provide clarity for project stakeholders, but they can't do it from a position of isolation

But today, the complexity of transportation projects and the pressures upon them – to be on time, to be sustainable, to be more efficiently constructed, to run within tighter budgets, to be accountable to the public – means **this waterfall approach can no longer meet the demands** of most project stakeholders.

A more iterative methodology is required, one where geotechnical engineers can constantly change and refine their own recommendations because they are involved at every step of the project development. They're part of a rich connected workflow that brings all stakeholders together.

When you create such a workflow you can **witness changes ripple through an entire project** – smoothly, collaboratively and in time for you to react to each unknown as it presents itself.

Yet there are projects where workflows continue to be siloed and digital transformation is not sufficiently advanced. This lack of connectivity means that critical project changes are not quickly made apparent during the design process. For the geotechnical engineer, this lack of connected data means changes need to be entered manually for the analysis to be revised, potentially introducing design errors.

Driving the success (and managing the cost) of new transportation projects is as much about mindset – a digital mindset - as it is about technology. It's about getting people to trust each other and giving them the tools to connect, collaborate, and talk, so true partnerships are forged between consulting companies, software vendors, project owners, and all other stakeholders.

A GREATER CERTAINTY

It takes a community of solutions and stakeholders to bring surface and subsurface together for success

Between Seequent and Bentley, we have an array of solutions and platforms with which geotechnical engineers are familiar. For example, GeoStudio and PLAXIS are used to analyse ground conditions, validate designs and make decisions on site. Leapfrog Works and OpenGround can take inputs from boreholes and other site data to provide detailed insight into soil properties and layers.

We can help engineers **understand the key geotechnical factors that drive their design** – soil-structure interaction, ground deformations, groundwater conditions, slope stability risks – enabling infrastructure that can support changing climate and user needs for years to come.

Even more, these subsurface solutions can connect with the transportation design workflow to give all stakeholders a **'twinned' foresight for any project** – the infrastructure and the subsurface brought into view through the same lens with the data from both merged together to provide a complete picture of the site. Bentley products such as OpenRail, OpenRoads, and OpenBridge, operating in partnership with Leapfrog Works, connect the above ground transportation design with a detailed picture of the subsurface to enable a full view and understanding of the project.

With each of these products feeding into a common data pool, transportation designers, geotechnical engineers, asset owners, and other stakeholders can **make better and more confident decisions** relating to the ground conditions; thereby reducing risk, controlling costs and protecting project timelines.

EXPERT TIPS

- **Build confidence.** The more you can demonstrate your thorough knowledge of what's below the ground surface, the more confidence your clients will have in your recommendations. A dynamic 3D site model delivers that detail and an easy visual way to showcase it.
- **Test without losing momentum.** Keeping your 3D models in a central, accessible location lets you test new hypotheses faster, solve issues sooner, and prevent delays.
- **Simple actions save time.** For example, using a mobile device onsite to log your findings into a cloud-hosted database reduces overall data processing time.
- **Tell a story.** It's easier to get stakeholders on side when you can show and tell clearly. 3D visualisations of anticipated site conditions are a great way to do that.
- **Target your wins.** Digital transformation doesn't have to be done all at once. Focusing your digital efforts on specific parts of the value chain – and getting some early successes – will demonstrate value and bring people onboard

THE CASE STUDY

Solving a complex road corridor route through twisting New Zealand terrain

THE PROJECT

With the population of Auckland now exceeding 1.5 million, the more northerly region of Warkworth is a growth centre. By 2026 more than 31,000 cars are expected to be travelling daily between Warkworth and Puhoi, 15km south of it. (In 2012 that figure was under 20,000.) The 18km motorway extension between the two sites will be crucial to the area's expansion, and will cost NZ $700m.

THE CHALLENGE

However, the road corridor cuts through steep hills and valleys, requiring the creation of seven bridges, including three viaducts. Combine this with the cutting of 7 million cubic metres of earth (and the filling of 5 million), plus the challenge of soft alluvial sediments, and it's easy to see why a project-wide ground model is essential as a basis for geotechnical design, and to mitigate project risk.

THE SOLUTION

Leapfrog was used in the tender phase to create a 3D geological model of the route, and then imported into the OpenRoads civil design software. This allowed the slope profiles and cut and fill quantities for different alignments to be quickly and easily compared, and for optimisation of the earthwork's mass-haul to assess the most cost-effective alignment. Understanding the material makeup of the mass-haul balance has been key to minimising the cut and fill footprint. This not only reduces waste, but through better understanding of earth composition, the extracted earth can be used to fill in another part of the site, saving time, money and environmental impact.

THE OUTCOME

Stuart Cartwright, Senior Engineering Geologist, Tonkin + Taylor, said: "Leapfrog really helped us on what has been a significant and challenging project. The length of the proposed motorway and its alignment through such steep topography made the ground model development challenging. But by being able to show the model in 3D, and cut sections at any desired location, this instantaneously enabled others to visually understand the complex geological conditions of the site with much better clarity. We collaborated much more as a whole project team."

> **...instantaneously enabled others to visually understand the complex geological conditions of the site with much better clarity.**

To see the full case study, go here

Image source: NX2 Group

2:
WORKING WITH TIGHT BUDGETS

Roger Chandler
Director, Geotechnical Information Management, Bentley Systems

THE CHALLENGE

Can technology minimise site investigation budgets while still reducing the risks of unforeseen ground conditions?

THE DOUBT

Site investigation reports can arrive too late to add as much value as they should, and be too expensive to redo if issues are raised.

Unforeseen ground conditions are a major headache for transportation projects, and are often cited as a cause of costly overruns. The degree of these overruns will likely **far exceed the cost of additional site investigation**, yet geotechnical engineers (the world over…) still find it difficult to convince clients to increase site investigation budgets.

One of the main problems is that site investigation is seen as something that just 'has to be done'. Deadlines and budgets are given; a report duly expected. However, the time-consuming nature of report production means it is often delivered too late to be fully utilised, offering the client poor value for money.

Site investigations are typically carried out in a linear way, sometimes called a 'waterfall' approach. This is a common project management style, defined by a number of fixed contractual milestones. Unfortunately, it doesn't allow for major disruptions or unforeseen circumstances arising – a serious problem when dealing with the ground.

While computing power and emails potentially allow results to be delivered much faster than before, it is still often weeks, or even months, before meaningful data can be issued up the supply chain or to the end-user.

By the time anomalies are detected during analysis, or more information is needed, the site team is already long gone, and another phase of investigation has to be commissioned. That's if the associated re-mobilisation costs and delays even allow for this additional gathering stage to be completed (more often than not, they don't).

But… if budgets can be managed more effectively, the team can prioritise activity within that budget and timeframe to match the client's risk appetite, e.g. in the number of boreholes, samples taken, in situ tests carried out and laboratory testing undertaken. How can teams do this effectively, win clients over and control costs in the process?

> One of the main problems is that site investigation is seen as something that just 'has to be done'.

A BETTER UNDERSTANDING

With a more agile approach, information can be continuously reviewed, reaction time shortened, and costs reduced.

If the project team was able to take a more agile approach, information could be reviewed continuously during site investigation works. This would **empower teams and decision makers to react quickly**, develop 'live' solutions, test hypotheses and make clearer, more confident calls on next steps - is more information needed, has enough data been gathered, or can investigations now be safely halted?

