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Holographic models of closure landscapes for stakeholder engagement: when you need more than words and pictures

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Abstract

The Giant Mine Remediation Project (Giant) and Faro Mine Remediation Project (Faro) are abandoned mine projects in northern Canada with long legacies and many complex challenges. BGC Engineering Inc. has been working with Crown-Indigenous Relations and Northern Affairs (CIRNAC) using holographic projections to collaborate with First Nations and local communities on key mine closure information. This paper shares experience with using Microsoft's mixed reality HoloLens devices (HoloLens) as a tool that creates a safe and equitable environment to collaboratively engage with communities where previous experience and technical understanding are not prerequisites to contributing. This is important, as engaging in meaningful discussions involving mine closure planning involves effectively communicating engineering and earth science information to rights holders and stakeholders with diverse experiences.

The Faro project is beginning to develop several 3D digital models to encourage conversation, discussion, and engagement on the progress of mine closure, showcasing a time lapse of how the mine has changed over the past few years and its current state, and to explore the staged approach to reclamation. HoloLens was used to incorporate a broad spectrum of data into holographic models that were shared with multiple users to experience together. The digital models incorporated historical topographic and aerial imagery and current conditions, and include proposed future conditions based on designs and reclamation plans. The participants can collaboratively experience this collated information from different viewpoints, including in tabletop models, as 3D objects in the middle of the room, and as immersive 3D scenes.

At Giant, there is a complex underground mining legacy that the community wanted to better understand. Holographic models were created that allow users to visualise and walk around the surface and underground together, as a community, and ask questions, voice concerns and ideas, and see how groundwater conditions change throughout the seasons and into the future. Additionally, as there are several locations throughout the mine that will be reclaimed based on input from the community, it is important to be able to visualise the design beyond 2D engineering-based drawings. Real-life-scale immersive views were created, providing experiences of how these areas might look once reclamation is finished.

We hope that by sharing the experience of sharing information in this way that the state of practice for creating holistic and sustainable mine closure designs that reflect the input of rights holders and stakeholders can be advanced.

Keywords: *mine closure, remediation, reclamation, community engagement, mixed reality, holograms, Microsoft HoloLens, Clirio, reconciliation, Indigenous engagement*

1 Introduction

Communicating challenging earth science projects is difficult. Being able to imagine future conditions of earth science projects is debatably even more of a challenge. Many mines involve the assessment and communication of technical engineering and earth science data and greatly benefit from multi-stakeholder collaboration to create more holistic and socially acceptable closed mines. This creates a challenge. Technical writing and 2D figures presented in posters or on PowerPoint require some experience to translate this information into a mental picture of a proposed development. Given that successful collaboration on post-mining land uses requires collaboration from diverse individuals with different lived experiences, it cannot be assumed that everyone forms the same mental model from this information. If we can show communities information in more digestible formats, then input can be given and a culture of being 'heard' can be created. Many of us loved dioramas as children – with digital models, we can show dioramas that animate, and show what is happening underground, and then we can stand people inside the models. The Microsoft HoloLens (HoloLens) can place digital 3D models in the real world and lets people experience them in a shared way. We hope that by sharing these experiences the state of practice for creating holistic and sustainable closure designs that reflect the input of local communities, rights holders and long-term stewards can be advanced.

1.1 What is mixed reality?

Mixed reality (MR) blends both physical and digital worlds together to provide an immersive experience for users. The MR spectrum extends from the physical reality (i.e. real world) to the digital reality and includes augmented reality (AR) and virtual reality (VR). With AR, users use devices to overlay digital images on the physical world, typically using a 2D screen such as phones or tablets. Immersive VR devices block out the physical world and replace it with a fully immersive computer-generated 3D environment (i.e. a digital experience). For this paper, we will use MR to denote placing 3D virtual objects into the users' real-world space. The scale of the digital objects can be from the palm of your hand to so large that the user experiences being inside the object.

MR is the next wave in computing. It liberates users from screen-bound experiences by offering natural and intuitive interactions without the need to travel to a project site. We use Microsoft's holographic technology to anchor virtual objects (3D holographic models) onto the real world. Using head-mounted displays (HMD), as shown in Figure 1, with transparent lenses such as the HoloLens, users can maintain visual connection with their surroundings while they manipulate and interact with the 3D holographic models by leveraging spatial mapping and anchors, hand tracking, eye tracking, voice commands and spatial sound in an immersive setting.

