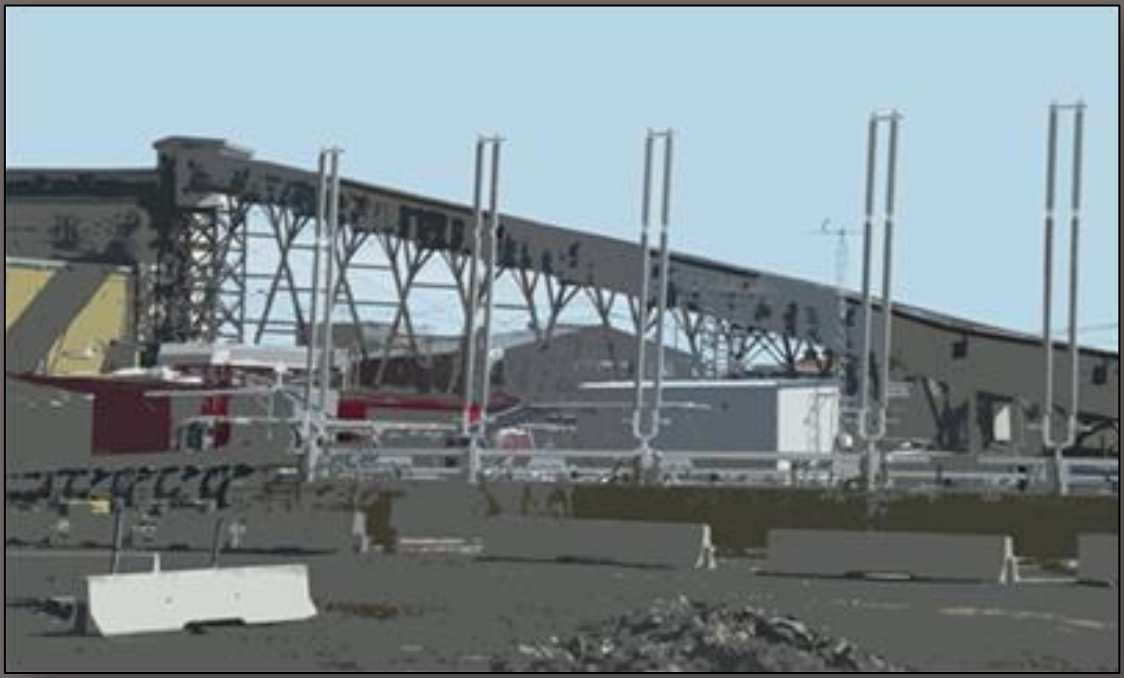
Communicating Danger



A Community Primer on Communicating the Arsenic Hazards at Yellowknife's Giant Mine to Future Generations

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September 2014

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Author Background

Since 2009, the research project, Abandoned Mines in Northern Canada, has studied the social, environmental, and economic impacts of historic mines on Aboriginal communities in northern Canada. The work has been funded by the Social Sciences and Humanities Research Council of Canada (SSHRC) and conducted by independent scholars based primarily in the Departments of History and Geography at Memorial University, with co-investigators at the Universities of Winnipeg and Manitoba. Our research has focused on the study of archival documents and oral history research related to five major case studies:

- Giant Mine, NWT;
- Port Radium/Eastern Great Bear Lake District, NWT;
- Pine Point Mine, NWT;
- Keno Hill Silver District, Yukon;
- Labrador/Quebec Iron-ore District.

In 2012 we received funding from SSHRC to expand our work on Giant Mine as part of the new **Toxic Legacies Project**. Specifically, we have formed partnerships with local groups such as Alternatives North and the Goyatiko Language Society to produce publically accessible material (videos, reports, films, etc.) on the history of Giant Mine and how to communicate with future generations about the long term legacies of arsenic at the site. This report was co-produced by the researchers at Memorial University in partnership with Kevin O'Reilly of Alternatives North (a coalition of social justice and environmental groups in Yellowknife). For more information, please visit our website.

Summary: Communicating with Future Generations at Giant Mine

The Giant Mine Remediation Plan proposes to freeze 237,000 tons of toxic arsenic trioxide dust where it is currently stored underground. It is likely that water pumping, monitoring, and maintenance at the site will be necessary for a very long time to prevent the arsenic from seeping into the local environment. The recent environmental assessment of the project requires ongoing research into a permanent solution to the arsenic problem at Giant Mine within a 100 year time frame. Despite this, a century is a very long time (people have forgotten about toxic sites over shorter periods), and there is no guarantee that technology can be developed to safely remove all arsenic from the site.

A system to communicate with future generations about the arsenic hazards will reduce the risk people will forget about the site. Such a system should have two goals:

- To warn future generations about the hazards from arsenic at the site
- To ensure future generations have all required information to properly maintain the site (and also the knowledge to not damage existing equipment such as the thermosyphons).

Designing such a communication system involves many challenges. One of the most difficult is to imagine who your audience might be. What languages will they speak? What level of technical knowledge will they have? Will they have the resources to maintain the site?

A great deal of work has been done on communicating with future generations at nuclear waste repositories; there is consensus that the "unknown audience" problem can best be addressed by having lots of different types of messages such as simple pictures, monuments, small markers, simple text, detailed text and complex technical archives. Some have also suggested that oral traditions and stories can be as effective, or more effective, than written messages in passing information from generation to generation.

At Giant Mine, a messaging system might involve simple warning signs and text messages imploring people not to damage the thermosyphons, with more detailed technical information on how to replace this equipment when necessary and maintain other facilities such as the water treatment plant. Unlike nuclear waste, it is possible that the arsenic threat might be removed within a relative short period of time (a matter of decades rather than the centuries it takes for nuclear waste to decay), so the emphasis might be on "relaying" information on how to maintain the site to people roughly a century from now.