However, it is worth emphasising how important it is to have fully-collaborative team input. Daily meetings are a great way to achieve this – either face-to-face or virtually, via Teams, for example. By involving everyone using the data in the meeting, from ground engineers, to civil and structural engineers and the client, everyone can play a part in taking these critical decisions.

This encourages everyone to be engaged in, and take responsibility for, the development of the ground model, so that collectively they can decide where more data is needed. It also **helps clients realise the cost and risks involved**.

It is also essential to give the site team the authority to take decisions on site, such as deepening a borehole to collect additional samples, to carry out more in situ tests, or to dig another trial pit if more information is needed. Gathering additional data in these circumstances can be relatively inexpensive, yet deliver great value.

A GREATER CERTAINTY

With help from the cloud there need only be one phase of site work, leading to higher quality and more useful results.

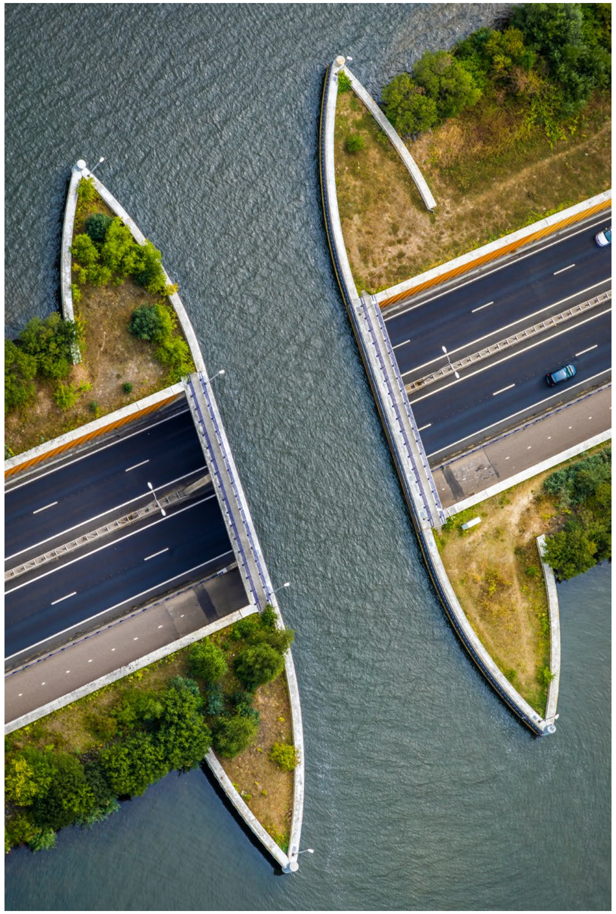
cloud-based data sharing, processing and analysis, such as in Bentley's OpenGround, is key to better collaboration and the adoption of an agile approach.

Without the cloud, such an approach would be extremely difficult to establish or maintain. Collecting data electronically on site and automatically uploading it in a cloud environment makes it more valuable and brings the entire project team, including clients, closer together. This **allows everyone to play an active and valuable role** in decision making and the entire process is accelerated.

Information is more secure, issues around software compatibility are reduced, and the integration of geotechnical data with project BIM becomes far easier. Importantly, a single source of truth is also maintained.

Additionally, taking an agile approach should mean there is **only one phase of site work** which, even if it lasts longer than originally planned, will be more cost-effective and speedier than having to commission future phases with their associated mobilisation costs.

The quality of investigation results will also be far higher and more useful to end-users and stakeholders throughout the lifetime of the project (including its operation and maintenance phases). The focus would be on areas presenting the greatest risk, rather than wasting time in low-risk areas, enabling the team to develop mitigation strategies that, in the long run, would save time and money.



EXPERT TIPS

- **Log borehole data electronically on site.** Using tablets that synchronise data back to your single source of truth unlocks an enormous amount of geotechnical data value. It also overcomes one of the biggest hurdles to agile site investigation.
- **Control the level of data access for clients.** Data restrictions allow you to hide data that is not quite ready for client scrutiny. With proper controls in place, project teams worry less that unQA'd data will be available to the client.
- **Ensure your supply chain can deliver data more than PDFs.** Supply chain companies, such as laboratories, still consider PDF files to be the legal deliverable. It is important to ensure that your supply chain fully understands the value of timely data delivery to your projects.
- **Let your data and thinking out of the box.** Once your data is in a platform that allows you to securely access it via an API, it can be connected to a much larger range of solutions. That includes ones you may not have written yet.
- **Promote an agile approach to your most significant clients.** An agile approach is useful, but it has the maximum benefit for projects with large teams or large datasets. Be prepared for clients of your smaller projects to be wary of acting as early adopters of this new approach.
- **Store and use historical data.** Adopting a cloud-based, single source of truth allows you to maximise the value of historical data from inside your organisation. But don't forget these systems can also store and use data from publicly available sources too.

THE CASE STUDY

Reducing borehole drilling by 30% to build a Norway highway faster, cheaper and with fewer emissions

THE PROJECT

The glacial fjords, coastlines and landscapes of Norway are known for their outstanding beauty. However, they don't have such a glowing reputation among geoscientists when it comes to planning highway routes across what can be extremely variable sediment thicknesses and properties. The team working on an 18km stretch of E6 Ranheim-Vaernes highway knew this only too well.

THE CHALLENGE

There was a lot of heterogeneity and therefore an even higher need for full spatial coverage of the data they would base their decision on. It was estimated that they would need 600 boreholes to confidently map the route – a real challenge to the budget.

THE SOLUTION

The team opted for an airborne, high-resolution transient electromagnetic (TEM) survey to find regions where the bedrock depth varied, so that drilling could be constrained to those areas. That meant fewer boreholes needing to be drilled, and the survey was able to cover its target area in just two days. With the help of SkyTEM systems for the airborne surveys, EMerald GeoModelling to analyse the survey data, and Workbench to build models from it, drilling was reduced by 30% and nearly six months (50%) shaved off the time.

THE OUTCOME

"If you take an airborne survey over a huge area and then interpret it using existing knowledge from drilling, you can create models where you can understand the uncertainty," explains Toke Søltoft, director and geophysicist at Aarhus GeoSoftware (part of Seequent). "Then you can do more drilling in the areas where uncertainty is highest." By doing less drilling overall, and creating the road where it's most feasible, the project has also been able to reduce emissions and its environmental impact.

To see the full case study, go here

"It was estimated that they would need 600 boreholes to confidently map the route – a real challenge to the budget."

3:
COMMUNICATING INSIGHTS TO EVERY STAKEHOLDER

Janina Elliott
Global Central Technical Lead, Seequent

THE CHALLENGE

Communicating insights across a broad variety of stakeholders so data stays accessible, understandable and useful for all.

THE DOUBT

Fast, easy, multi-disciplinary interaction is key to the smooth running of transportation projects at any scale

Throughout the lifespan of a transportation project, the “line of sight” from start to completion is commonly obscured.

Obstructions can relate to the size or intricacy of the design as well as economic and political factors. But more frequently, it’s the **lack of consistent data flow and communication** that contributes to delays and increased costs.