Figure 1 An example of using the HMD HoloLens to see the subsurface and the users' surroundings at the same time

MR allows technical experts to render mathematical and science-based numerical simulations and their findings into a real-world space to provide their audiences, both subject matter experts and non-experts, with a deeper understanding of the scope and scale of a particular project. As the user can see the real world around them, including other users seeing the same model at the same time, participants can walk freely around the data in a natural way, allowing a self-directed interrogation of the data being presented in a collaborative and immersive environment.

1.2 Who uses mixed reality?

More than 100 new companies with immersive technology products and services were founded in Canada between 2014 and 2017 (Farmer & Matthews 2020). Since the release of the HoloLens 2 headset by Microsoft in 2019, approximately 520,000 units have been sold worldwide (Build Wagon 2022). This technology is being used across different sectors and disciplines, including automotive, medicine, engineering, architecture, defence, retail, education, and training. For example, MR is reported to be radically changing the world of medicine, including enhancing medical education and patient outcomes (Whitney 2021).

1.3 Why use mixed reality for collaboration with rights holders and stakeholders?

BGC Engineering Inc. (BGC) has been using MR HoloLens devices and the Ada Platform (Ada) software created by Clirio Inc. (Clirio) to communicate complex applied earth science problems to project team members and stakeholders since 2016. Clirio is a Canadian-based technology company dedicated to creating leading-edge tools and experiences that allow users to get the most out of their 3D data. Ada is a software that allows the creation of holographic 3D content from digital 3D models, and the deployment of the holographic content to the HoloLens using a cloud-based portal.

Based on the experience acquired since 2016, the following is a summary of the key advantages of using MR over both traditional communication tools and methods, such as drawings and 2D screens, and emerging technologies, such as AR and VR:

- **Immersive:** Humans understand data better when it is presented in 3D and can walk through the data.
- **All data together:** The user can consult many data sources and look at them simultaneously. For example, the assessment and communication of site investigation drilling and geophysical data typically include the preparation of several plan views and cross-sections that the audience must mentally construct as a 3D model. With MR, all subsurface data can be shown together as is, at the correct location for users to walk through it.
- **Right level of sophistication:** 3D holographic models can be as simple or as complex as needed, but not more so, allowing the interrogation of data with the required level of sophistication for the project.
- **Collaborative:** Multiple ‘engaged users’ interrogating many data sources and looking at them simultaneously, not one ‘driver’ leading the experience and multiple ‘passengers’. By collaborating around the 3D data in a more natural way, participants can reach a shared understanding on the challenges faster.
- **Show, not tell:** Different brains process data in different ways; there is a need to show data instead of telling participants what they must see. To respect the independent thought and critical thinking of participants, professionals must show the evidence that supports decisions in a manner that participants can ask questions. This conversation allows professionals to know the needs of key rights holders and stakeholders and to explain ideas considered but not chosen, demonstrating transparency, objectiveness, and the capacity to reason.
- **No size limits:** Pull data out of your monitor and fill the room by manipulating the 3D holographic model, adjusting its size, rotation, location, and elevation.

MR allows users to see not only the digital information but also their physical environment and other users easily, and it is the authors' experience that this enhances communication and trust. Other technologies, such as fully immersed VR experiences, can give a different experience and should also be considered depending on the outcome desired and the ability to incorporate the right safeguards for users. The Meta Quest 2 VR device can warn fully immersed users of objects in their space. Using the Guardian system, a user can also set up a safe area to avoid colliding with walls or objects in the real world, though this area is typically limited to 2 × 2 m. Another alternative is to use VR headsets that bring the real world into the device via passthrough cameras and added to a pixel-dominant experience. This technology continues to advance and is heading towards overcoming the challenges of bulky VR headsets and near-eye focal dynamics for illuminated pixels on the device.

From a communication perspective, any VR 'connected session' relies on digital avatars. For some users, being able to speak face to face and look someone in the eye is easier to adopt than avatars and is important to building trust. Some users of VR technologies experience nausea and vertigo, whereas this occurs less frequently in MR as the users' peripheral vision of their surroundings is preserved.

To support the needs of Giant and reach a wider range of devices, iOS and Android apps were also created to leverage AR to show the digital models. This approach helps reach a broader audience and improves user adoption. For many mine closure type projects, technology should not be a barrier to entry, so working with many different technology options is important.

