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WHITE PAPER

MINIMISING CIVIL PROJECT RISK BY STRENGTHENING GEOTECHNICAL ANALYSIS WITH 3D MODELLING

Learn how Leapfrog Works helps teams intuitively model geology to optimise civil and environmental project outcomes.

SEEQUENT

Seequent, The Bentley Subsurface Company

Introduction

Modern construction projects must balance cost, timelines, regulatory requirements, and carbon reduction goals while being built in increasingly challenging locations, such as urban centres, contaminated sites, and areas with poor ground conditions. As a result, a thorough understanding of an area's geology is more essential than ever for managing ground risk, ensuring safety, and delivering successful civil and environmental engineering projects.

Traditional geotechnical workflows often rely on static 2D representations of complex subsurface conditions, making it difficult to assess risks and adapt to changing site conditions. This can slow decision-making, limit collaboration, and lead to costly surprises during construction.

Leapfrog Works helps engineering geologists, geotechnical professionals, and environmental scientists build 3D geological models by integrating borehole data, geophysics, GIS layers, and engineering designs. It enables faster modelling, better collaboration, and seamless integration with tools like OpenGround, PLAXIS, and GeoStudio, so that geotechnical analysis and decisions are based on the latest subsurface data throughout the project lifecycle.

This white paper explores the importance of 3D geological modelling in geotechnical engineering, the benefits of a connected geotechnical workflow, and how Leapfrog Works helps geotechnical teams work more efficiently and align with industry best practices such as the International Association for Engineering Geology (IAEG) C25 guidelines.

Key challenges in infrastructure projects and how 3D geological modelling solves them

A poor understanding of ground conditions is one of the leading causes of cost overruns, delays, and safety risks in infrastructure projects. Traditional subsurface investigation methods—2D interpretations, fragmented workflows, and static reports—often fail to capture the full complexity of geological conditions, leading to inaccurate engineering assumptions and unexpected challenges during construction.

3D geological modelling provides engineering geologists, geotechnical professionals, and civil engineers with a dynamic, data-rich subsurface model. Because 3D models incorporate a wide variety of data into a single, cohesive model, compared to multiple 2D interpretations, geologists can better visualise complex subsurface formations. This improves risk assessment, reduces uncertainty, and supports better engineering decisions.

Integrating geological models into the broader project workflow ensures that subsurface data is effectively incorporated into infrastructure design and construction. This approach aligns with IAEG C25, which provides "guidelines for the development and application of engineering geological models on projects."

Challenges 3D modelling addresses in civil engineering projects

1. Incompatible software tools create data silos

Project teams use various software tools that lack interoperability, leaving data spread across multiple systems rather than consolidated into a single view for a more comprehensive understanding of the underlying geology.

How 3D geological modelling helps

- By bringing data into a common platform, users can see all relevant information in one place to better understand spatial relationships and detect patterns between different data sets.
- Users can visualise geological structures in three dimensions, making it easier to comprehend complex subsurface conditions.
- With all data centralised, engineers, geologists, and project managers have the same understanding of the subsurface and can work together cohesively, without significant reliance on CAD and ancillary teams.

2. Insights based on limited data are required for early decision-making

The amount of data available increases as a project progresses, but geoprofessionals need to accelerate their understanding of the underground to enable downstream decision-making.

How 3D geological modelling helps

- Users can build a conceptual model based on available data early in the project and efficiently create interpretations where data is currently unavailable.
- As a project progresses, new data can be easily added to validate or disprove the conceptual model, providing better insights for decision-making faster than with traditional methods.
- By blending conceptual and observational modelling into a seamless process, project teams can implement best practices for engineering geology as prescribed in IAEG C25 guidelines.

3. Scope change and cost overruns occur from unforeseen ground conditions

Unforeseen ground conditions arise from insufficient data or a lack of opportunity for conceptual modelling. This is increasingly common due to "speed to build" pressures; according to HKA's CRUX Insight seventh annual report, design shortcomings were a factor in more than half of the projects disrupted by scope change.