Of course, many industries rely on multi-disciplinary interaction and the use of consultative and contractional services, and therefore face similar issues. However, the transportation world is confronted by an added layer of complexity - the linked interaction between the above and below surface dimensions.

This can lead to an exponential increase in the need for **organised retention of data**. Reliable, real-time exchange of professional expertise through clear cross-disciplinary communication also becomes even more important.

A BETTER UNDERSTANDING

Stakeholders may be separated by geography and expertise, but have to be connected simply and transparently for effective collaboration

In most cases, transportation projects over a certain budget are large, multi-year engagements that connect a range of stakeholders.

Throughout the lifecycle of the project, from initial studies and site investigations through to design, construction and eventually operation, one guideline holds true: the data provided by each of those stakeholders must be **consistently organised, easily accessible, and contextually understood** if it is to provide the maximum benefit to all.

One of the best ways to do this is to have data collaboratively curated in a peer-reviewed and highly visual environment.

While well-established BIM systems provide part of the solution regarding the above surface world, the high levels of uncertainty encountered in the subsurface dimension tests this existing approach considerably.

Scarce subsurface information and changing hydrogeological or geotechnical system conditions require a multitude of geoscientists to develop new datasets and models, constantly updating them and ensuring meticulous cross-correlation. These then need to be integrated into the larger scale design and construction effort, which invites additional project stakeholders to the table. Without effective and easily understood communication to all parties, the project may stall, mushroom in scope and see costs multiply.

For geoscientific contractors and consultants this **constitutes a real challenge**. They commonly enter the conversation at variable stages and may only be privy to a disconnected subset of information, often presented in an unstructured or 2D format.

To provide true insight, contributing parties need to be able to navigate a version-controlled project history and understand how the data and models were developed, who created them and why decisions were made - all without compromising the security of the information accessed.

Even today, extensive transportation projects can still **rely on outmoded data sharing** and communication techniques to coordinate and develop subsurface models; for example, untracked emails, 2D sections, spreadsheets, and folders on ftp-sites.

It may only take small mishaps, or changes that aren’t tracked or fully communicated, to result in large repercussions and jeopardise the success of the project in the long term.

> ”
> **...the transportation world is confronted by an added layer of complexity**

A GREATER CERTAINTY

A cloud-based 3D data visualisation system can help minimise the risk of miscommunication, data loss, delays and cost overruns

The prospect of digital transformation can be daunting. Nonetheless it is invaluable, if not essential, in mitigating the risks associated with miscommunication and data loss. And, if taken in small steps at first, it need not be so intimidating and can quickly add value. The introduction of advanced technologies to support real time project communication can actively provide a competitive edge in an already highly competitive market.

Seequent firmly believes in the power of connection; that when we enable people to work across traditional boundaries, **they can unlock much greater potential**. As part of Bentley, Seequent has connected site investigation to modelling and analysis in an integrated workflow, taking you from the site unseen to slope stability.

Seequent Central is fundamental to the modelling process and site analysis. It represents a cloud-based data management system that invites all to interactively share, version-control, communicate and visualise their models in a secure and auditable environment.

In addition to its 3D web-based visualisation platform, Central lets you publicly share subsurface 3D models and communicate through a real time notification system. It can also **dynamically connect data and models** from geophysicists and engineering geologists together with Geotechnical engineers to enhance the flow of information and reduction of superfluous data.

Its data storage, upload and download capabilities were built with a spatially distributed user base and low bandwidth access in mind. As such, it invites **multi-disciplinary experts and reviewers** from all over the world to partake in an efficient and rich intellectual exchange to collectively build a robust subsurface digital twin - the foundation for a successful transportation project.

EXPERT TIPS

Don't shy away from digital transformation because it seems such a daunting task. Small steps might be all you need to see major advantages. Take data management and collaboration – this is something you already do but can streamline and enhance with time.

- **Begin with cloud-based data management.** Once a system is in place, you can slowly evolve the way how you handle data. Get organised and create a reliable and easily searchable version history of all your files and models. But don't stop there...
- **Start to actively share.** Leverage from each other's efforts and dynamically link files, objects, and full models in Leapfrog to maximise efficiency and productivity of the team. No need to reinvent the wheel or store superfluous data.
- **Communicate and learn.** Sharing data is great, but to get the most out of it, we need to tell a story. Use web visualisation and team collaboration features to make your project history come alive for everyone involved.
- **Step beyond the threshold.** Invite your contractors and partners to the table and give them customised access so they can support you in the most effective way possible.
- **Share with the public.** Allow the immediate stakeholders in your project with a public link to visually experience your work and the progress made. Bridge the gap between communities and professionals, and bring clarity to complexity.

THE CASE STUDY

Inspiring collaboration, insight and understanding for the UK's ambitious HS2 rail project

THE PROJECT

HS2, the UK's high-speed rail line to the north, is set to be the country's largest ever construction programme. Essential to success is the ability of its designers and engineers to not only address significant technical ground and construction challenges, but also inform – and bond – large multi-disciplinary teams and stakeholders across offices, companies and time zones.

THE CHALLENGE

For example, Phase 1 alone spans approximately 225km with over 350 assets (including tunnels, viaducts, overbridges, and underpasses). A joint venture behind the northern 90km section brings together Balfour Beatty, Vinci, Mott MacDonald and Systra, all of whom need to collaborate seamlessly.

THE SOLUTION

Mott MacDonald's team of more than 80 engineering geologists and geotechnical engineers has been using Leapfrog Works and Seequent Central to manage models and share a mass of ground investigation (GI) data (more than 5500 locations and 24 GI contracts) with key stakeholders, in near real time. This has been decisive in delivering 'Just in Time' GI, and allowing risks and opportunities to be understood, and value engineering to be undertaken.