2 History of mines

2.1 Giant Mine Remediation Project

The Giant Mine is an abandoned gold mine located in the City of Yellowknife, Northwest Territories, approximately 5 km from the city centre. The mine site is approximately 1,116 hectares in size. The project is on Commissioner's Lands of the Government of the Northwest Territories. The site is in an area with co-existing rights within the asserted traditional territory of the Akaitcho Territory Dene First Nations and the Môwhì Gogha Dè Nîîtåèè boundary as defined in the Tłįchǫ Land Claim and Self Government Agreement; and is adjacent to, or on the boundary of, the Interim Measures Agreement Area of the Northwest Territories Métis Nation.

Gold was discovered on the property and mineral claims staked in 1935, but the true extent of the gold deposits was not known until 1944, when a massive gold-bearing shear zone was uncovered beneath the drift-filled Baker Creek Valley. Giant Mine entered production in 1948 and ceased operations in 2004. There were several owners of the mine during its operation. Royal Oak Mines Inc. operated the Giant Mine from 1990 to 1999 and then entered receivership in April 1999. In December 1999, the Ontario Superior Court of Justice ordered the transfer of the Giant Mine property from the interim receiver to Crown-Indigenous Relations and Northern Affairs (CIRNAC) of the federal Government of Canada. In 1999, Canada sold the mine's assets to Miramar Giant Mine Ltd., a division of Miramar Mining Corporation. This ensured a maximum number of jobs continued at the mine and that a knowledgeable, experienced operator would stay onsite to oversee the care and maintenance of the site. Until July 2004, Miramar Giant Mine Ltd. continued to mine ore from the Giant Mine on a greatly reduced scale. The ore was trucked to the Miramar Con Mine, located on the southern edge of Yellowknife. No further processing of ore took place at the Giant Mine and the roaster did not operate after 1999. As a condition of the sale, Canada acknowledged Miramar would not be responsible or liable for the existing state of the mine. This meant CIRNAC became a caretaker for the site, including the arsenic trioxide stored underground. Miramar Giant Mine Ltd. ended its obligations under the Reclamation Security Agreement in 2005. At that time, Giant Mine officially became an abandoned mine site.

The Giant Mine produced over 7 million ounces of gold between 1948 and 2004 and contributed significantly to the economic viability of the city of Yellowknife and the Territory. The gold at Giant Mine was extracted from arsenopyrite, an arsenic-rich mineral, using a high temperature roasting process, which created arsenic trioxide as a byproduct. From 1948 to 1999, approximately 237,000 tonnes of this collected dust was stored underground in areas of the mine that had been excavated during mine operations and in purpose-built chambers sealed with cement bulkheads. As such, the biggest concern at the site currently is the arsenic trioxide dust stored underground. If left unmanaged, the greatest potential risk is the possibility of uncontrolled flooding of the mine that could result in a release of arsenic into the groundwater, and eventually to local bodies of water, such as Great Slave Lake and Baker Creek. Closure plans to deal with this complex situation have been developed by CIRNAC and its engineering consultants, and later this year Giant Mine is entering the full-scale remediation phase, for approximately the next 15 years.

2.2 Faro Mine Remediation Project

The Government of Canada, as represented by CIRNAC, is responsible for the management and final remediation planning of the abandoned Faro Mine Complex, located approximately 13 km north of the town of Faro in central Yukon, Canada. The Faro Mine Complex is approximately 25 km^2 and consists of three distinct areas: the Faro Mine Area that includes the Faro Pit and surrounding waste rock dumps, the Rose Creek Tailings Area, and the Vangorda/Grum area (Vangorda). The sulfide-bearing waste from the historic zinc and lead mining operations at the Faro Mine Complex from the 1960s through to 1998 is stored in several waste rock dumps and in the Rose Creek Tailings Area. Seepage from the storage of sulfide-bearing waste has variably impacted groundwater and surface water reporting to Rose Creek. CIRNAC and its engineering consultants have developed remediation plans to manage these impacts.

The project is located on the asserted traditional territory of the Kaska Nation, and upstream from Selkirk First Nation. Engagement with First Nations is part of Canada’s commitment to good governance and to the reconciliation agenda (Truth and Reconciliation Commission of Canada 2015). Considerable work has already taken place to build relationships with the Kaska Nation and increase First Nation involvement at Faro.