How 3D geological modelling helps

- Models can be rapidly refreshed to validate new data against conceptual models, enabling teams to swiftly respond to unforeseen ground conditions.
- Alignment changes based on planning permissions, environmental factors, or changing directions from a client can be more quickly accommodated into new designs.
- Users can produce new cross-sections on demand rather than relying on CAD or ancillary teams, increasing their agility.

4. Climate resilience

Infrastructure must withstand climate-related stresses, including extreme weather events, landslides, and changing groundwater conditions.

How 3D geological modelling helps

- Users can model subsurface behavior under different environmental scenarios, enabling proactive risk mitigation.
- Models integrate hydrogeological data to assess flood risks, groundwater flow, and soil stability.
- Modelling software can enhance predictive capabilities, allowing infrastructure owners to plan for long-term resilience and maintenance.

5. Industry skills shortages

A shortage of skilled geotechnical professionals limits the industry's ability to meet growing infrastructure demands, increasing pressure on existing teams.

How 3D geological modelling helps

- Software provides intuitive, user-friendly tools that reduce onboarding time and training requirements.
- Repetitive tasks can be automated, allowing teams to focus on high-value engineering decisions and accomplish more without additional resources.
- Collaboration is more efficient with subsurface data more accessible across multidisciplinary teams.

How Arcadis used 3D modelling as part of a connected geotechnical workflow to design London's South Dock Bridge

The construction of the South Dock Bridge—a bascule bridge with a span of 75 metres—presented significant technical challenges due to its location within a dense urban environment in Canary Wharf, London, the presence of submerged obstructions, and the need for sustainable design.

To ensure the bridge combined functionality with its iconic status as a destination landmark, global design and consultancy firm Arcadis needed an integrated digital solution to coordinate multiple stakeholders and manage complex engineering data. The team used Seequent's Leapfrog Works to create intuitive 3D models of subsurface geology and integrated the models seamlessly with geotechnical analysis tools like PLAXIS and GeoStudio. This connected geotechnical data workflow enabled positive project outcomes, including:

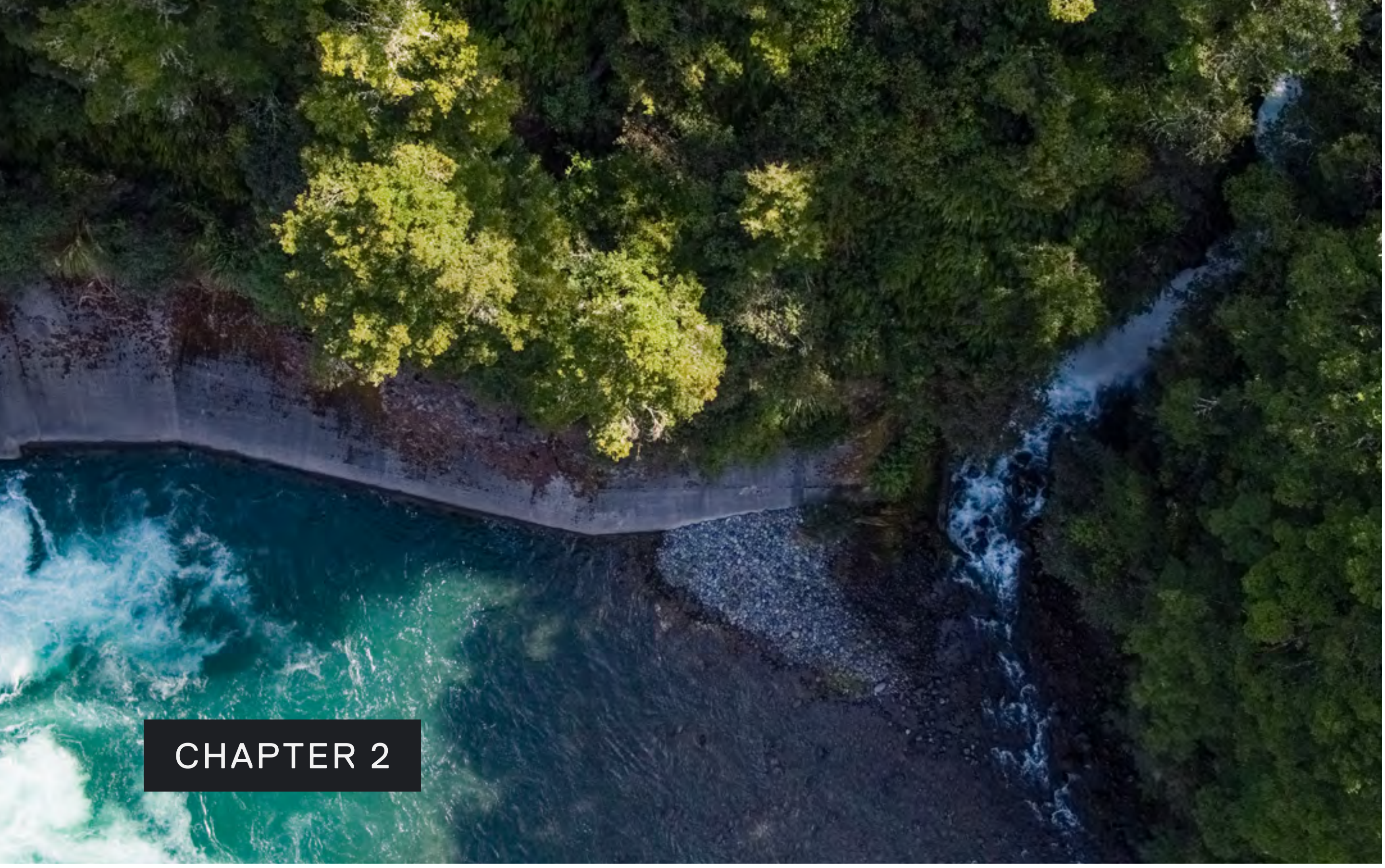
- **Simplified ground investigations**: Leapfrog Works helped reduce the scope of ground investigations by 30%, saving over £70,000 while ensuring the bridge's foundations were designed with precision.
- **Enhanced design coordination**: Integrating 3D subsurface models with BIM tools and GIS platforms ensured seamless collaboration among over 50 project team members across 10 offices and two continents.
- **Data-driven decision-making**: Real-time collaboration and intuitive visualisation enabled more educated decision-making, ensuring the design balanced aesthetics, functionality, and sustainability.

Andrea Gillarduzzi, Arcadis's Senior Technical Director, noted:

> "Our 3D Leapfrog models integrated with project visualisation software allowed us to demonstrate complex geological conditions and optimise our design while meeting budget and sustainability goals."

This digital-first approach not only supported streamlined collaboration during the design phase but also future-proofed the South Dock Bridge by laying the foundation for ongoing monitoring and efficient maintenance.

Read the full story →



Mitigating environmental risks with 3D ground modelling

Environmental risks—such as contaminated land, groundwater pollution, and unstable subsurface conditions—pose significant challenges to infrastructure and remediation projects.

Accurately assessing these risks requires a comprehensive understanding of the subsurface. 3D geological modelling allows environmental professionals to consolidate diverse datasets into a single, dynamic model. This improves contaminant risk assessment, regulatory compliance, and stakeholder communication, ensuring projects are based on the most current and accurate subsurface data.

Challenges 3D geological modelling addresses in environmental projects

1. Complex site assessments

Traditional site assessments are time-consuming, costly, and often rely on fragmented field data that fails to capture full subsurface complexity.

How 3D geological modelling helps

- Combines borehole, geochemical, and geophysical data into a single, interactive model for a more comprehensive view of all geological complexities.
- Reduces field investigation costs by allowing users to efficiently incorporate existing data to predict contamination trends.
- Refines site assessments in real time, incorporating new data as it becomes available and creating a more complete visualisation of the underground as the project progresses.