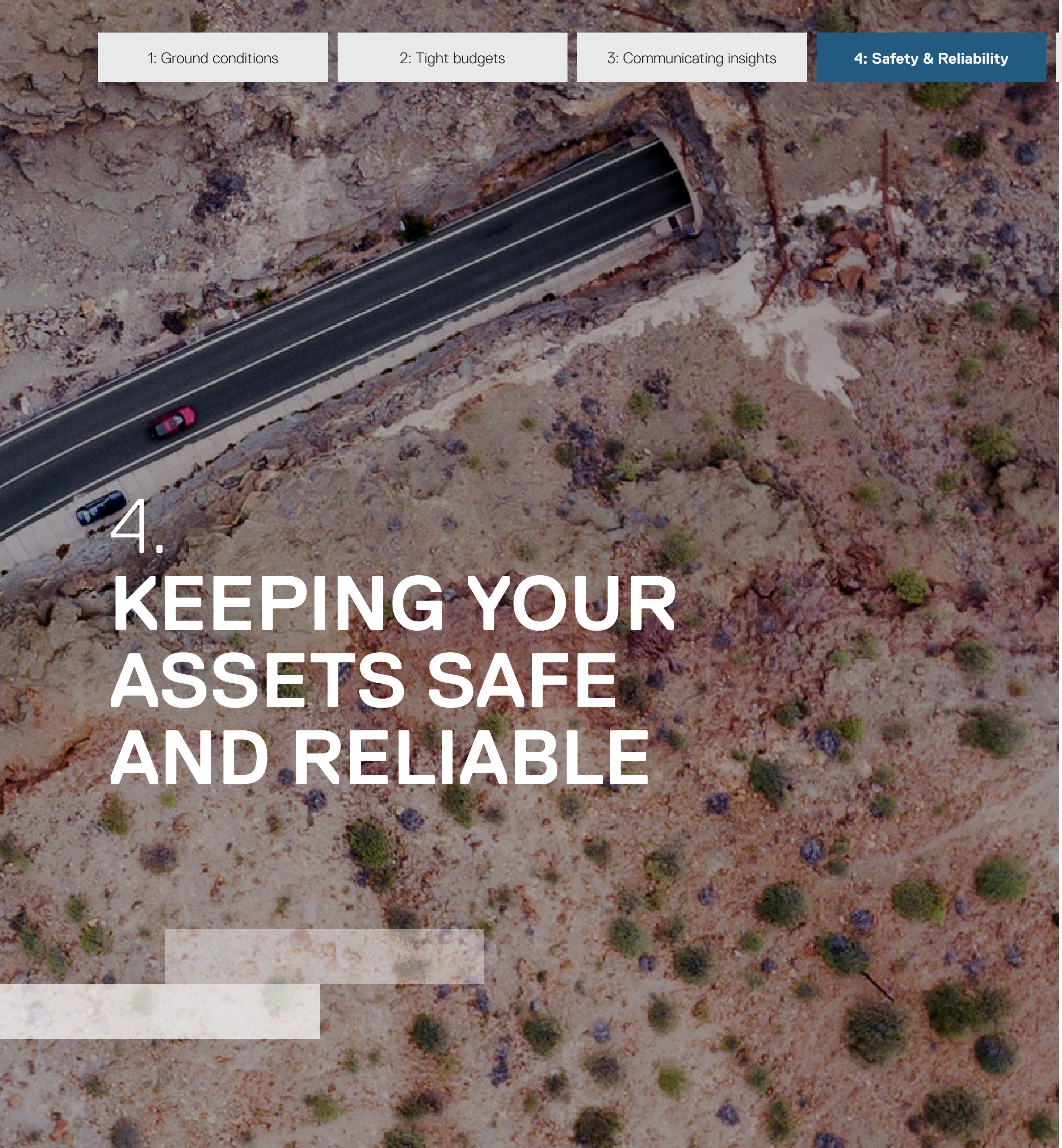
THE OUTCOME

Christopher Brook, Associate, Mott MacDonald, says: "Seequent's digital innovations allow us to produce higher quality Building Information Modelling (BIM) deliverables, communicate to stakeholders, and deliver controlled and robust ground models in 4D. It also helps the onsite ground investigation team to make informed decisions for the project, resulting in time and cost savings and risk reduction."

For a more detailed exploration of Central's contribution to HS2, see our Lyceum webinar with Peter Fair, Mott MacDonald 3D Geological Modelling Specialist.

To see the full case study, go here

> **This has been decisive in delivering 'Just in Time' GI, and allowing risks and opportunities to be understood...**



4.

KEEPING YOUR ASSETS SAFE AND RELIABLE

Joshua Johnson
Senior Product Manager, Transportation, Bentley Systems

THE CHALLENGE

Ensuring the safety and reliability of transportation infrastructure assets throughout their lifecycle (and sometimes beyond...)

THE DOUBT

Legacy infrastructure is showing the strain, but still needs to be kept safe.

Much of the transportation infrastructure we use today was built in the 1970s, 1960s and even 1950s, and from a physical condition standpoint, it's starting to age out. It's also had to cope with traffic volumes and speeds often **far in excess of those originally imagined for it**.

So it faces challenges both in reliability - continuing to support those volumes while potentially approaching the end of its life - and doing so safely and persistently.

How can owner operators relieve congestion, improve reliability and maintain safety when they are dealing with such legacy infrastructure, not to mention the public expectation that they will keep it running smoothly even beyond its expected lifecycle? How can they **make their transportation network resilient**, especially in a world where climate change can lead to more frequent natural disasters that place transportation infrastructure under even greater strain?

A BETTER UNDERSTANDING

This requires a fresh approach to data gathering and analysis

In part the answer is a shift in mindset. Traditionally the approach has been to focus on condition; we have some potholes, lets fix them and then the condition will return from poor to fair or fair to good. But that's only taking one view of the problem and treating it in a restricted and siloed way.

Infrastructure owner operators can plan ahead and forge the resilience they need by looking at all their **data much more holistically**, and considering not just its use today, but how someone else might be needing it in 10, 20 or 30 years time.

They'll need to collect every piece of data they can, and federate it in a way that allows for major, holistic decisions about their assets. And this will be a tougher challenge and a bigger change in thinking than it first appears. How much digital data will exist on a bridge built 60 years ago? How do you **recover from an historic culture** that often saw plans as something required for the construction, but disposable afterwards?

This search for long term resilience and safety requires a new hunger for data. We're going to want to collect everything we can, whether it be from design, regular monitoring, a construction inspection or whatever, then retain it and reuse it in as many ways as possible. Because **if we don't need it now, somebody else somewhere down the line will.**

And that will mean not just collecting the surface data about the asset itself, but also the subsurface data – the ground it's built on and how that might be modified by generations of overlaid construction, or impacted by climate change, floods or earthquakes.

This new mindset, to create synergistic big data from a range of sources, will not just make it easier for owner operators to maintain their assets safely. It will also create greater transparency for stakeholders (the public among them), drive efficiency and help owners answer increasingly tough questions around budgets and performance. But it will need help...

> **How can owner operators maintain safety when they are dealing with such legacy infrastructure...**

A GREATER CERTAINTY

Digital twin technology can create this whole-lifecycle master view for owner operators

Once completed, transportation infrastructure owners will have an asset they may need to operate for 100 years. (For example, the UK's HS2 has a **projected 120-year life span**.) During that time, ground conditions will continue to shift, impacting safety and reliability.

Our technology solutions help manage and model all ground investigation data in 4D, creating a digital twin of the subsurface. But importantly, this twin can persist and be continually updated with new data long after construction has finished. It can integrate monitoring feedback and requirements with a detailed portrait of ground conditions, often in near real time. This provides a long lasting, **always-up-to-date resource** for owners responsible for ensuring safe and stable operation across a very long lifecycle.

The distance transportation corridors are constructed across inevitably lead to gaps on subsurface understanding along the route. An open approach to data means you accommodate information from a wide range of sources – from boreholes to geophysical surveys. This rich picture of the ground over which the network lies not only helps fill those gaps, but **expands organisations' own subsurface archives** for use in future extensions, alterations or maintenance.

At the heart of our transportation solution is OpenGround for geotechnical data and Seequent Central for ground models, bringing every piece of digital twin data into a single source of truth, with robust centralisation, versioning, audit trail and tightly controlled user permissions. This enables contractors, consultants, managers, operators and Departments of Transportation to **work at the highest levels of professionalism** (for example ISO 19650 for BIM).

Data continues to flow to your teams in the best possible way long after the last digger has departed... The right people see the right information at the right time; standardisation avoids wasted time or errors introduced through translation; and decisions are backed by an automatically generated audit of the data they were based on.

Our transportation solutions support **every phase of an infrastructure project**, from planning and design through to construction and handover. Throughout these many stages it is always positioning insight, data and asset creation ready for ownership.