Much of the work on communicating with future generations in the field of nuclear waste was completed by experts, but we suggest that a community working group would provide a crucial forum for input on the issue from residents of Yellowknife, Ndilo, and Dettah.

Background: Why Think about the Future?

For a more than a century, the production of energy, materials and industrial products throughout the globe have produced large quantities of chemical and radioactive waste. Toxic material may be released through many means, including the production of waste rock (often laden with toxins such as heavy metals) during mining processes, chemical waste during factory production, or the production of radioactive waste associated with nuclear energy. At many former industrial sites (or current nuclear waste repositories) dangerous waste products will persist for centuries, in some cases forever. These places raise questions about how we can communicate with people in the distant future about how to avoid toxic hot spots, or maintain them over long periods of time so they do not become dangerous.

Giant Mine is one of these long term hot spots, a site where toxic legacies may persist for centuries, if not forever. The current Giant Mine Remediation Project will freeze 237,000 tons of stored underground arsenic as a means to reduce the threat of toxic material escaping through groundwater or into the air through inadvertent drilling. The plan also calls for highly contaminated soils and the roaster complex demolition materials to be frozen in the bottom of a pit, above one or more arsenic chambers. The original plan of the two project proponents—Aboriginal Affairs and Northern Development Canada (AANDC) and the Government of the Northwest Territories—was to leave this material underground for all time.

The project has raised questions about how to communicate with future generations about the long terms hazards and perpetual care requirements at the site. The recent environmental assessment required that the Giant Mine remediation team think of the "frozen block" method as an interim rather that permanent solution to the arsenic problem, with a mandate for further research that might reveal a way to remove or otherwise neutralize the toxic threat within a one hundred year time frame. Whatever the future holds for Giant Mine—permanent frozen blocks of arsenic beneath the ground or removal of the material within a century—the long term nature of the project suggests a moral responsibility and practical management challenge to ensure that future generations have the knowledge they need to care for the site, and are warned of the dangers that exist at the surface and underground. There is also a commitment, now legally binding upon the project, that a perpetual care plan be developed for the long-term care and maintenance of the site.

This report will highlight work that has been done on communicating with future generations about the hazards at permanent nuclear waste repositories, primarily at the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico, since the 1980s. It will suggest how these lessons could be applied in the Giant Mine remediation project, raising key issues about imagining the future in the Yellowknife region and how the nuclear waste issues might be applied to the slightly different issue of long term arsenic storage. It is meant as a community "primer" on the issue of communicating with future generations, with the hope that residents of the City of Yellowknife and Yellowknives Dene First Nation, along with the federal and territorial governments, can apply lessons learned from WIPP to their own plans for perpetual care and the transfer of knowledge to the near and potentially distant future.

The report was produced by the "Toxic Legacies Project," a Social Sciences and Humanities Research Council (SSHRC) funded research partnership that includes Memorial University, Lakehead University, Alternatives North, and the Goyatiko Language Society. We have prepared the report as backgrounder for local workshops and a local working group we are facilitating in order to develop a community-based strategy for communicating with future generations about the Giant Mine site.

Communicating with Future Generations: What are the Issues?

Imagine Yellowknife in the year 2115, or even 3015. What would the city look like in a century or 1000 years' time? Would it be bigger than today or smaller? What kinds of economic activity would sustain the city? What will the climate, vegetation and wildlife be like? Will people still drive cars and fly planes, or will energy scarcity in the future mean a return to older forms of transportation technology? Will people still carry wireless devices, or will human communities in the Yellowknife area be largely cut off from communication with the global village as they have been in the past? What languages will people speak? Will they still be part of the country that is today called Canada? And the big question, of course, is whether people will still live in the Yellowknife area at all nearly four centuries from now.

The answers to these questions are difficult if not impossible to determine, and certainly point to the challenge of trying to communicate long term dangers and perpetual care requirements across generations. The future is, in effect, a moving target: we don't know much about the audience to whom we are sending messages.

This is not to say we shouldn't try. Though there have been some dissenting opinions about costs versus potential risks of communicating hazards across generations at supposedly secure underground nuclear repositories, few would suggest that the enormous amount of toxic material at Giant Mine represents a low level of risk. Given all the attention focused on Giant Mine today, it may seem unlikely that the underground arsenic could be forgotten. Nonetheless, people have lost track of major toxic dump sites established in the early to mid-twentieth century, with disastrous consequences as people build on, drill into, work in, or play on lands that have been contaminated decades previously. Even a few high profile examples of partially or wholly forgotten toxic sites suggest the potential for disaster: the infamous Love Canal, NY, where chemical waste dumped by Hooker Chemical 1940s was rediscovered in the 1970s beneath suburban homes and schools built in the 1950s; the city of Carson, CA (near Los Angeles) where 285 houses built on the Carousel Tract sit on top of a decades-old for gotten oil dumping site formally used by Shell; and the Spring Valley neighbourhood near Washington, D.C., where a large chemical weapons production facility was closed after WWI and quickly forgotten, only to be rediscovered in 1993, with cleanup efforts in the now-residential area continuing to the present day. Closer to Yellowknife, there is at least one prominent example of institutions forgetting in a short period of time. The Northern Frontier Visitors Centre in Yellowknife is built on discontinuous permafrost, so the building design required the use of piles in the ground that needed to be kept frozen. Over a 20 year period, with successive managers, the knowledge of keeping the foundation frozen was lost and the building now requires extensive repairs.