2.3 Community engagement and relations

CIRNAC has led engagement and consultation with Indigenous communities and the public over the last two decades since it became responsible for these legacy mine sites. Engagement with Indigenous communities is a key part of both projects. The Giant and Faro project teams understand the importance of the remediation to the local Indigenous communities. Established engagement channels are a key method through which the project teams interact with representatives of affected parties in a meaningful way, both to provide information and to solicit input. Over time, a range of rights-holder and stakeholder engagement groups have been established to address the needs and interests of affected parties and the project team, and to satisfy the regulatory requirements established on both projects.

Both Giant and Faro recognise that these projects can contribute to reconciliation with Indigenous communities by healing of the land through remediation activities, providing socio-economic opportunities through employment, and by building relationships through engagement and communications activities.

The projects use the following six principles to guide their engagement efforts modified from the Northern Contaminated Sites Program (NCSP) overall guidance for engagement, adopted by CIRNAC for Giant and Faro (CIRNAC 2021):

- **Shared responsibility:** It is essential that engagement is a coordinated process within the co-management system of the region, which reflects the responsibility of Giant and Faro, Indigenous governments/organisations, and the regulatory boards to enable meaningful involvement of affected parties.
- **Appropriate disclosure:** All information is made available in a timely and understandable manner and considers the culture(s), language(s), and tradition(s) of the affected parties.
- **Inclusiveness:** Those potentially affected should be given the opportunity to be heard and involved.
- **Reasonableness:** Giant and Faro, affected parties, regulatory boards and the Crown must be reasonable when setting expectations for engagement and consultation processes and be willing

to enter these processes in the spirit of cooperation. This includes the provision of reasonable resources, where appropriate, for carrying out and participating in consultation and engagement processes.

- **Acknowledgement and respect:** All experiences with respect to the history and legacy of the Giant and Faro mines, their impacts on traditional use, and the current remediation projects are real and deserve to be heard.
- **Openness:** All questions and concerns are welcomed as an opportunity to build clarity, understanding, and trust.

3 Initial scopes

Based on the complexity (technical, social, and economic) of these projects, closure landscapes presented holographically in MR have been an instrumental tool for social licence, collaboration, holistic design, and general understanding. Giant and Faro are at two different stages in their MR projects. Based on Giant's successful integration over the past five years, Faro has followed suit, beginning their pilot project in early 2022. The following sections review the scopes completed to date.

3.1 Giant Mine Remediation Project

The original MR remediation scope at Giant began in 2018 and has evolved over time to include tabletop models, underground visualisations, immersive scenes, and videos. These are available within their own app, the Giant Mine Reclamation Viewer, in English and Wıìlıìdeh Yatıì (one of two traditional languages of the Yellowknives Dene First Nation).

To date, the following holographic 3D models of Giant have been created using the Ada Platform, and have been used in several community engagement sessions:

1. Tabletop 3D model of Yellowknife's regional terrain.
2. Tabletop 3D model of terrain in the vicinity of Giant Mine.
3. Tabletop 3D model of terrain in the vicinity of Giant Mine with closure plan overlay.
4. Visualisation of Giant Mine's underground infrastructure and groundwater conditions.
5. Close-up visualisation of one proposed underground freeze drift (Government of Canada 2018).
6. Baker Creek viewpoint (immersive scene) – A view to the downstream reaches of Baker Creek, the new road crossing, and areas where the floodplain has been widened to allow for the passage of major floods. This scene also includes the gradual stepped slope where a pit once was.
7. Thermosyphon viewpoint (immersive scene) – A view across Baker Creek to the thermosyphons above the underground stopes to enable ground freezing.
8. Spillway viewpoint (immersive scene) – From this highpoint, the viewer can see the remediated North Tailings Pond with rock cover in place and remediated Baker Pond wetland.
9. Gravel pit viewpoint (immersive scene) – A view of the footprint of the reclaimed Northwest Pond quarry. The Northwest Pond quarry was one of several onsite quarries that were developed to supply various sized rock material to support the remediation of the Giant Mine site.

The Giant Mine Reclamation Viewer app for HoloLens is available free of charge via the Microsoft HoloLens store. Throughout the session, the participant is provided with information about sites of interest, plans for remediation, and an idea of what the site will look like after remediation.