EXPERT TIPS

- **Why throw away good data?** As a structural engineer, I was always very dependent on geotechnical data, whether it be for a retaining wall, a deep foundation, or whatever. Commonly, the results would be supplied to me, I'd put them into the design, and that would be last anyone would ever see of that material. But in 15 years' time, is that rock formation really going to change? If you keep that data readily accessible, you can act quickly when you see a problem with your asset; more quickly than if you have to gather that information all over again.
- **Just having a repository of information is not enough.** If you keep a lake of data, you'll be constantly swimming in it to find the one piece you want. By ensuring it's all tied to your asset, and your asset's digital twin, it will be easier to find when you need it, and enable you to be more agile when problems arise.
- **Build good data habits**. In fact, if you always consider your asset through the lens of your digital twin, you'll inevitably start to build better data habits. It will force you to break away from the traditional thinking of data being a siloed resource.
- **Spec for the future**. Write your specs not just for what the project might need today, but what it - and you - might need in 5, 10, 15 or 20 years' time.
- **Think resilient.** Finally, perhaps consider changing your mindset from 'reliability' to 'resilience'. Better monitoring of active geological environments can be a major win, with the growth in IoT making it easier than ever.

THE CASE STUDY

Improving the safety of a 100-year-old retaining wall by updating it to be earthquake resistant

THE PROJECT

For 100 years, the 200-metre-long, 7.5-metre-high retaining wall along Wellington's Chaytor Street has been protecting this key arterial route into New Zealand's capital. The wall supports a sharp embankment adjacent to a deep, in-filled gully, and helps ensure safe access from the central city to some of Wellington's largest suburbs. Engineers from WSP New Zealand have been working with Wellington City Council to tackle the difficult task of modernising this historic landmark for earthquake resistance.

THE CHALLENGE

To achieve the required level of seismic performance, the wall was engineered to have over 100 steel reinforcing rock anchors socketed into the bedrock at different angles. A slope stability analysis in GeoStudio assessed the wall, which is built on fill overlying a greywacke bedrock edge that undulates to follow the steep contours of the site. Rock condition is dependent on surface proximity and groundwater infiltration.

THE SOLUTION

3D models and a digital twin interpreted these geological variations to inform decisions, such as the expected drill depth to viable bedrock, and the balance of anchors and piles to optimise the construction cost. WSP has also been working with the Wellington City Council to help stakeholders without engineering expertise understand the complexities of the project. Simplifying complex data into a 3D visualised solution gives them clearer and more comprehensive insight.

THE OUTCOME

"There's real value in being able to showcase the design details and share what the wall will look like after the earthquake strengthening is complete," says Jordan Miers, WSP Geotechnical Technician. A constantly updated 3D model also delivers a long-term asset management tool for Wellington City Council and its community, enhancing safety for decades to come.

> ...the wall was engineered to have over 100 steel reinforcing rock anchors socketed into the bedrock at different angles.

To see the full case study, go here

5:

ENSURING WHOLE LIFE OPERATION AND MAINTENANCE

Penny Swords
Director, Seequent Evo, Seequent

THE CHALLENGE

Building connected ecosystems that turn a mass of disparate data into real-world value for infrastructure maintenance and operation.

THE DOUBT

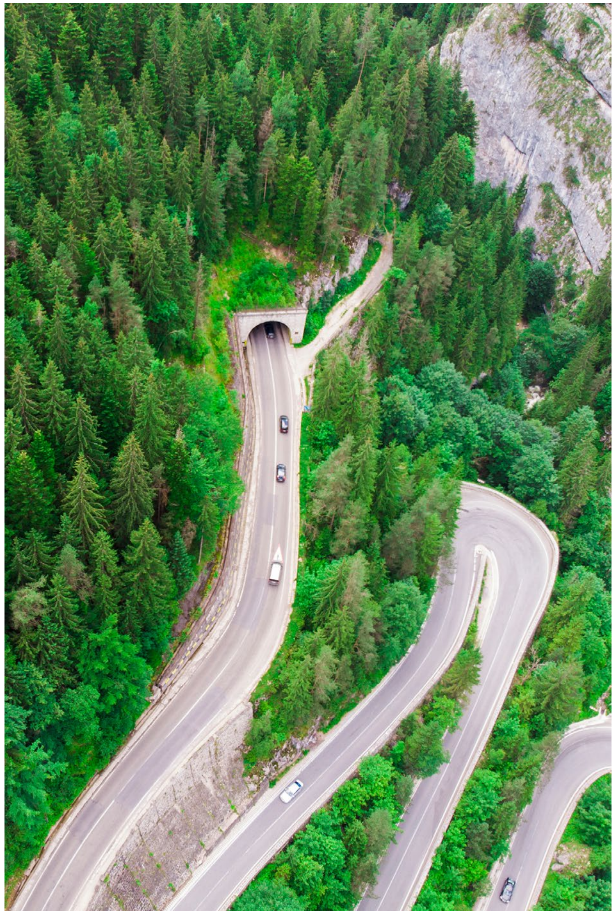
Data can empower decisions that reduce cost and minimise risk, but its sheer quantity can be overwhelming

Decades of under-investment from governments globally have placed ageing transportation infrastructure assets under strain. The impact of more frequent severe weather events has only added to the urgency of their replacement or repair.

Following Covid, many governments across the world have announced **large recovery packages**, heavily targeted on infrastructure projects (e.g. Infrastructure Investment and Jobs Act (IIJA)). But welcome (and overdue) though this investment may be, it is also partnered with increased regulatory, environmental and economic pressure for these projects to optimise costs, minimise risk, increase transparency and reduce embodied carbon. This is both during build and across ongoing lifetime maintenance.

We are in the midst of a digital revolution, where the vast amounts of data we collect has the potential to help us make clearer, better, faster decisions. However, the processes used to manage and analyse this data **are often disconnected and manual**. Its volume and variety are overwhelming and constantly changing. Quite often data arrives at such a rapid pace that it can be hard to understand the significance of the changes it portrays, while the opportunity value of data capture and storage may also be missed.

How can infrastructure owner operators tame this mass of data and ensure it delivers the economies, productivity and compliance they require? As infrastructure increasingly becomes about data and analytics, how do we **facilitate the convergence** of that data to ensure better and more confident decisions?



”

...data arrives at such a rapid pace that it can be hard to understand the significance of the changes...

A BETTER UNDERSTANDING

A digital twin secures the data convergence that can more accurately model an asset's performance

One versatile and powerful solution to this onslaught of data is to harness it in the form of a digital twin - a digital representation of a physical asset that also encompasses its engineering information. Bringing together data in a **comprehensive digital twin** helps us to understand and model the assets' performance in a detailed and insightful manner. It allows for a full representation of the data even when the nature of that data is enormously varied. Importantly it can also be continuously updated from multiple sources, including sensors and surveying, delivering a near real-time representation of its status, working condition or position.

Subsurface conditions can have **a dramatic impact on the stability** and conditions of an infrastructure asset. Therefore, a discerning digital twin should – and can - not only represent the above surface design and data, but also incorporate the subsurface interpretation and geotechnical data.