If Giant Mine becomes a long term perpetual care site, the challenges of communicating the hazard across multiple generations becomes much greater. Not only does the possibility of political instability increase the likelihood of a breakdown in management of the site, but it is far from certain that people hundreds, or even thousands of years in the future will understand messages we send. We know that languages shift over time; Old English from even 500 years ago is extremely difficult to follow for people today. The meaning of many monuments left by ancient societies – the Serpent Mounds in Ontario come to mind here – has been lost over time.

At Giant, any forgetting or loss of continuity in the environmental management of the site could produce a range of problems. Drilling, inadvertent intrusion into the mine works (through digging, mining or opening of old tunnels), and large-scale mining could result in local arsenic contamination or damage to freezing and water pumping systems. Over long periods of time people may forget the purpose of the thermosyphons (though they are themselves a kind of marker or monument to the future), and may damage them or fail to maintain them. All of this could result in a worst case scenario at Giant: melting of the frozen blocks and failure of water pumping and treatment facilities, producing flooding and seepage of arsenic from underground chambers. Although the government has pointed out it will take twenty or more years for an individual frozen chamber to melt, without active management or intervention the arsenic will eventually seep out and contaminate local groundwater and surface water for very long periods of time. As arsenic is tasteless and odourless, contamination of the local water could occur without people in the future knowing, especially if they have also lost the knowledge necessary to monitor the release of toxic material. Even if people no longer inhabit the area around Yellownife (assuming, perhaps, a very long-term scenario) the impact on wildlife on the land and in water could be catastrophic. How can governments and the Yellowknife community guard against such releases of toxic material from underground repositories over potentially long periods of time?

Lessons from Nuclear Hazards: The Waste Isolation Pilot Plant

Although there are thousands of chemical waste sites globally that present similar long term perpetual care issues, our survey of the literature revealed almost no planning for communicating these challenges to the future. The issue has received a much more thorough airing, however, in the field of nuclear waste management. From the 1980s to the 2000s, the United States Department of Energy (DOE) engaged in a wide ranging discussion of how to communicate with future generations at the world's first permanent nuclear waste repository, the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico. WIPP was built in the 1980s and opened in 1999; the DOE has since drawn on a wide range of expert advice to produce a comprehensive plan on communicating the hazards at WIPP up to 10,000 years in the future (the time period over which the radioactivity of the waste will decay). The plan will be implemented when the WIPP is finally sealed in approximately 75 years. Although these plans are not without problems, and have been subject to criticism by journalists, activists and scholars, there is still much we can learn from the WIPP experience.

The most important general lessons can be summarized as follows:

- At any given long term waste site, **systems meant to directly deter intrusion or interference such as guards, fences, gates, etc. (what experts terms Active Institutional Controls, or AICs) are likely to collapse in roughly 100 years** due to failures of funding and governance structures;
- More likely to be effective are **deterrents to intrusion that do not require maintenance**, generally warnings that use **signs, symbols, and text**, with more detailed information held in an archive (these are called Passive Institutional Controls, or PICs);
- Plans to communicate with future generations should include **some imagining of what that future might be like** so as to best determine what kinds of intrusion threats different futures might present;
- Because it is difficult to imagine the future, however, plans to communicate hazard over a long period of time should rely on **multiple ways of conveying danger** (text, images, multiple languages, monuments, stories and oral traditions, etc.) organized into a coherent system of communication.

This report will highlight all of these issues, providing background and ideas for approaches that might be adopted or adapted to the circumstances at the Giant Mine site. The report will begin with a discussion of key differences between nuclear repositories and the dangers of the underground arsenic repository at Giant Mine. It will then briefly describe the general issues and threats associated with the different future scenarios imagined in the WIPP project. Most importantly, the report will describe the specific plans for communicating with future generations about the hazards at WIPP, and point in a general way to how a similar system of layered message might be developed for Giant Mine. Finally, the report touches very briefly on some of the practical challenges that must be considered when actually implementing plans to commemorate hazardous sites for future generations.

Arsenic Versus Nuclear Waste: How the Material Can Shape the Message

At first glance, the arsenic problem at Giant Mine seems very similar to that of long term nuclear waste storage. In both cases, large amounts of toxic material are stored underground, potentially over unimaginably long periods of time, and in both cases inadvertent or intentional human-caused disturbance at the site (drilling, mining, intrusion, etc.) could result in the release of toxic material into the surrounding environment. On this basis alone, we think the work done at WIPP is relevant to the Giant Mine arsenic issue.

However, there are significant differences between the problems of storing nuclear waste over the long term that will need to been taken into account when thinking about communicating the arsenic hazard to future generations. While it is not possible to foresee all problems and future issues, there are several clear distinctions between the radioactive and chemical dangers at WIPP and Giant Mine:

- Nuclear waste breaks down over time, allowing regulatory authorities to target communication strategies to particular end points in time (1000-10,000 years), whereas the arsenic at Giant Mine will remain a potential threat for all eternity if new technology does not allow for a more permanent solution to the problem;
- The US Department of Energy chose the site of the WIPP repository with an eye to minimizing threats from groundwater and geological instability; Giant Mine's underground arsenic was deposited through a somewhat haphazard arrangement between mine officials and federal bureaucrats in 1951, with almost no assessment of threats from groundwater or geological instability (cracking in chambers, leakage, etc.);
- According to proponents, nuclear waste sites such as WIPP do not require perpetual care or monitoring once they are sealed, whereas the arsenic repository at Giant will require some form of human intervention for all of eternity (barring new technologies that can remove the arsenic threat), including water pumping and periodic replacement of the thermosyphons;
- Radioactivity would spread immediately from WIPP if there is any serious physical breach of the repository containment structure, whereas a breach of the frozen arsenic blocks would only represent a potential threat if the blocks had thawed, and if groundwater enters the site (along with the failure of the water treatment system), or if dry arsenic dust were removed from or mobilized at the site.