An AR version of the Giant Mine Reclamation Viewer app was also built for mobile devices (both iOS and Android) to share the data more easily, acknowledging that some community members may not have easy access to a HoloLens device or the engagement sessions. The AR version of the Giant Mine Reclamation

Viewer app, which is available free of charge, includes an introduction to users not familiar with AR environments by providing step-by-step instructions on how to set up the model and walk through the scenes through a 2D screen using their personal devices. These features are designed to enhance the usability and user experience through an introductory sequence at app launch, demonstrating key MR concepts and a user interface guide to provide a curated experience. In addition, users of the AR version of the Giant Mine Reclamation Viewer app can submit comments or provide feedback to the Giant Mine Project team via the in-app Help Centre feature. As per the HoloLens version of the app, both the mobile app and video also include localised content in Wıìlıìdeh Yatıì.

3.2 Faro Mine Remediation Project

Based on the success of using the HoloLens at Giant, the Faro Community Relations Team (Faro team) requested a pilot project to investigate how a similar scope could support the Faro Mine Remediation Project. The objective of the work was to begin with a 'starter pack', showing key features at the Faro Mine Complex. This pilot project, which is in its infancy, included the creation of tabletop models from existing data available on BGC's records, which are intrinsically engineering focused. The main goal was to create a set of holographic 3D models to work through together (BGC and Faro team), identify the areas of potential discomfort, confusion, uncertainty, and/or importance with respect to community and industry engagement that could be overcome with the creation of additional holographic 3D models, immersive scenes, or applications, all part of a future scope.

The Faro pilot project included the following holographic 3D scenes, showing both current and future site conditions:

1. Tabletop 3D model of the province and territory boundaries and Kaska and Selkirk traditional territories.
2. Tabletop 3D model of the town of Faro, Faro Mine Complex, main access road and surface water bodies.
3. Tabletop 3D model of the Faro Mine Complex, including the Faro Mine Area, Rose Creek Tailings Area, Vangorda/Grum area, haul roads, access roads and main surface water bodies.
4. Tabletop 3D model of the Vangorda/Grum area, access roads and surface water bodies.
5. Tabletop 3D model of the Faro Mine Area, Rose Creek Tailings Area, and main streams.
6. Tabletop 3D model showing the main remediation challenges for the Faro Remediation Project.
7. Tabletop 3D model of Faro Mine Area showing the current water management strategy, key sources of contamination, contaminated water collection system, water treatment plants, and transportation of contaminated, treated, and clean water.
8. Tabletop 3D model showing 'as-built' records of the North Fork Rose Creek Diversion Channel.
9. Tabletop 3D model showing the General Closure Plan for the Faro Mine Complex.

4 Lessons learned

Both Giant and Faro have had opportunities to engage with local communities. At each session, the project team learned something new, allowing the improvement of the MR models and providing valuable feedback to the teams working on each project. During the session, project team members were able to interact with the holographic 3D models together with community members and other stakeholders, providing a fun, collaborative, and safe environment for participants to ask questions, voice concerns, and provide feedback.

4.1 Model preparation

All types of data can be presented via holographic 3D models, so determining what to include based on the challenge is paramount for the success of a project. Collaborating with a broad stakeholder group is important to find a balance between the data included and its presentation to create a self-explanatory experience. A project typically starts with the preparation of storyboards and problem statements to create a more thorough outcome. As part of this stage, the team should discuss the number of labels/descriptors to be included on the models and consider the integration of traditional languages.

Modellers compile a broad spectrum of data from the rights holders and stakeholder groups, such as topography, imagery, traditional knowledge, sites of cultural importance, design and engineering work, artistic composites, and survey scans, and create comprehensive 3D holographs. Having all the data and design work in the same real-world coordinate system allows the data to be brought together, and ensuring the datasets are in similar space may be a significant undertaking when dealing with historical data from disparate sources. Having an intermediary between the engineers working on design work, communities providing local knowledge, and 3D artists interpreting the overall vision is helpful to create a representative set of holographic 3D models. Depending on the device to be used, reducing the resolution of survey or design data may be required.

Compiling all required data to create the holographic 3D models can be challenging. As mentioned, the data is variable, and range from conceptual designs requiring extensive creative licence to substantive designs or 'as-builts', which show actuals from construction. Ensuring that the models are accurate and reduce confusion is important. In mine closure, the value is being able to see the history of yesterday, the reality of today, and the future of tomorrow by letting the user experience being in and surrounded by the environment.

