

Automating surface paste backfill reticulation: From routine operations to emergency response



Wayne Johnstone¹,

¹ Victaulic, Sudbury, Ontario P3A5K2, Canada

Received: 2 Dec 2025
Revised: 13 Feb 2026
Accepted: 9 Mar 2026
Online: xx xxx xxxx

KEYWORDS

paste backfill,
hydraulic fill,
cemented rock fill,
reticulation,
diverter valves,
automation,
decision tree,
safety

ABSTRACT

Backfill reticulation systems, whether for paste, hydraulic fill, or cemented rock fill (CRF) require coordinated control of pumps, boreholes, flush water, high-pressure injection, and emergency dump circuits. In many underground mines, these functions are still managed manually, with crews physically reconfiguring piping during routine pours and blockage events. This approach increases downtime and exposes personnel to pressurized systems where confirming a true zero-energy state (ZES) can be difficult. While automation of individual backfill components has become more common, integrated control of surface reticulation networks remains inconsistent across the industry. This paper presents a surface-based automation strategy that centralizes reticulation control using remotely actuated diverter valves combined with a structured operator-driven emergency response plan. At the paste plant, pumps, boreholes, flush water, high-pressure injection, and emergency dump circuits are brought into a single coordinated valve network. Routine functions such as borehole switching and line flushing can be completed from the control room without manual pipe handling. During upset conditions, a Trigger–Action–Response Plan (TARP) guides operators through defined steps based on pressure response, flow behavior, and pour point observations. When paired with remote valve actuation, this approach enables rapid isolation, controlled flushing, or emergency dumping while keeping personnel clear of pressurized lines. Using operating examples, the paper demonstrates how surface-level reticulation automation reduces intervention time, improves response consistency, and strengthens verification of safe isolation. The findings suggest that starting automation at the paste plant provides a practical foundation for safer, more reliable backfill operations.

Address correspondence to Wayne Johnstone: wayne.johnstone@victaulic.com

© The author(s) 2026. The articles published in this open access journal are distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>).

1 Introduction

Paste backfill systems are now widely used in underground mining to manage tailings while providing ground support and improving operational efficiency [1]. Backfill reticulation—the distribution system—is one of the most critical systems in an underground mine. It must deliver paste safely, reliably, and with enough capacity to keep up with production demands. Yet in many operations, routine tasks such as switching pumps, changing boreholes, or flushing lines still rely on manual effort and local valve handling. These practices slow production and expose workers to unnecessary risk.

Advances in surface plant automation are changing that. Incorporating diverter valves at the surface makes it possible to bring multiple pumps, multiple boreholes, high-pressure water injection, flush-water control, and paste delivery into one coordinated network. With all major reticulation functions managed from the surface, operators gain safer, faster, and more consistent control of the backfill system. This paper describes how that approach improves safety, shortens downtime, and sets the foundation for future intelligent backfill networks.

2 System overview—integrating surface plant automation

Traditional backfill reticulation systems still depend on manual valve changes and physical reconfiguration between pours or during upset conditions. These tasks require multiple workers, lifting equipment, and the movement of heavy elbows—sometimes under residual pressure. The result is a process that is slow, physically demanding, and difficult to complete under a confirmed zero-energy state (ZES).

Modern surface paste plants take a different approach. A centralized, automation-ready valve network manages all major functions—paste pumping, borehole selection, high-pressure water injection, flush-water delivery, and emergency dumping—through a common diverter-valve bank at the surface. These valves act as the control core of the system, allowing operators to redirect or isolate flow remotely from the control room, maintaining safety and efficiency without hands-on

intervention at the piping.

2.1 Dual-pump, flush-water, emergency dump, and dual borehole configuration

The design used at the Niobec operation in Northern Quebec, Canada (Figure 1) illustrates a dual-pump configuration in which two positive-displacement paste pumps (GEHO-1 and GEHO-2) are connected to two independent boreholes through remotely actuated three-way diverter valves. Each valve assembly provides multiple flow paths that can be selected to



Figure 1 Niobec phase 2 surface automation layout

- Switch the active paste pump,
- Redirect discharge between boreholes,
- Divert paste from the hopper to a dedicated sump for controlled dumping,
- Inject high-pressure water to clear a blockage,
- Switch to lower-pressure flush water to clean the lines or
- Isolate a borehole entirely for maintenance or emergency control.