These four points have broad implications for the creation of long term communication strategies at Giant Mine.

First, we do not know how far forward in time futures communications about the Giant site should be targeted. Is it a very, very long time (i.e., forever, assuming no technology is developed to fully remediate the underground arsenic problem)? Or is it one hundred years into the future, with the idea that messages created today should urge people a century from now to develop new communications strategies that reflect the state of the site and remediation plans at that time (or, in the best case scenario, the arsenic problem is solved in the near future so no communication is necessary)? Or is it best to try to develop both types of communications now?

Second, as noted above, the WIPP communication strategy is focused squarely on stopping inadvertent intrusion, with technical knowledge transferred in archives primarily so that future societies can dig up the nuclear waste and use technologies to process the material as an energy source or transform it into a more benign form. While that latter point can clearly be applied to Giant, the perpetual care requirements associated with the arsenic chambers suggest the issue is less one of sealing off the site and hoping nobody intrudes, but ensuring that knowledge about these care requirements is passed as clearly as possible from one generation to the next. As noted above, the more passive nature of the nuclear waste threat allows for a communications strategy for WIPP focused on warning signs, symbols, monuments and text, some of these even to be buried underground as a layered defence against anyone trying to breach the repository. At Giant, where site intrusion likely represents less of a danger (because arsenic does not spread in the same way as radiation), the emphasis might be placed more on archives, technical documents, and simpler messages that ensure the perpetual care requirements are never forgotten as long as the arsenic remains a threat. In short, **WIPP officials hope to warn people in the future away from the repository site, while at Giant Mine local communities have no option but to *live with* a toxic site, potentially exposed to its hazards for decades to come. The close proximity of Yellowknife, Ndilo, and Dettah to Giant Mine highlights the importance developing communication systems that allow the communities to manage and co-exist with the threat of a toxic waste repository over multiple generations.**

Thinking about the Future: Different Scenarios

Impossible as it may be to peer into the future, during the WIPP process the Department of Energy organized several expert teams to imagine future scenarios for the southern western region of the United States. These teams considered everything from future political configurations—with some even imagining New Mexico joining a new state with the northern parts of Mexico—to the likelihood of non-renewable resource extraction proceeding at the WIPP site.

When imagining a future scenario for Giant Mine, at least some consideration should be given to possible social, technological, environmental, and economic changes that might occur. These in turn help to identify the potential threats to guard against. While the Giant Mine Remediation Team did provide modelling data for the impact of climate change on the frozen blocks, environmental changes are only one among myriad threats that future changes might bring to the site. For instance, is it possible that future societies might identify remaining gold deposits or other previously unvalued resources as economically valuable at any point in the distant future, leading to drilling or digging at the site? Will political change mean Canada no longer exists as a country? How then can knowledge of perpetual care requirements or funding remain intact for maintenance activities at the Giant Mine site?

In the nuclear waste field, three broad futures have often been discussed in terms of the different level of threat they represent to a repository:

1. Western society transforms back to a low technology society based on hunting, gathering and small scale agriculture, reducing threats to the repository almost to nothing as no means to drill or dig underground exits (though such societies would be extremely vulnerable if the repository were breached in some unforeseen way);
2. Western society declines to roughly 19th century levels, with the technological ability to breach underground repositories through mechanized digging or drilling, but without the technical knowledge of the nuclear waste threat or how to mitigate damage from any breach of the repository;
3. Western society maintains high levels of technology, able to interpret the warning signs and technical documents left in a repository, thus avoiding completely or quickly able to repair any accidental breach.

In the case of arsenic at Giant Mine, the **"low tech" future scenario 1 represents a much more serious threat than in the case of nuclear waste**. If Yellowknife is inhabited by societies that cannot understand the technical requirements for perpetual care and maintenance of the site, the frozen block and water pumping and treatment systems for the site will fail, possibly leading to contamination of the local environment and acute and/or chronic arsenic poisoning of local people, wildlife, and fish. As mentioned above, **future scenario 2 presents a threat if exploration and underground development lead to a breach of the arsenic repositories**, or a **similar breakdown in the frozen blocks as occurs in scenario 1. As with the nuclear waste case, only scenario 3** (the persistence of technologically advanced society) provides reasonable assurance that the Giant Mine site will be maintained (assuming continuity of knowledge across generations).

Undoubtedly, any future changes in Yellowknife will be more complex than the three general scenarios described above. Nonetheless, any planning for a communication strategy with future generations should consider key general questions about the future:

- What are some other general scenarios to consider when thinking about the future at YK/Giant?
- What social or political changes might affect the care and maintenance of Giant Mine?
- How robust are these scenarios, under different time frames (100 years, 250 years, 500 years)?

Methods of Communication

The daunting task of trying to communicate with people in the distant future is complicated by the fact that almost any method used carries some likelihood of failure. To compensate for these weaknesses, the WIPP expert teams concluded that only a system that uses many different types of communication is likely to succeed. If people in the future no longer understand today's languages, they proposed signs, symbols, and monuments will be placed to warn them away from the site. If above ground monuments erode, or are destroyed, underground markers and even an information centre are planned to warn people from intruding in the repository. In addition, WIPP experts concluded that messages should be replicated several times, or repeated in different ways so that the risk from the loss of one marker or information source is offset by the survival of others.