Starting with the available data and reviewing early and often with a broad stakeholder group can provide valuable feedback for both improving the holographic 3D models and to the teams working on the remediation designs. Additionally, by including a broader group, the feedback is more diverse, supporting more thorough and well-rounded experiences.

For AR, the team should be aware of the limitations of the technology, such as the reduced size of the screen of some mobile devices. Early in the model preparation process, the team should also consider the need to create user help menus for AR apps.

4.2 Hardware and setup

There is an optimal environment for viewing holographic 3D models with the HoloLens – away from windows and direct light, in a room without reflective surfaces, a carpet not too dark or too light, and with enough features to help the HoloLens locate itself as users move around, thus ensuring the holographic 3D model stays put. The HoloLens leverages spatial anchors to place and hold maps in a space. The HoloLens can do so by identifying unique environmental features to locate itself in a space. These 'landmarks' are critical for the device to know where it is located. If possible, the session would take place in a community centre, gym or large boardroom without too many tables or chairs to facilitate mobility of participants and to allow the visualisation of the holographic 3D model at large scale.

The sessions to date for Giant and Faro generally included a maximum of 10 HoloLens devices locally connected to a shared session using Wi-Fi or a travel router. Participants using HoloLens can see the same holographic 3D model anchored in the middle of the room, at the same position and at the same scale, and walk around the data while they interact with other participants. It is helpful to have a 'host' equipped with a HoloLens to see what other participants are seeing and pointing at, and a support teammate without a HoloLens to work with any participants struggling with the hardware, troubleshoot issues and provide support for questions or to record comments. During the session, it is important that participants walk around the data being presented and to look at the holographic 3D models from different heights and angles for a full experience, as seen in Figure 2.

Figure 2 Example of multi-user visualisation to support community engagement of a tabletop holographic model, with users observing the model from different perspectives, heights, and experience levels

Sometimes the group needs encouragement to do this, and as the host or support team, it is always worth walking around to show others that the model is a virtual object that will not move while they walk around, facilitating the interrogation of the data in a more natural way. The host and support teammate should be trained on the use of the HoloLens and the app being presented and should have experience providing demonstrations to multiple participants.

4.3 User experience and feedback

From using MR during community engagement sessions, the authors have learned that the models can help build legitimacy, credibility, and trust among all rights holders and stakeholders. Before the use of MR technology, community engagement sessions were generally quiet, with a presenter providing information to an audience using traditional methods. With MR, attendees were able to visit areas previously not accessible to them, such as the underground mine workings, and were able to see data in a more natural way. Participants started talking and asking questions, providing valuable feedback for the project. From these experiences, we know that having the HoloLens available and ready to use for every engagement session consistently adds value.

MR's 3D representation of digital data and analysis results can also be of benefit to experts with deep experience in traditional 2D information representations, allowing them to interrogate 3D data at their own pace and from the perspective of their choice (Figure 3).