Continued development of this digital twin during the construction phase of a project serves another valuable purpose. It introduces a robust level of transparency across the project, for all the stakeholders involved, and helps ensure the right people get the right data, at the right time. Not only does this minimise risk, it can also enable decisions that ultimately **optimise costs on** the project during the build.

Once the project has been completed and moves into the operation stage, digital twins can continue to collect fresh data. In this way they support the maintenance of those new assets, keep track of subsurface conditions, inform stakeholders of changes in the data and outline the impact of those changes in an easily visualised and understood way.

> It allows for a full representation of the data even when that data is enormously varied.

WE ARE PROUD TO ANNOUNCE

INFORMATION SECURITY UPDATE

As this eBook was going to press, we were delighted to confirm that Seequent Ltd is now officially ISO27001 certified – an important step in our commitment to prioritising information security, and to our investment in people, processes and technology to protect your information assets.

"ISO certification means we are aligning ourselves closer with our customers' security requirements," said Seequent's Information Security Manager Tiaan Wagener. "We increase the reliability and security of our systems, and bolster our resilience against risks associated with data breaches."

"It's an achievement we are enormously proud of," concluded Tiaan.

A GREATER CERTAINTY

When backed by the cloud, the user experience can be seamless, overcoming incompatibility problems between competing software

As governments and organisations move toward modernising their IT infrastructure, cloud technology is gaining popularity. The **practical benefits of the cloud** in reducing IT costs, increasing backup and redundancy of data, enabling low storage costs and speeding deployment have all been well argued. However, the cloud also offers an important opportunity in creating a connected and automated environment, one that can extract maximum value from the **zettabytes of data** collected by our modern world.

Geoscientists and engineers need to be able to use the right tools for the right job. Sometimes these tools will come from a single vendor, but most often not, adding extra layers of conversion and data manipulation. cloud-based technology, when linked to a digital twin, allows for **seamless data interfaces** between software vendors. This removes manual tasks from users' workflows, so reducing the potential for delays and errors.

At Seequent, we understand the benefits of a well-connected ecosystem, which is why we have created Seequent Evo. Our vision for Seequent Evo is to provide connected solutions in an environment that enables teams to work seamlessly across multiple workflows and solve problems in the moment.

It is not a single product or solution, but an ecosystem made up of cloud-based capabilities that enable you to manage, automate and visualise data. Seequent Evo empowers connection via a set of open APIs used by our customers and partners, allowing for seamless interoperability of 3rd party applications.

Finally, the **sheer quantity** of data collected by sensors, surveys and other methods is only going to increase, and this adds to the possibility that it may be underused. Infrastructure owner operators might never realise its potential to lessen costs and risk.

At Seequent we see a future where applying Artificial Intelligence or Machine Learning to workflow tasks can step in to **master this ever-growing pool of data**. The solutions we are developing can remove or automate repetitive tasks, so reducing human error and enabling geoscientists to concentrate on what they do best.

This will support organisations to become proactive rather than reactive. Instead of waiting for change to happen, owner operators can anticipate that change and take a proactive approach to maintaining the assets under their control – extending their life, increasing their reliability, and containing their budgets.

EXPERT TIPS

Don't just think of the cloud as cheap storage or a way of saving on IT. Get it right and it can be the cornerstone of a powerful connected environment. Companies may initially be drawn to the cloud by the promise of cost reductions or as part of a larger digital transformation, but there are more benefits to be realised:

- **Access your data anywhere**. Teams get what they need, when they need it. Remote and home workers - permanent parts of the post pandemic world - become a thoroughly effective part of the equation. Time wasted hunting for the right data is reduced, as is the risk of missing important information.
- **Flexible payment.** Most cloud applications are consumption based, or pay-as-you-go, so you don't pay for something you don't need or don't use.
- **Secure your data**. Cloud providers now offer a more secure environment than most organisations can achieve. Disaster recovery and backup is part of the service.
- **Easily connect ecosystems.** Reduce manual tasks on your desktop environments by bringing data and vendor ecosystems together in the cloud.
- **Powerful computing** Perform large processing tasks in a cloud environment to reduce time spent waiting for them to complete on the less powerful desktop systems.
- **Automate.** Start automating manual tasks using AI and Machine Learning, gain better insights and be more proactive in your decision making.

THE CASE STUDY

Cloud-based collaboration brings long-term support to the UK's largest road infrastructure project

THE PROJECT

The Lower Thames Crossing (LTC) is a new motorway connecting Kent, Thurrock and Essex through a tunnel beneath the River Thames. With a projected cost of GBP 6.8 billion, it is England's single largest road investment project since the completion of the M25 more than 30 years ago. It will be the longest road tunnel in the UK, and at 16 meters in diameter, one of the largest diameter bored tunnels in the world.

THE CHALLENGE

LTC requires enormous geological and geotechnical investigation along the entire route, facing complexities such as protected wetlands, boring beneath the river, and historical land development in the north. The project included investigating more than 700 locations with over 400 boreholes, some of which will be up to 100 meters deep. A multi-partner joint venture will require a large number of teams to collaborate. Workflows need to connect them seamlessly with both new and historic data.

THE SOLUTION

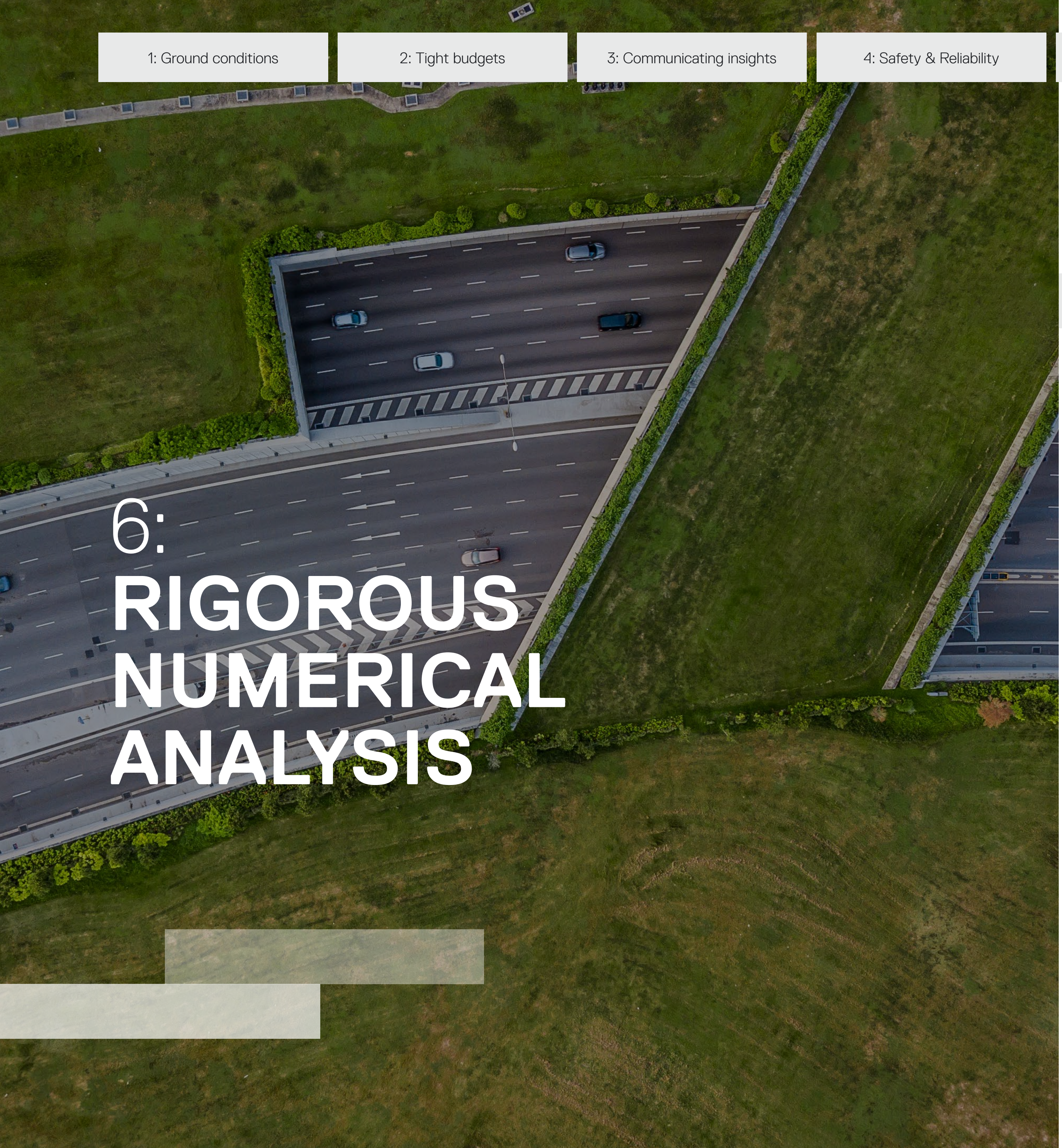
To remedy these challenges, and equip the project with an asset for its whole life operation, the LTC team opted to deploy OpenGround cloud. Its collaborative nature allows BIM teams, suppliers, partners and clients to access project data easily, and be actively involved in any decision processes for as long as the project requires, either through connected apps or a web portal. OpenGround cloud also helped the team eliminate outdated solutions and enabled LTC to implement a cost-effective and quick technological upgrade with the latest geotechnical software.