The WIPP expert panels identified a system of communication with five different levels of complexity, from the simple to the more intricate.

- **Level 1 Messages**: These are meant to grab people's attention and to let them know something that is potentially significant at the site. At the design stages of WIPP experts imagined a variety of spike fields, or a sculpted landscape of "menacing earthworks." The final design included 32 large vertical monuments at the outer perimeter of the site, a berm and 16 additional monuments marking footprint of the underground repository. Buildings such as an information centre and the leftover "hot cell" facility will also convey the message that there is something potentially important about this site.
- **Level 2 Messages:** These are simply messages meant to convey the idea of danger. They may include symbols and signs, and possibly simple text messages that warn of the danger of digging, intrusion, drilling, etc. At WIPP these types of messages will be engraved on the large surface monuments and on small subsurface disk markers.
- **Level 3 Messages:** These are more complex messages, often a combination of images and text that provide information on the precise danger at the site, the location of underground workings, the size of the site, and where to avoid disturbing the ground. They also may convey when the nuclear waste was buried and how long it should remain undisturbed. At WIPP these types of messages will also be engraved on the large surface markers.
- **Level 4 Messages:** These messages contain a high degree of complexity. At WIPP aboveground and underground information centres are planned that will include detailed information on the precise nature of the radioactive material, potential leakage pathways, the time period of its decay, the geological features and layout of the repository, the impact of radioactivity on human health, maps of other nuclear repository sites, and some detailed technical information on how and why the waste was generated.
- **Level 5 Messages:** These are archives which contain technical summary manuals and if possible as complete a documentary record on the site as possible. This is a final stopgap measure that gives future societies with sufficient technology the possibility of responding to any problems or finding a permanent solution prior to the 10,000 year decay period.

For each of these levels of communication, there are challenges and pitfalls that must be considered, particularly the questions of whether the messages will be understood, and whether they will last. While it is difficult to provide an exhaustive list of potential concerns, throughout the many WIPP reports the following key issues arose:

- Will large-scale monuments *attract* rather that warn people away from the site?
- Will future societies understand the symbols employed as signs of danger, especially considering how the meaning of signs such as the skull and crossbones and the swastika have changed very rapidly within our own time?
- What languages should be employed at the site and how can we account for the fact that languages change rapidly over time (i.e., the English spoken in the 14th century Canterbury Tales is difficult to understand today)?
- What materials should be used to construct monuments and signs at the site?
- What media should be used to preserve archival records about the site?

These issues were addressed through several measures and conceptual design approaches for the site:

- For the first two questions, the potential for misinterpretation was addressed through the idea of a system of different signs, symbols, and text, with the hope that people in the future might understand at least one of them;

- For languages, WIPP experts decided to use the six official United Nations languages (English, Spanish, French, Russian, Standard Chinese, and Arabic) and also Navajo to address the local First Nation in the region;
- Textual messages should include a "relay statement" asking people in the future to translate text if it starts to seem archaic and hence become difficult to understand;
- After several studies of what materials might prove most durable at the site, experts identified granite as the most long-lasting of rock types, though various types of cement could also be used;
- Marker messages should be engraved directly rather than mounted on plaques (which could be removed) or painted (which would not last long enough);
- Records should be kept on the most durable forms of paper; other technologies such as microfilm are subject to decay and digital technology undergoes rapid format changes over time (try finding a machine in which to insert a floppy disk!).

If you would like to see some of the images and textual messages that the various WIPP artists and conceptual teams developed at various stages, there are three online collections (web addresses are also in the source list at the end of the document):

- **First WIPP Web Page http://www.wipp.energy.gov/PICsProg/articles/WIPP%20Exhibit%20Message%20to%2012,000%20A_D.htm**
- **Early conceptual images for permanent markers and symbols – prior to 1996 (click on the "early concepts" image [a field of spikes] to download the collection at http://www.wipp.energy.gov/picsprog/pics_images.htm)**
- **Conceptual Design Drawings http://www.wipp.energy.gov/PICsProg/Test1/Conceptual_PM_design_images.pdf**

One issue that WIPP experts dismissed was the use of oral tradition, suggesting that stories, legends and myths were too subject to change over time to be a reliable means of intergenerational communication. Yellowknives Dene First Nations members (and indigenous people more broadly) have a different perspective, however, suggesting that oral tradition has been a primary and reliable means of passing knowledge from generation to generation for thousands of years in their communities. As the next section suggests, there are other issues arising from the local realities and context for any strategy to communicate with future generations at Giant Mine.

Implementing a Strategy at Giant Mine

As noted above, the arsenic problem at Giant Mine is a unique product of local geology, the pollution control methods used at the mine, and the decision to store arsenic trioxide dust underground with little thought for short- and long-term consequences. The ground under Giant Mine became a long term toxic waste repository without any input or decision making power from those who live in and near Yellowknife. In a similar way, the arsenic on site has the potential to threaten future generations who had no part in the decision to store the material underground, and no part in the decision to freeze the arsenic chambers, possibly for all time.