All valve actuators are powered and controlled through the plant's programmable logic controller (PLC) and displayed on the human-machine interface (HMI) in real time. This setup lets operators redirect paste between boreholes or dump circuits immediately after a controlled flush sequence, minimizing downtime and keeping production continuous. Just as important, it allows a verified ZES to be achieved from the surface before any mechanical work begins on the

reticulation network.

2.2 Integration of high-pressure water and flush systems

A second schematic from the Eldorado operation in the Abitibi region of Quebec, Canada (Figure 2) illustrates how the network of diverter valves enables simultaneous operations—allowing paste to be poured through one borehole while flush water is circulated through another. This dual-function capability eliminates the downtime traditionally required to switch between pouring and flushing, allowing for continuous system utilization and maximizing backfill productivity.

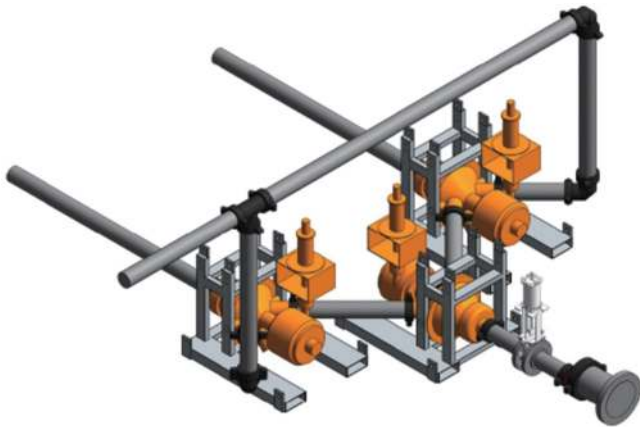


Figure 2 Eldorado paste, high-pressure water, dump, and flush integration

The system ties the high-pressure water injection pump and the regular flush-water circuit into the same control network used for paste delivery. The piston-pump circuit provides controlled, high-pressure water that can be directed to any borehole or pour point through the valve network. This configuration removes the need for separate underground water-injection lines or manual tie-ins and allows operators to transition seamlessly from routine flushing to high-pressure injection in response to a blockage.

2.3 Operational and safety benefits

The integrated surface automation design described above delivers three main advantages:

1. Safety: eliminates manual pipe handling and

improves the ability to confirm a ZES before maintenance or emergency blockage response.

2. Efficiency: reduces the time needed to switch between paste pours and water flushes from hours to minutes, allowing reticulation adjustments during normal operations or shift changes without interrupting production.

3. Reliability: provides redundancy between pumps and boreholes while maintaining continuous monitoring of pressures and flows through the plant's control system.

Together, these capabilities form the foundation of a modern, surface-based reticulation strategy. Automation and structured operator tools—such as dynamic decision trees—replace reactive manual steps with controlled, repeatable processes. The result is a safer, faster, and more predictable backfill operation that can respond immediately to both routine and emergency conditions.

3 Dynamic emergency response framework

Even in well-engineered backfill networks, pipeline blockages and over-pressure events are inevitable over the life of the reticulation system. The consequences of delayed or inconsistent response can be severe, ranging from cured paste in boreholes to lost production and infrastructure damage. At many operations, these events still rely heavily on individual experience and verbal direction, which can lead to hesitation or inconsistent actions—especially when personnel are unfamiliar with the network or working under pressure.

