DEFINING, DESIGNING, APPLYING AND REFINING RESILIENCY IN NORTHERN WATER INFRASTRUCTURE

By George W. Thorpe, Senior Engineer, BI Pure; and Ken Johnson, AECOM, Senior Planner and Engineer

In spite of the abundance of water in Canada, it can be a scarce commodity, particularly in Northern communities that require a clean source of water year-round. Winter can last eight to 10 months of the year, and in winter, most of the surface water is covered with ice up to two metres thick. The north is also a desert, with most regions receiving less than 250 millimetres of annual precipitation, most of it as snow. Given these fundamental challenges, the supply of community drinking water and wastewater treatment in Nunavut are particularly challenging due to its geographic isolation, extremely cold climate, permafrost geology, extreme costs, limited level of services, and other unique northern community attributes.

These circumstances, as well as additional stressors, can move Nunavut's natural and human systems toward their tipping point and that may trigger extremely large responses. If these systems are networked or interconnected, the impact on them could be even greater.

By relying on a method called "design for resilience", the infrastructure and systems put into place in Nunavut communities can be such as to allow for a quick return to near normal levels of functioning even in cases of severe disturbances. The term resilience, or the ability to bounce back after being disturbed, has been used in many different contexts. However, in this case, it is used specifically to refer to the ability of critical infrastructure to

CALL FOR ARTICLES

2019 edition for the *NTWWA Journal* – the theme water and sanitation practices in remote European communities.

780-984-9085
ken.johnson1@aecom.com

bounce back with reliability and robustness (strength) after a severe disturbance. Critical infrastructure includes processes, systems, and services that could cause death, discomfort, or destruction even if only momentarily disrupted.

A wide range of shocks and stresses can impact critical infrastructure. These events might include damage, loss of power, water, human access, and reduced control of infrastructure due to severe rain, flooding, high winds, lightning, earthquakes, other natural disasters, or even cyber attacks.

In the Arctic, there are additional issues with permafrost thaw, ground slumping, water shortages, distance between communities, and communication challenges. Longer-term climatic influences including sea level rise, floods, higher temperatures, severe storms, less permafrost, lower river levels and lower stored water levels will also have to be considered.

Measuring resilience is one of the most demanding tasks due to the complexity of the processes. Infrastructure and system health after severe disturbances were initially calculated by estimating and managing the risks. Design of infrastructure was thereby limited. Therefore, several years ago, this way of designing critical infrastructure evolved into "designing for sustainability" and has now advanced into a more comprehensive design for resilience.

Using a design for resilience involves combining stakeholder interaction with various engineering skills, as well as taking into account disaster experience, risk management, systems design and strategic planning. A major factor is covering the extra capital cost for these improvements. Some are skeptical about the value of resilience. Can the infrastructure life cycle be extended when integrating higher cost factors such as artificial intelligence, increased design safety factors, and system redundancies?

Figure 1 – Dynamic framework for planning and implementing resilient infrastructure.

Resilience of an engineered system can be improved through dynamic design principles. The science of designing for resilience is key to integrating the factors required for a successful future. It is therefore defined as the strategic design and construction of critical infrastructure systems to sustain required operations during and after the impact of severe disturbances, plus preventing, or adapting to, longer-term influences.

Substantial progress has been made in the science of designing for resilience for southern infrastructure, but to advance an understanding of the best detailed methodology for northern latitudes, major collaboration between institutions and stakeholders is required. Infrastructure resilience isn't easy to spot until after a severe disturbance when the full recovery time is recorded. Each system has a specific value that can be measured, and measuring these values is of key importance.

Design for resilience framework

The most cost-effective manner of achieving infrastructure resilience is by using an integrated set of engineering design guidelines based on collaboration between stakeholders and the use of engineering knowledge in many areas of expertise. The input of local stakeholders is an important part of the process.

Three attributes that can provide a resilient system are: adaptability, integrity, and tolerance. Resilient infrastructure and systems will have: 1) reduced probability of failure; 2) reduced consequences from failures, in terms of lives lost, damage, and negative economic and social consequences; and 3) reduced time for recovery (restoration of a specific system or set of systems to their "normal" level of functional performance). When resilience is not designed and built in, there will most often be no performance of the system or infrastructure after a severe stress, and it will take a significant amount of time to recover.

What is the best methodology for planning for resilience and then building resilience? Figure 1 shows a framework which starts with planning – determining the current threats and hazards and characterizing and analyzing the risks until the resilience options are developed. The plan then needs to have the resilience actions prioritized and implemented. Moving into the building phase, the key is funding these activities, which is a proactive investment for harm reduction. The detailed design for resilience then takes place, followed by construction and monitoring of these improvements in order to learn from the things that went wrong or slowed things down. Refining and improving the loop of planning for resilience and then building for resilience can continue with new knowledge and an improved methodology.

The Canadian Standards Association is working to assist in the improvement of northern infrastructure by providing detailed documentation for designs to withstand a changing climate. The first five standards deal with drainage, permafrost, and snow load. Under development are several more standards covering wastewater and erosion. These standards will assist with the establishment of Canadian infrastructure for an uncertain future.

Conclusion

As the impacts of climate change on the North are increasing in frequency and severity, the new climate reality must be confronted with urgency. The process of accelerating and promoting the establishment of resiliency in the North should:

- Mobilize existing knowledge by teaming up, and collaborating, with stakeholders;
- Research known unknowns with a cross-functional team in order to build capacity;
- Transform existing infrastructure and systems by making funds available for resilience efforts; and
- Build new climate resilient and cost-effective infrastructure.

The design for resilience methodology is advanced enough to allow a theoretical foundation for understanding best practice. It will continue to evolve as it is refined by adapting and applying new scientific practices and knowledge. To achieve northern critical infrastructure resilience goals, experimentation, iterative learning, and discovery by stakeholders is required.