2. Regulatory compliance and reporting

Environmental projects must meet strict regulatory requirements, including detailed cross-sections, contaminant maps, and transparent audit trails.

How 3D geological modelling helps

- Generates regulator-ready reports, including interactive 3D contaminant visualisations.
- Ensures traceability so all data and assumptions can be reviewed and defended.
- Supports compliance with evolving environmental legislation and best practices.

3. Identifying high-risk areas early in remediation projects

Failure to accurately map contamination at the outset can lead to costly delays and unnecessary remediation work.

How 3D geological modelling helps

- **Allows early risk identification, minimising financial and environmental impact.**
- **Characterises and visualises contaminants in land and groundwater environments.**
- **Creates auditable estimates of contamination levels.**

4. Managing environmental impact in mega-projects

Large-scale infrastructure projects must carefully assess their long-term impact on groundwater, soil stability, and ecosystems.

How 3D geological modelling helps

- **Creates and visualises MODFLOW and FEFLOW grids/meshes directly from geological models.**
- **Simulates long-term environmental risks, helping teams develop mitigation strategies.**
- **Improves engagement with regulators, investors, and communities through clear, visual outputs.**

Evaluating drinking water options for PFAS-contaminated communities

PFAS contamination presents a complex environmental challenge due to its pervasiveness in the environment and the potential health risks it poses.

To address PFAS-contaminated groundwater in Minnesota, leading engineering and professional services firm WSP used Seequent's Leapfrog Works and Seequent Central alongside Hololens technology to create a 4D hydrogeological model that visualised subsurface PFAS contamination and groundwater flow, enabling advanced communication with stakeholders through mixed-reality platforms. This enhanced understanding of hydrology and contaminant transport among all stakeholders.

Read the full story →

How Lieberman Engineering transformed its urban development with 3D implicit modelling

The SAGA Group, a housing construction cooperative in Hamburg, Germany, contracted Lieberman Engineering to evaluate subsurface risks for a residential development on a site adjacent to a former landfill. The project aimed to transform the land into nine residential buildings, providing much-needed housing for a growing city. However, the presence of contaminants and the need for a safe and efficient landfill disposal concept required sophisticated environmental and geotechnical solutions.

Lieberman faced two primary challenges: preparing a geotechnical report to recommend safe foundation methods and excavation strategies and developing a landfill disposal concept to address contamination while minimising remediation costs. Traditionally, such tasks would rely heavily on time-intensive 2D modelling methods or BIM-capable tools requiring advanced CAD expertise. However, these tools often present steep learning curves that limit their practicality for small or mid-sized projects, where the effort required for 3D modelling can outweigh the benefits.

With Seequent's Leapfrog Works, Lieberman developed a dynamic 3D model of the site, integrating geological, groundwater, leachate, and contaminant data into a single, interactive model. This advanced modelling approach provided actionable insights to address environmental risks while facilitating better collaboration with stakeholders, including city authorities and environmental regulators. Key benefits included:

- **Streamlined remediation planning**: By combining 3D models of contaminant zones with geological and site excavation data, Lieberman could determine exact contamination volumes and classify materials according to German waste regulations. This precise approach significantly reduced projected remediation costs.
- **Improved communication and regulatory alignment**: The 3D model allowed Lieberman to visualise and communicate subsurface conditions and contamination risks effectively to all stakeholders. Dynamic updates ensured transparency throughout the project lifecycle, streamlining regulatory approvals and aligning project teams.
- **Enhanced decision-making with real-time data integration**: The model's ability to incorporate new data, such as soil sampling results, supported iterative planning and provided a reliable basis for ongoing environmental assessments. This ensured that decisions were grounded in the latest information, reducing the risk of unforeseen complications.