THE OUTCOME

"OpenGround cloud improved the workflow for all members of the team," said Cedric Allenou, LTC's ground engineering lead. "The various add-ins are faster within the cloud version of the database, which is useful when dealing with large datasets such as CPT data. In addition, maintaining the link with the database when members of other organisations need to access the data has improved the workflow. Also, external support teams can more easily solve issues that arise due to the servers being cloud-based. The process allows rapid responses to any issues, and minimises any potential downtime on the project."

> **"The various add-ins are faster within the cloud version of the database, which is useful when dealing with large datasets such as CPT data...**

To see the full case study, go here



6: RIGOROUS NUMERICAL ANALYSIS

Francisco Diego
Director, Product Management,
Geotechnical, Bentley Systems

THE CHALLENGE

Tunneling and deep excavations on transportation projects require rigorous analysis of soil-structure interaction and are key challenges for geotechnical engineering.

THE DOUBT

There are numerous important requirements for a successful project. The evaluation and control of stress bulb development under high tower loadings during a tunnel construction sequence is one. Metro Station excavation and influence on adjacent buildings' movement another. But there are many more.

Several scenarios and technical disciplines need to be addressed and integrated in a 3D digital environment. One of the great complexities is the prediction of the geotechnical and structural impact from the simulation of a realistic staged construction program.

> The increase in construction productivity brought by digital and mobile technologies is even more critical in tunneling.

A BETTER UNDERSTANDING

Geological and geotechnical represent an ever-growing array of data sources coming from different project and construction stages.

Compiling and interpreting the data to derive the engineering parameters of the different geotechnical units is highly correlated with the analysis behavior. Reliability of a geotechnical project to a large extent depends upon how it accounts for the uncertainties in the analysis parameters and constitutive models. This is especially so in cases encountering **complex stress-strain behavior** that cannot be captured appropriately by simple models.

The soil-structural interaction can provide a substantial difference in designing how buildings are behaving closely to the reality of the underground site conditions. Tunneling projects in urban areas encounter an additional layer of complexity on constructing in zones with possible pile **foundation vibration effects** and others. Consequently, these structures affect each other's response and mean this is very much a 3D problem to be solved.

For transportation owners, an optimised design can deliver time and cost savings while enhancing safety. Conversely though, for the firms executing the analyses, the challenges of integrating models and progressively optimising design, with an accurate understanding of site investigation and the construction program, may consequently lead to delays on deliveries and project execution. While leaner – and greener – solutions may be possible, a low tolerance for risk means that few have the confidence to push for them.

Innovative firms and digital integrators are partnering more and more with technology providers for a continuous, incremental and progressive **'going digital' approach** on design and construction cycles. Geological and geotechnical projects are good case examples demonstrating such a movement. Clarity on the underground information leads to confidence on solving problems and decision making.

The increase in construction productivity brought by digital and mobile technologies is even more critical in tunneling.

Every day engineers are faced with a new excavation front that requires a fresh set of "just-in-time" site explorations, analyses, simulations and informed decisions. This requires **quick decision cycles**, which in turn require a truly digital workflow that allows data to move freely between software applications.

Nowadays geotechnical engineers are aware of the advantages of implementing 3D finite element analysis for a range of applications such as tunneling, excavation and foundation design. Supporting that, geological models and structural effects can be better represented in the 3D space with **a higher-fidelity digital representation**. This allows engineers and geologists to infer full geometry, for example, in the simulation of the structural elements of tunnel and buildings with surrounding geotechnical conditions.

A GREATER CERTAINTY

The 3D digital twin of the tunnel and surrounding geological structures can be used to run geotechnical simulation.

This gives the ability to model and analyse the contractor's design scheme during tendering, to design associated underground structures, and to perform construction simulation. The solution can be used to model highly complex soil and rock behavior to better predict settlements and prevent unexpected failure conditions and critical tensional effects.

Rigorous 3D analysis is proven to show savings from reducing overdesign while still meeting all serviceability and factor of safety requirements in a transportation project.

Consequently, the capability of handling soil-structure interaction in an **"all-in-one" analysis** can lead to a better-quality prediction. In turn this can deliver savings in materials and lift confidence in a safe and reliable calculation – while still meeting all serviceability and factor-of-safety requirements in a transportation project.

EXPERT TIPS

Five steps to planning, designing, analysing, constructing and operating for increased safety and reliability in projects.

- **Plan.** Import, report, manage, and integrate geotechnical data from planning through to site work and reporting. Collaborate with data integrity Ground to cloud.
- **Design.** Build 3D conceptual models of soil and rock deformation and stability, as well as soil structure interaction, groundwater flow, and heat flow climate impacts. Build your model once and use it throughout the project.
- **Analyse.** Use sound computational finite element and limit equilibrium geotechnical analysis to provide a higher confidence in the geotechnical stability and serviceability of your designs on factor of safety with both finite element and limit equilibrium analysis. This practice allows for data-informed decision-making and the ability to adapt designs accordingly.
- **Construct.** Stage and implement simple and complex construction, including excavations, tunnels, foundations, and embankments. You can rely on continuous analysis and real-time monitoring from BIM technology in a digital twin workflow.
- **Operate.** Digital twins can span the entire asset lifecycle. Create a living model and integrate site data as it changes over time, including monitored climate data, ground settlement, and subsurface water conditions like monitoring settlement and ground changes.