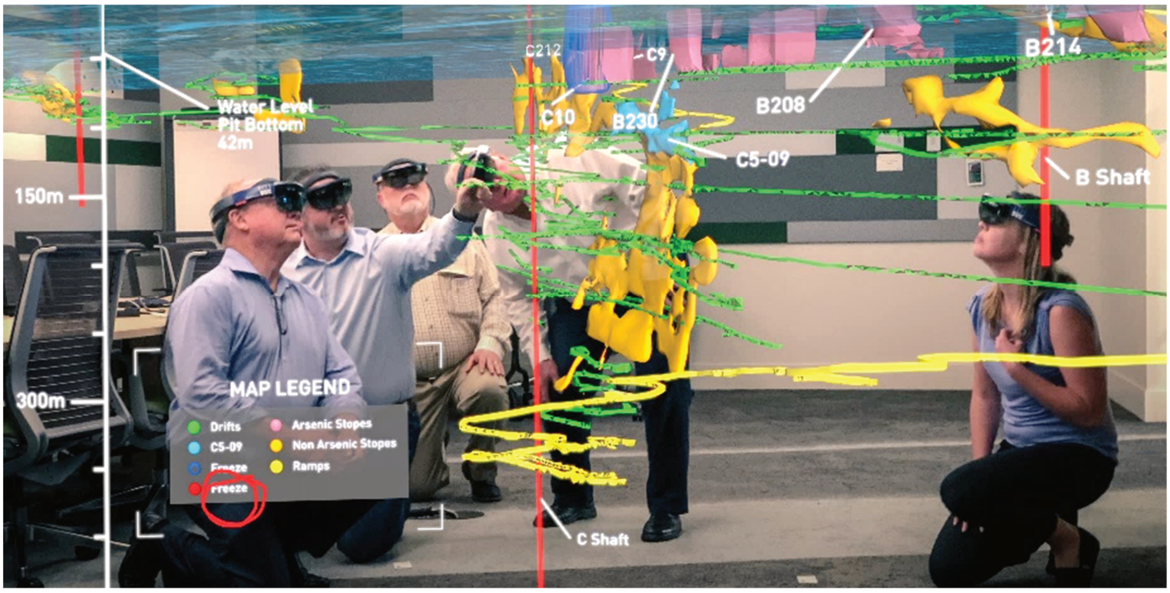

Figure 3 Example of multi-user visualisation to support a review board of an underground holographic model, with users observing the model from different viewpoints in a boardroom

4.4 Remote hosted sessions

For many, COVID-19 meant that local engagement sessions were paused or disrupted due to travel restrictions. The HoloLens can be used with remote access, where users join hosted sessions and can explore the models together, continuing discussions through the headsets equipped with spatial audio. Each user is visible virtually as a HoloLens device and other users within the session can see where they are pointing. This kind of remote access allows for collaboration from many different rights holders and stakeholders and would have been a helpful tool to continue discussions with the local communities.

In addition to remote access, the AR version of the Giant Mine Reclamation Viewer app allowed team and community members to interact with existing material and project data during the pandemic, without the need of a HoloLens, and from their homes. This was supported by more user-friendly help menus and starter guides and tutorials, which were updated within the apps to facilitate a single-user experience, providing new and experienced users with enough information to use the apps independently.

5 Evolution and upcoming opportunities

There are many exciting evolutions and upcoming opportunities based on the advancement of technology.

5.1 Expanding content

For the next steps at Giant, the project team will be discussing the creation of additional immersive scenes to complement the existing Giant Mine Reclamation Viewer app based on feedback received from community members. The app will also be updated to reflect the approved closure plan and implementation plan. Future opportunities include incorporating more content to reflect and preserve the history of land use and culturally significant sites by leveraging new LiDAR scanning capabilities (i.e. new LiDAR scanner sensor on iOS personal devices).

For Faro, the project team is considering adding the output of numerical simulations of groundwater and surface water interactions above and below the ground surface, including pumping locations, diversion channels, pipelines, and water treatment centres, which support one of Faro's goals to keep clean water clean, and treat contact water before releasing it back into the environment. The creation of a time lapse, with construction changes, climate change impacts and mitigation methods, is also being discussed.

5.2 Training opportunity

Local knowledge is a critical piece of data that can be brought into these models. This data brings context for non-technical community members, using relatable and important landmarks and allows local communities to be the creators of project information. The basic creation and inclusion of MR tabletop models from GIS software and LiDAR scans from iPads can be adopted by communities with appropriate training and access to hardware. The authors see an opportunity to be able to share these skills with local communities and support the inclusion of traditional and local knowledge, so the communities can bring in data that they would like to share within and outside their community.

5.3 Expanding visualisation and interaction

In addition to the HoloLens 3D (x, y, x) experience, we have experimented with the use of a fourth dimension: time. For example, holographic 3D models can include time series showing instrumentation data, such as slope inclinometers, slope accelerometer arrays, and piezometers. A fifth dimension can also be added to show chemical change, such as rain/groundwater leaching materials off a tailings pile, which may change the water chemistry. By visualising numerical simulations on the HoloLens, users would be able to see where the chemistry changes and its path through the environment (through surface or groundwater systems).

Future interactions could allow users to utilise a ‘game’ to make policy decisions. Updates from variations to a project system (e.g. climate conditions or water usage) could be rendered in real time so users can understand what a decision today may have as an outcome in the future.

6 Conclusion

MR is a helpful tool that allows the interrogation of data in a natural way and brings people together in a way that creates understanding and trust. The authors hope that by sharing these experiences, the state of practice for creating holistic and sustainable mine closure designs, which reflect the input of rights holders and stakeholders, can be advanced.

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