With Leapfrog Works, Lieberman not only minimised the environmental impact of the redevelopment but also set a precedent for digital transformation in environmental remediation. The project demonstrated how integrating advanced 3D subsurface modelling with a connected workflow can address complex environmental challenges, from contamination management to efficient resource use.

Read the full story →

Industry-leading 3D subsurface modelling with Leapfrog Works

Built specifically for civil and environmental projects, Leapfrog Works 3D modelling software has been designed to help civil and environmental consultancies, government bodies, and civil engineering contractors address the challenges explored in this paper. Trusted by thousands of geologists, geotechnical professionals, engineers, and environmental scientists and proven in projects worldwide, the software has become essential to the engineering process due to its combination of speed, flexibility, and user-friendly interface.

Workflow-based design for efficient, intuitive modelling

Unlike "toolbox" solutions, which offer a variety of tools without an end-to-end workflow, Leapfrog Works is designed based on the geologist's workflow, enabling engineering geologists, hydrogeologists, engineers, and geotechnical professionals to learn the software quickly and work within it intuitively.

Dynamic refresh for accelerated incorporation of new data

When new data or interpretations are added, models in Leapfrog Works dynamically update to reflect this new information. Such model updates would traditionally require time-consuming rework, contributing to project delays or increasing the risk of errors if rushed. By accelerating and simplifying this process, Leapfrog Works reduces this risk and enables users to create 3D models that evolve through the project lifecycle, thereby increasing subsurface understanding as the project progresses.

Powerful tools to reduce reliance on CAD teams

Traditional workflows typically require multiple drafts and iterations of an interpretation to be passed back and forth between geoprofessionals and ancillary teams, such as CAD teams, in order to create deliverables for stakeholder input or consultation.

Within Leapfrog Works, users have access to geometric modelling and editing tools that enable them to produce cross sections and basic plans from 3D models, designs, and data inputs. Complex data can be more easily communicated to non-technical stakeholders, such as management, clients, and the general public.

Geologists, engineers, and geotechnical professionals have full control over their deliverables, without significant reliance on CAD and ancillary teams, accelerating multiple project stages.

Contaminants and hydrogeology capability for environmental projects

Leapfrog Works is frequently used by engineering geologists and hydrogeologists at civil and environmental consultancies and government bodies to make informed decisions across environmental projects, such as management of waste, water, and contaminated land. It can be used to combine

FUN FACT

Leapfrog was once featured in an answer on the U.S. quiz show, Jeopardy!

geological, hydrogeology, geophysical, and geochemical data in a single model to visualise ground and groundwater domains. Users can integrate 3D plume analysis and flow modelling into conceptual models, which form the basis for remedial design and monitoring strategies.