A well-planned strategy to communicate the presence of underground arsenic, and to ensure knowledge about the perpetual care requirements persists across generations, offers at least some hope that actions today can minimize the burden that Giant Mine places on the people of the near and distant future. As development of the communication strategy moves forward, there are several key issues that specific to the arsenic problem, Giant Mine, and Yellowknife, that should be addressed. We suggest the following points and questions for consideration:

- No matter how many warnings are placed at the Giant Mine site, there is no escaping the fact that the frozen block, water pumping, and water treatment systems will fail if the funding and knowledge necessary to maintain the site are disrupted;
- The strategy to communicate with future generations should therefore be intimately tied to perpetual care planning, and needs to focus more on the issue of *transferring knowledge over time* rather than simply abandoning the repository with warning signs;
- The issue of long term funding is central to perpetual care funding and a strategy to communicate with future generations, and may require special arrangements such as a trust fund (Measure 6 of the Giant Mine Remediation Project environmental assessment mandated investigation of long term funding options while Suggestion 5 recommends the creation of an independent trust fund to provide multi-year funding);
- The potential long-term nature of the arsenic problem may require novel institutional arrangements, possibly a some sort of stewardship foundation that provides an alternative site management authority to the potential instability of governments and funding;
- The perpetual care requirements at Giant suggest that the preservation of records and technical manuals, along with simpler messages that highlight how to maintain the site, may be more important than warnings signs and symbols;
- The clusters of thermosyphons will already form a series of monuments (a bit like the spiky fields mentioned above) and some thought on how to communicate the purpose and maintenance requirements of these features is critical;
- Several WIPP experts proposed the idea of a “nuclear priesthood” a quasi-religious institution that would develop rituals and rites devoted to communication of radioactive hazard. Should similarly novel institutional arrangements be part of the strategy to communicate with future generations at Giant Mine?
- Given the First Nations cultural context, how can oral tradition and local languages be mobilized as part of the strategy to communicate with future generations? What myths, legends, and stories could be developed to help warn people about the dangers and the necessary care requirements at Giant Mine?
- While the WIPP experts thought in terms of communicating with people over vast time periods (up to 10,000 years), does the perpetual care scenario at Giant suggest a relay system, where communications strategies focus on 100-200 year time periods, with explicit instructions to adapt and change the communications system as circumstances change?

These questions and issues represent a daunting challenge that reflects the magnitude and complexity of the arsenic threat at Giant Mine. Because of this, we do not provide a prescriptive roadmap for communicating with the future. Although the WIPP process was driven by expert knowledge, we believe that the Giant Mine strategy should be developed through a community-based process that accounts for the diverse interests in the Yellowknife region (First Nations, Métis, municipal government, concerned citizens, etc.). We envision a working group that will identify key issues and possible pathways forward on the issue communicating with future generations. As a starting point, we suggest that the working group consider adopting a four stage process that addresses the following issues:

1. Envision future scenarios, with an emphasis on social and political conditions;
2. Highlight problems, challenges and issues related to methods of communication for explaining the toxic threat of Giant Mine to future generations;
3. Consider key messaging strategies as part of a system of communication for Giant site;
4. Propose an implementation strategy for the Giant Mine messaging system.

In turn, the implementation of this strategy will require “buy in” from federal government (and possibly territorial government authorities) who can mobilize expertise (designers, engineers, etc.) and funding.

Helpful Sources (Accessible web sources are hyperlinked)

Analytic Sciences Corporation, Kaplan, Maureen F. 1982. *Archaeological data as a basis for repository marker design.* United States Department of Energy, Battelle Memorial Institute, Office of Nuclear Waste Isolation.

This is an early report that discusses the potential for ancient monuments to guide the process of creating markers for nuclear waste repositories. The report discusses six ancient monuments: The Egyptian Pyramids, Stonehenge, the Marco Lines (Peru), the Serpent Mound (Ohio), the Acropolis, and the Great Wall of China.

Andrew Moisey. 2012. Considering the desire to mark our buried nuclear waste: Into eternity and the waste isolation pilot plant. *Qui Parle* 20 (2): 101-25.

This is a really well written article comparing some of the approaches to communicating with future generations at WIPP with the issues raised (or not raised) in the film *Into Eternity*. The article highlights why the engineers at the Onkalo deep geological nuclear waste repository did not develop an extensive communications strategy in the same way as at WIPP.

Benford Gregory, Kirkwood C.W., Otway H., Pasqualetti M.J. 1991. Ten thousand years of solitude? On inadvertent intrusion into the waste isolation pilot project repository. Los Alamos National Laboratory: Los Alamos, New Mexico.

This is a standalone version of Benford's future scenario team—the Southwest Team—and their conclusions on future societies and their potential to intrude on the WIPP. The report is reprinted as an appendix to the large Sandia report, Expert Judgment on Inadvertent Human Intrusion into the Waste Isolation Pilot Plant (see below).

Benford, Gregory. 1994. Comporting ourselves to the future: of time, communication and nuclear waste. *Journal of Social and Evolutionary Systems* 17(1): 91-113.

Highly readable account of Benford's time spent working on one of the Future Scenarios panel set up to imagine what kind of society might exist in the area surrounding the Waste Isolation Pilot Plant (WIPP) 10,000 years into the future.

Benford, Gregory. 1999. *Deep time: How humanity communicates across millennia*. New York: Avon.

Benford's popular book on communicating with future generations, with part of the focus on WIPP and messaging radiation hazards to future generations.

Cruickshank, Douglas. 2002. How do you design a "Keep out!" sign to last 10,000 years? *Salon* (May 10, 2002).

A journalistic account of monument proposals for WIPP and Yucca Mountain, the author adopts a cynical tone describing the initiatives as "nutty" and "kooky."

Enviromental Protection Agency. 1996. Passive Institutional Controls. CARD No. 43. AND Compliance Recertification Application for the Waste Isolation Pilot Plant Passive Institutional Controls (40 CFR § 194.43)

These two reports reflect EPA's assessment of the WIPP markers plans. The report does have some criticisms of the plan, particularly the fact that success cannot be assured.