To improve consistency and eliminate guesswork, a dynamic decision tree—sometimes referred to as a Trigger–Action–Response Plan (TARP)—was developed by Andy O’Neil at Agnico Eagle’s Goldex Mine to guide operators step-by-step through a blockage event [2]. This approach is not an automated control system but a human-centered algorithm designed to complement automation by providing a clear, structured response path. The operator remains in control, but each action is defined in sequence and tied to measurable parameters such as pressure, flow, and water clarity at pour points. This ensures that both experienced and less-familiar operators respond

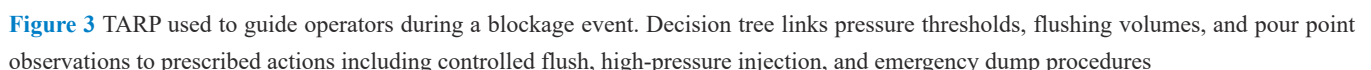
normal flow can be restored and helps determine if the blockage is partial or complete.

2. Assess pressure response: If pressure does not decrease after the initial flush, continue flushing or redirect water through alternate paths using diverter valves in accordance with the purge plan until pressures stabilize or begin to drop.

3. Verify pour point clarity: Once clear water is observed at the pour points and line pressures return to normal, the network can be progressively returned to paste service following standard operating checks.

4. If pressure persists: The decision tree guides the operator to initiate an emergency paste dump to a controlled containment area to safely relieve pressure, then isolate the affected section using diverter valves. Once pressures have stabilized, lock-out procedures are performed, and manual inspection is coordinated only after a verified ZES is achieved.

- This structured approach removes guesswork and ensures that every response follows a defined sequence of actions. By managing flushing, diversion, and



emergency dumping remotely from the control room, operators maintain procedural control while keeping personnel clear of pressurized lines and potential discharge areas. While the TARP defines the operator's actions, its true value is realized when combined with the surface automation system described earlier.

3.2 Integration with surface automation

The effectiveness of the decision tree increases significantly when paired with the automated control system described in Section 2. Remotely operated diverter valves allow each prescribed step—flushing, switching pumps, redirecting flow, injecting high-pressure water, or activating dump circuits—to be carried out instantly from the control room. Instead of dispatching crews to move elbows or open bypass lines, the operator simply follows the procedure and actuates the required valves through the HMI.

This setup makes every TARP action consistent and verifiable. Operators can see how the system reacts in real time and respond immediately, removing guesswork and delay while combining human judgment with engineered control.

3.3 Safety and risk reduction

From a safety standpoint, the decision tree brings structure to what used to be an ad hoc response. It helps operators stay aware of conditions, communicate clearly, and confirm a verified ZES before anyone works on the line. With remote actuation, crews stay clear of pressurized piping and energized equipment, reducing exposure to line failure or an unexpected paste release.

Standardizing the response steps and linking them to real-time control turns backfill upset management from on-the-fly troubleshooting into a repeatable, disciplined process. The result is fewer risks to people and a much lower chance of a cured blockage—an event that can shut down production and lead to costly borehole rehabilitation.

4 Safety, zero-energy verification, and system reliability

Safety remains the foundation of any backfill system.

High pressures and abrasive slurries make manual intervention inherently risky, particularly when isolating sections or responding to blockages. The surface automation system strengthens control and safety by allowing full energy isolation and verification from the control room.

4.1 Establishing a verified zero-energy state

Automation provides a consistent and verifiable way to achieve a ZES. Diverter valves include position indication and remote feedback through the control system, allowing operators to confirm valve status and line pressure from the surface. When isolation is required, the operator closes or dumps the affected valves, verifies valve position on the HMI, and confirms that pressure has fully dissipated before any work begins. This process minimizes the need to handle pressurized piping and creates a digital record of valve and pressure readings as proof of safe isolation.

Beyond isolation procedures, the same capability strengthens day-to-day operations. Real-time visibility of valve positions and pressures enables operators to detect irregularities early and respond before they affect production. Built-in redundancy—through dual pumps and multiple borehole pathways—allows flow to be redirected instantly if a component or line becomes unavailable, maintaining continuous operation and ensuring both safety and reliability.

5 Discussion—Integration complexity and future developments

While the benefits of automation in backfill systems are well recognized, applying it at the surface paste plant brings its own set of engineering challenges. A wide range of specialty products are now available for remote actuation of valves, pumps, and isolation devices; however, each often comes with its own communication protocol, power requirement, and logic controller. Integrating several of these proprietary systems into a single reticulation network can quickly add layers of complexity. The result is a system that is difficult to operate, prone to communication issues, and slower to respond during critical events—undermining the very reliability automation is meant to improve.