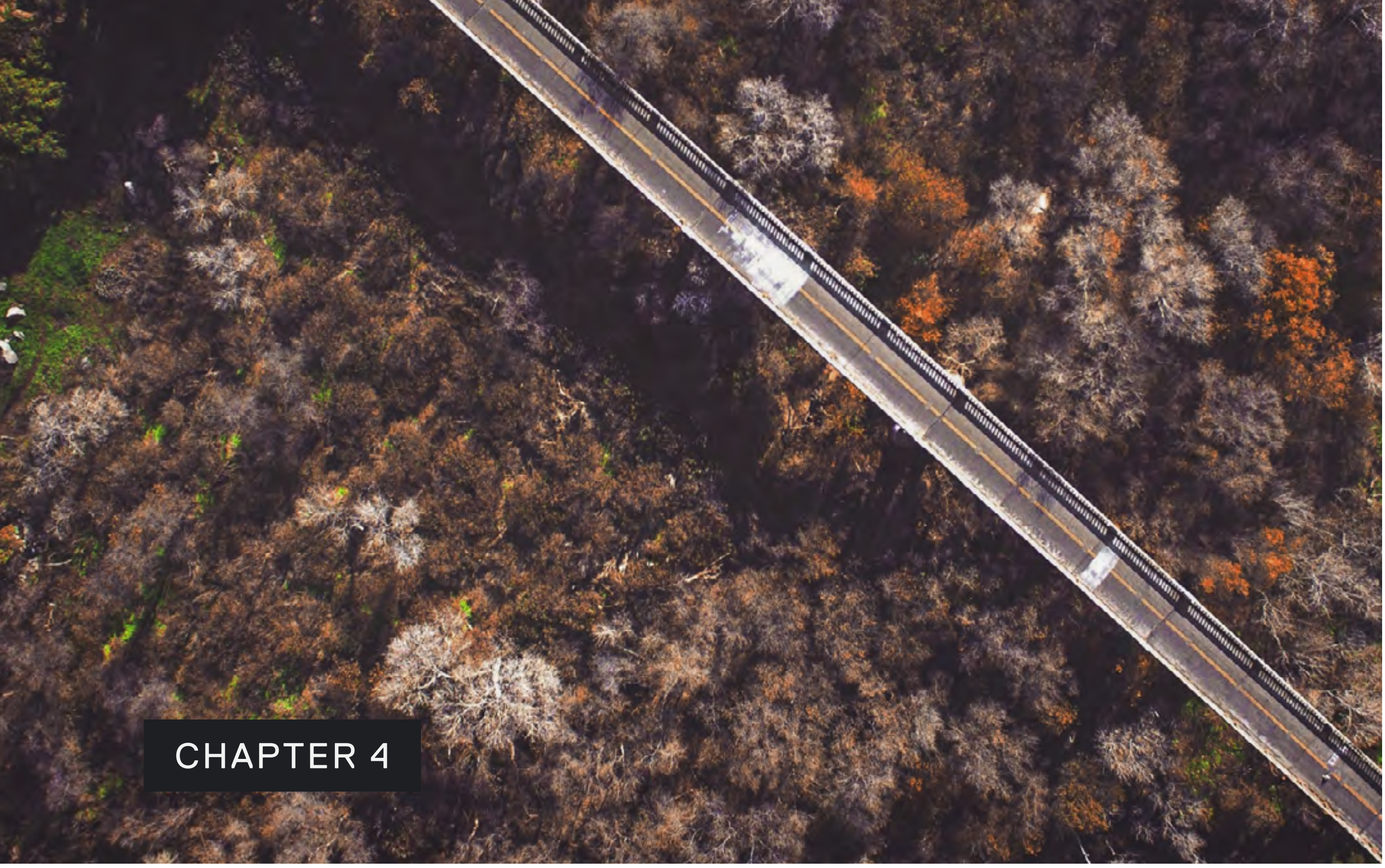
The Contaminants extension for Leapfrog Works provides intuitive and robust geostatistical tools to create transparent and defensible estimates of contaminant mass and location in saturated and unsaturated zones.

The Hydrogeology extension provides the capability to convert a geological or conceptual model to MODFLOW and FEFLOW model grids and meshes, as well as import existing models and simulation results.

Pioneering RBF technology

Leapfrog's roots trace back to a technology originally designed for prosthetics and medical imaging. This technology, known as the radial basis function (RBF), was soon applied to various industries, including Hollywood for special effects in films such as The Lord of the Rings, and even NASA for mapping asteroids.