Evans, David, Mike Stephenson, and Richard Shaw. 2009. The present and future use of 'land' below ground. *Land use Policy* 26, Supplement 1(12): 302-16.

A broad conceptual article about the use of underground space as storage areas, it contains little on communicating hazards to future generations. The article does help put the underground storage of arsenic at Giant Mine into some kind of context with respect to other similar initiatives throughout the globe.

Eysler, Adriana. 2006. Here be monsters. *Eye Magazine* (62).

A short article that asks why no graphic designer was ever appointed to the various panels that considered communicating hazard to future generations at WIPP.

Givens, David B. 1982. From here to eternity: Communicating with the distant future. *Et Cetera* (39): 159-79.

Givens was a member of the task force commissioned by the U.S. Department of Energy to design a communication system to warn of the nuclear hazards at WIPP. The article provides a good overview of the key issues and the task force's main approaches to the issue.

Hart, John and Associates. 2004. *Passive Institutional Controls Implementation Plan. Waste Isolation Pilot Plant Carlsbad, New Mexico.*

This is a broad planning document on implementation of the full suite of communication strategies, or PICs, at WIPP. The report covers not only permanent markers, but issues such as archival material, records management textual message, the information center, etc. The document also describes a testing program for the PIC plan.

Hart, John and Associates. 2004. *Permanent markers implementation plan. Waste isolation pilot plant Carlsbad, New Mexico.*

This report outlines in great detail the final plan for permanent markers at the WIPP. It includes many drawings, blue prints, and final design details for the messaging system developed for the site.

———. 2000. Ancient cementitious materials. *Waste Isolation Pilot Plant Carlsbad, New Mexico.*

Broad ranging report on whether concrete would be comparable or even better than granite as a base material for engraving messages to the future. The reports concludes that some types of concrete have lasted up to 9000 years, and that a blending of old and new technologies offers potential.

———. 2000. *Permanent markers materials analysis. Waste Isolation Pilot Plant Carlsbad, New Mexico.* Carlsbad, NM.

This report specifies that granite is likely the most durable base material for permanent makers, though concrete mixed with fly ash also has potential

———. 2000. *Permanent markers monument survey. Waste Isolation Pilot Plant Carlsbad, New Mexico.*

The report highlights monuments and images from the past (especially petroglyphs) and evaluates their potential to communicate with future generations.

Hora, Stephen C., and Detlof Von Winterfeldt. 1997. Nuclear waste and future societies: A look into the deep future. *Technological Forecasting and Social Change* 56 (2) (10): 155-70.

This is a useful summary of the Sandia Human Intrusion report noted below. Some of the report veers into improbable scenarios such as a battleship full of returning human warriors crashing into and/or firing lasers at the WIPP cite. The report also mention the possibility for a fictional character such as "Mickey Nuke" to provide warnings about the site over many generations.

Human Interference Task Force. 1984. *Reducing the likelihood of future human activities that could affect geologic high-level waste repositories: Technical report*. Prepared for the Office of Nuclear Waste Isolation, Battelle Memorial Institute.

Along with Sebeok's report below, this is one of the most important early reports to come out of the U.S. Office of Nuclear Waste Isolation. The report ranges widely, discussing future scenarios, systems of communication, and specific ideas for monuments and text messages.

Jensen, Mikael. 1993. Conservation and retrieval of information: elements of a strategy to inform future societies about nuclear waste repositories. Nordic Committee for Nuclear Safety Research, Nordic Council of Ministers.

This is a comprehensive survey of the issue for the Scandinavian context. This broad ranging report focuses on some of the same issues as the U.S reports, but also contains the most comprehensive survey of the issues associated with establishing archives related to nuclear waste repositories.

Kaplan, Maureen, and Adams, Mel. 1986. Using the past to protect the future. *Archaeology* 39(5) (Sep): 7-8.

Considers what symbols and monuments from the ancient past serve as good models for communicating across generations. Kaplan was a member of the Human Interference Task Force and the WIPP marker panel.

Lomberg, Jon, and Stephen C. Hora. 1997. Very long term communication intelligence: The case of markers for nuclear waste sites. *Technological Forecasting and Social Change* 56(2)(10): 171-88.

Lomberg is an artist who served on one of the WIPP panels tasked with designing markers for the site. Hora served on the expert panel that assessed the viability of each team's proposals (see Trauth et al. below). This article provides an excellent summary of the basic approach to communicating with future generations at WIPP and several of the images used in the marker design process.

Mann, W. B. 1986. Identification of nuclear-waste sites over ten millenia. *Nuclear and Chemical Waste Management* 6(2): 95-100.

This brief editorial is highly critical of the efforts to communicate the hazards of nuclear waste at WIPP to future generations. The author argues that the risk from nuclear waste is minimal and that if human societies survive, there are likely to be nuclear scientists who can solve any problems that emerge.

McKinley, I. G., and R. Munier. 2003. Discussion of "In absurdum: Long-term predictions and nuclear waste handling": By N.A. Mörner (vol. 61, pp. 75–82). *Engineering Geology* 68(3–4) (3): 401-3.

A criticism of Mörner's work, the two authors argue that long term monitoring for deep waste repositories is not possible, and seismic disturbance unlikely at extreme depths.

Mörner, Nils-Axel. 2001. In absurdum: Long-term predictions and nuclear waste handling. *Engineering Geology* 61(2–3)(8): 75-82.

The author argues that projecting safety scenarios for underground waste repositories over thousands of years is absurd because even the most extreme events—such as seismic shifting—are likely to occur within that time frame.

Nolin, J. 1993. Communicating with the future: implications for nuclear waste disposal. *Futures*, *25*(7), 778-791.