THE CASE STUDY

Building homes while protecting the subway tunnels beneath them

THE PROJECT

In Western Bucharest, a EUR 2.5 million, nine-story residential building was set to become the first construction to sit above the city's existing subway tunnels.

THE CHALLENGE

The project presented a number of complex geotechnical challenges, including robust requirements on tunnel displacement and structural forces from the subway operator. The project's engineers needed to provide a safe and cost-effective solution that reduced the building's impact on the tunnel lining. While SAIDEL Engineering initially performed 2D analysis to answer the excavation and foundation problems, and receive approval, they later decided that 3D geotechnical modelling would give them a better chance to increase the safety of the foundation design. However, this would involve modelling more than 1.1million elements and 1.5 million nodes for the piles and pier loads.

THE SOLUTION

As a long term PLAXIS user, SAIDEL Engineering quickly turned to the software to perform plane strain analysis, and developed 3D models that improved confidence in both the foundation design and its reduced influence on the tunnels. The advanced design and analysis features supported evaluation of soil structure interaction and the usage of hexagonal prisms for the piles, as well as ensuring convergence modelling for the pier loads. Various solutions to reduce impact on the tunnel lining were modelled and analysed, not just for all stages of construction, but throughout lifecycle operations.

THE OUTCOME

After an earlier two-year long attempt to find a solution that satisfied the subway operator, SAIDEL got the project back on track within just three months, by using PLAXIS to deliver a foundation system that met the requirements for minimal influence on the tunnel. As a pioneer residential project for Bucharest, their work has helped unlock the potential for future developments over the city's tunnels, promising major benefits for local residents.

To see the full case study, go here

> ”
> **...this would involve modelling more than 1.1 million elements and 1.5 million nodes for the piles and pier loads.**

GOING UNDERGROUND

9 key software solutions to the subsurface challenges that will impact your next transportation project

GEOTECHNICAL INFORMATION MANAGEMENT

Improve collaboration among all contributors who utilise subsurface digital context for timely data-informed decisions on infrastructure digital twins.

- **OpenGround** is a secure, enterprise-extensible platform solution for geotechnical information management.
- **OpenGround Collector** enables field-based data capture for site investigations with real-time synchronisation to the cloud.

How it helps

Providing data integrity from ground to cloud ensures your teams no longer waste their time battling with disparate geotechnical data. OpenGround holds it as a single source of information everyone can use, and streamlines the jobs of collecting, reporting, managing, standardising and integrating all the data from your projects, both new and historical.

GEOPHYSICAL ANALYSIS

Save time and money by drilling fewer boreholes and filling in the geological and geotechnical model gaps with geophysical analysis.

- **Oasis montaj** supports comprehensive data processing workflows for magnetic, gravity, IP and resistivity, EM, and radiometric data, and support for seismic and GPR data, enabling integrated geophysical model interpretation.
- **Aarhus Workbench** and **Res2DInv/Res3DInv** are purpose-built solutions for resistivity and EM survey data that provide unparalleled inversion control and visualisation capabilities.

How it helps

Minimising the uncertainty between boreholes reduces project risk, cost, and time to completion. Improve confidence and reduce the uncertainty of geotechnical and geological models created for soil mapping, depth to bedrock, overburden thickness, cavities and groundwater detection in structures under road or rail embankments.

GEOLOGICAL MODELLING

Seequent's **Leapfrog Works** enables detailed analysis of subsurface terrain throughout a transportation project's entire lifecycle, from planning and design, through construction and handover, to operation and maintenance. Utilising a powerful implicit modelling engine, Leapfrog Works delivers highly visual, shareable and easy-to-understand 3D geological models.

How it helps

A 3D geological engineering model will change how you and your stakeholders look at the ground beneath your project, bringing clarity to even the most complex subsurface conditions. Improve productivity by rapidly generating cross sections and integrating your models with engineering design. Models dynamically update as new data comes in, saving time and money.

leapfrog | WORKS

GEOTECHNICAL ANALYSIS

Ensure you build and operate resilient and safe infrastructure.

- **GeoStudio** provides geotechnical analyses on all subsurface data to solve slope stability, groundwater flow, and environmental challenges.
- **PLAXIS** provides advanced analysis capabilities for soil and rock deformation, soil-structure interaction, groundwater and heat flow. Efficiently model and analyse complex geo-engineering projects, such as excavations, foundations and tunnels.

How it helps

Sound numerical analysis validates design and construction works, enabling contractors to safely deliver projects, and owner operators to ensure resilient and reliable operation that accounts for the long-term impacts of subsurface conditions on their assets. For underground and deep excavations, especially in urban areas, it's essential to understand how ground conditions and stresses impact excavations, accurately predict soil settlement and potential for displacement of neighbouring structures.

GeoStudio PLAXIS®

SUBSURFACE DIGITAL TWIN

A subsurface digital twin approach is future proofing for resilient and sustainable operation.

- **Seequent Central** allows users to visualise, track, integrate and manage all geoscience models from a centralised environment.
- **Seequent EVO** incorporates a new vision for geoscience software that brings all data, applications, APIs and tools into a single, frictionless ecosystem.

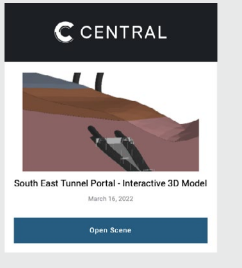
How it helps

CENTRAL

SEEQUENT | EVO

Give your teams a unified and cohesive workspace in the cloud that keeps everyone up to date with changes as they happen, ensuring consistency to minimise risk. Streamline workflows by dividing up a master model, allowing specialists to work on their part, then instantly pulling their updates back into the master.

Users can easily engage project stakeholders with or without technical backgrounds using simple public links to share models and 3D scenes, enabling faster decision making while maintaining security.



Click through to the South East Tunnel Portal scene above to see how easy it is to interact with this 3D model.

COMMENCING COUNTDOWN, ENGINES ON

Pat McLarin
Seequent Segment Director, Civil

Road and rail infrastructure projects are hugely complex, while at the same time being some of the most exciting, rewarding and worthwhile enterprises we can undertake.

Collectively, they will improve the lives of millions, if not billions of people. But to do that they must exist at and push forward the boundaries of construction technology, and remain resilient for the next century. This will be an exceptional undertaking, and should be a source of pride for everyone involved.

While I hope the solutions we've explored in this eBook might inspire you to fresh thinking, with new ideas to get excited about, we know we've only scratched the surface, or perhaps the subsurface...

Here you'll find a full breakdown of our products and services, as well as a number of case studies that demonstrate our technology in action on infrastructure creation across the world.

We hope this eBook has been helpful, and we look forward to working together to enable better ground engineering to advance civil infrastructure around the globe.

To know more about how Seequent and Bentley are innovating with subsurface solutions for infrastructure, **go here**

> ... I hope the solutions we've explored in this eBook might inspire you to fresh thinking...

SEEQUENT

FROM COMPLEXITY TO CLARITY

Solve complex problems, manage risk and make better decisions across the lifecycle of projects.

seequent.com