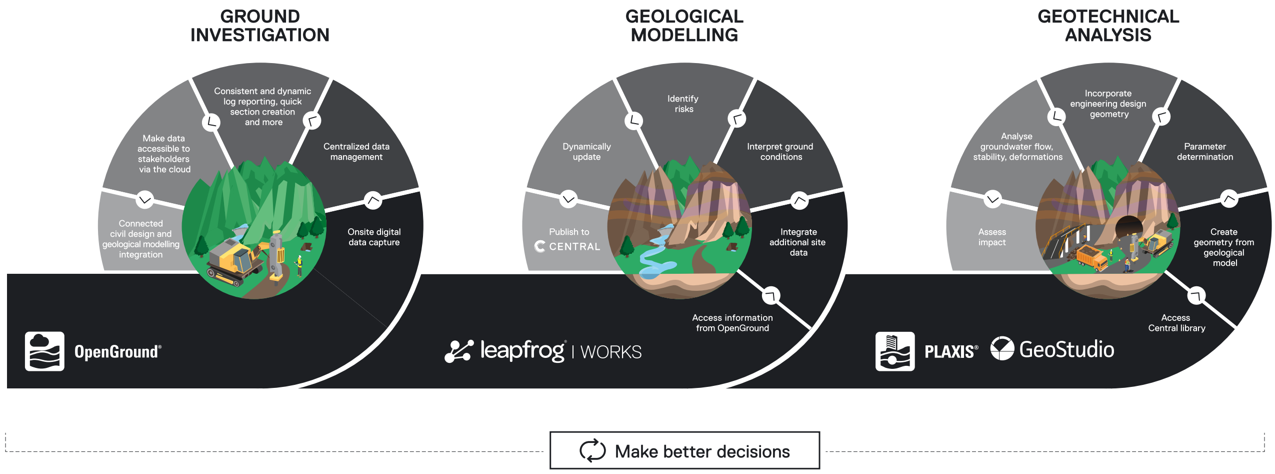
Leapfrog uses RBF to interpolate or fill in the gaps where there is no data, with user guidance; this is particularly beneficial for early decision-making with limited data. RBF's speed means that results can be quickly updated when new data is added, ensuring its implicit model is dynamic.



Building a connected geotechnical data workflow for civil and environmental projects

Unlike the majority of 3D modelling software, Leapfrog Works seamlessly links to geotechnical information management and analysis software. By connecting geological modelling directly into the geotechnical workflow, engineering geologists, geotechnical professionals, and environmental scientists can create dynamic 3D models that integrate borehole logs, geophysics, GIS layers, and engineering designs.

Geotechnical connected product workflow



This connected workflow eliminates manual data transfers and siloed workflows, enabling project teams to make better-informed decisions, reduce risks, and improve efficiency across civil and environmental projects.

A connected workflow also supports compliance with IAEG C25 guidelines for Engineering Geological Models (EGMs) by integrating:

Conceptual models

Leapfrog Works allows engineering geologists, geotechnical professionals, and environmental scientists to combine their conceptual understanding with site-specific data, building 3D subsurface representations that evolve as new data is collected. This aligns with the guidelines' focus on leveraging geological and geomorphological insights to anticipate ground conditions.

Observational models

With its dynamic integration capabilities, Leapfrog Works allows users to incorporate real-time observations, such as borehole logs and geophysical surveys, into the modelling process. Tools like Seequent Central provide a robust environment for storing, updating, and managing observational data, ensuring transparency, traceability, and version control.

Analytical models

By seamlessly connecting with GeoStudio and PLAXIS, Leapfrog Works bridges the gap between geological interpretation and engineering analysis. This ensures that analytical models are grounded in accurate geological frameworks, as highlighted in the guidelines.

Understanding the underground with a complete geoscience solution

The Seequent ecosystem combines tools like Leapfrog Works, OpenGround, GeoStudio, PLAXIS, and Central to create an integrated geoscience workflow. These tools allow users to manage, analyse, and share geological, geotechnical, and environmental data across the entire project lifecycle.

Inspiring the next generation of geoscientists

To inspire and equip the next generation of geoscientists, Seequent, developed Visible Geology, a free, web-based application designed to bring geological concepts to life for students and educators alike. Visible Geology moves beyond traditional 2D teaching methods and empowers students with an immersive 3D learning experience.

By encouraging students to explore the subsurface world in an innovative digital environment, Seequent is playing a key role in shaping the future of the geoscience field.

See Visible Geology for more →

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customers use Seequent software in over 140 countries

10/10
of the world's largest civil engineering companies use Seequent software

7/10
of the world's largest environmental consultancies use Seequent software

95%+
satisfaction rate with our front-line help and support

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