This is a conceptual academic article that does contain some information on the Swedish context.

Sandia National Laboratories. 1991. *Expert judgment on inadvertent human intrusion into the waste isolation pilot plant.*

Authored by Stephen Hora, Detlof von Winterfeldt, and Kathleen Trauth, this report focuses on the work of the futures scenarios panels, and makes recommendations for the WIPP communication system based on various possible forms of human intrusion at the site.

Sandia National Laboratories. 1993. *Expert judgment on markers to deter inadvertent human intrusion into the waste isolation pilot plant.*

Authored by Kathleen Truath, Stephen Hora, and Robert Guzowski, this large report incorporates the findings of the futures scenarios panels and develops many recommendations for the messaging system at WIPP. The report provided the most important concepts for the design of the messaging system.

Sandia National Laboratories. 2002. *WIPP case study - compliance monitoring, passive institutional controls, and record keeping*. Washington, D.C; Oak Ridge, Tenn.

While this report gives an overview of the entire messaging system proposed for WIPP, the emphasis is on record keeping, particularly the creation of on-site and off-site archives containing technical information about the site.

Sebeok, Thomas Albert. 1984. Communication measures to bridge ten millennia: Technical report. BMI/ONWI-532. Prepared by Research Center for Language and Semiotic Studies, Indiana University, Office of Nuclear Waste Isolation, Battelle Project Management Division.

An early and very significant public report on the issue of communicating the hazards of underground nuclear waste repositories, this document highlights now standard concepts such as the importance of message redundancy, the difficulty of interpreting visual images over long time periods, and the possibility of a relay system for messaging from generation to generation. Sebeok noted some advantages to using legends and rituals to communicate hazard, and was the first to suggest that an “Atomic Priesthood” might also be the best means to ensure continuity of knowledge about nuclear waste repositories. Sebeok is a linguist and was a key member of the Human Interference Task Force, a working group created by the U.S. government’s Office of Nuclear Waste Isolation to consider the issue of marking waste repositories for future generations.

Slaughter, Richard A. 1994. Why we should care for future generations now. *Futures* 26(10)(12): 1077-85.

This article is a very general discussion of the moral dimensions of our relationships to future generations of humans.

Swift, Peter N. Considerations of human intrusion in U.S. programs for deep geologic disposal of radioactive waste. in Sandia National Labs. Albuquerque, 2013.

This is a brief overview of the issue that focuses on regulatory requirements for WIPP.

TallBear, Kimberly. 2001. Tribal social & cultural institutions for long-term stewardship of hazardous sites. Presented at the National Academy of Sciences National Research Council Board on Radioactive Waste Management, Washington, D.C. (April 3rd, 2001).

This is one of the very few (if not the only) paper to deal with Native American worldviews and the issue of long term hazardous waste sites. The paper emphasizes how some Native American groups want to spend time lamenting the damage at contaminated sites, and thus cannot always be as forward looking as governments and regulators seem to want. The paper makes a powerful argument for the use of oral tradition as a means to pass on information about contaminated sites to future generations.

Tannenbaum, Percy H. 1984. Communication across 300 generations: deterring human interference with waste disposit sites: technical report. Office of Nuclear Waste Isolation, Battelle Project Management Division.

This is another in the series of reports on communicating hazard to future generations that came out of the ONWI in 1984. As with the other reports, the document presents key issues and conceptual models for maker systems and other forms of communication with the future.

Tonn, Bruce. 2001. Institutional design for long-term stewardship of nuclear and hazardous waste sites. *Technological Forecasting and Social Change* 68: 255-73.

This is a very useful article assessing the potential for various institutional arrangements to maintain care of hazardous waste sites and communicate their dangers over the very long term. The author suggests that a “sustainability institute” in the non-profit sector—something akin to the Nature Conservancy—might be the best option.

United States Department of Energy. 2000. Permanent Markers Testing Program: Waste Isolation Pilot Plant.

This report includes plans for full testing of the WIPP markers plan using wooden mock-ups of the monuments and messages.

Van Wyck, PC. 2012. An archive of threat. *Future Anterior* 9(2): 53-80.

An overview and analysis of the WIPP site and communication strategy (among many other potentially dangerous sites) from a cultural studies perspective.

Van Wyck, Peter C., and Inc ebrary. 2005. *Signs of danger: Waste, trauma, and nuclear threat.* Minneapolis: University of Minnesota Press, 26.

Much of this book is devoted to the WIPP case study. While thoughtful and useful on many levels, the volume is composed with extremely dense and theoretical academic language.

Waste Isolation Pilot Project. *Early conceptual images for permanent markers and symbols – prior to 1996 (linked direct to document).*

Collection of early ideas for drawings warning future generations of nuclear hazard

Waste Isolation Pilot Project. ***First Web Page. http://www.wipp.energy.gov/PICsProg/articles/WIPP%20Exhibit%20Message%20to%2012,000%20A_D.htm***

An archived version of the first WIPP website on communicating with future generations, the document contains interesting images and text – a good summary of early thinking on the issue.

Waste Isolation Pilot Project. Conceptual Design Drawings. http://www.wipp.energy.gov/PICsProg/Test1/Conceptual_PM_design_images.pdf

This document is a collection of drawings for the final WIPP communication plan.

Weitzberg, Abraham. 1982. *Building on existing institutions to perpetuate knowledge of waste repositories*. Columbus, Ohio: Office of Nuclear Waste Isolation.

The focus of this report is on institutional approaches to preserving records and other forms of information about nuclear waste repositories. The report incorporates information on a variety of themes, including archives, mapping, and the registration of markers with the Geodetic Survey.