5.1 Integration challenges in conventional designs

At many mines, automation of backfill reticulation has evolved in stages. Paste pumps—specialized equipment supplied and controlled through original equipment manufacturer (OEM) systems—are typically provided by one vendor, while others supply the high-pressure water injection skids, flush-water circuits, or emergency dump assemblies. Each subsystem performs well on its own, but because they may use different control architectures and communication protocols, every device must be powered, addressed, and operated separately. When a blockage or upset occurs, troubleshooting can become slow and fragmented, as operators work across varied systems that may not communicate seamlessly. This increases the risk of delays at the very moment reliable response is most critical. From a safety standpoint, the lack of a unified interface can also make it difficult to confirm a true zero-energy state if feedback from one component is not visible in the main control system.

5.2 Simplifying through unified surface control

The surface automation system described in this paper brings all major reticulation functions—paste pumping, high-pressure water injection, flush-water delivery, emergency dumping, and borehole selection—into one coordinated valve network controlled by the plant's central PLC. Every diverter valve runs on the same power, actuation, and feedback setup, so valve positions and pressure readings are shown together on a single HMI screen. This setup removes the need for separate control panels or stand-alone communication modules for each subsystem. When a blockage or over-pressure event occurs, the operator can flush, dump, isolate, or redirect flow directly from the control room using the same interface and the decision-tree process described earlier. The result is a quicker, more coordinated response with fewer failure points.

5.3 Toward intelligent, interconnected backfill systems

Looking ahead, surface reticulation automation is

moving toward fully connected, intelligent networks. Future diverter-valve systems will likely include built-in pressure and flow sensing, automated detection of abnormal conditions, and the ability to trigger predefined emergency steps based on decision-tree logic. Remote diagnostics will flag problems before they interrupt production, while higher-pressure designs, multi-outlet valves, and improved wear materials continue to extend system capability.

The goal is a truly integrated control environment—linking the surface paste plant, reticulation network, and underground monitoring systems in one coordinated platform. These advances follow the same principle already proven at the surface: keep control centralized, simplify the network, and let automation manage the repeatable and time-critical tasks. By focusing automation efforts at the paste plant—where control, data, and process logic come together—mines can simplify operations while improving safety, reliability, and overall performance across the backfill system.

5.4 Performance outcomes

To evaluate the operational impact of manual reticulation switching versus automated diverter-valve control, comparative data were reviewed from two underground installations where stope transfers required physical pipe reconfiguration. Although this data are based on underground reticulation, it illustrates how long manual changeovers can take. In emergency situations, the urgency to restore flow can further increase safety risk.

At a Red Lake, Ontario-based site, manual coupling-based switching required approximately 9 labor-hours per transfer, including travel time and pipe handling. Monthly downtime associated with transfers averaged 60 h. Following installation of a remotely actuated diverter-valve system, transfer time was reduced to approximately 0.75 labor-hours per event, with monthly downtime reduced to 11.25 h.

At a Sudbury, Ontario-based site, manual transfer procedures required approximately 8 labor-hours per event and resulted in 80 h of monthly downtime across 20 transfers. After automation, transfer time decreased to approximately 0.75 labor-hours per

event, and monthly downtime was reduced to approximately 15 h.

Annualized labor cost comparisons showed reductions exceeding 80%–90%, depending on site-specific labor rates and transfer frequency.

It should be noted that these figures reflect underground installations where travel time to the switching location was required. In surface-based paste plant configurations, where diverter valves are located adjacent to the pump station and controlled directly from the control room, travel time is effectively eliminated. As such, response time improvements at the surface are equal to or greater than those observed underground.

Table 1 Manual vs. automation performance

Parameter	Manual switching	Automated diverter system
Labor-hours per transfer	8–9 h	~ 0.75 h
Monthly downtime	60–80 h	11–15 h
Personnel required	2–3 workers	1 operator
Travel required	Yes	No (surface)
Isolation verification	Manual	PLC-verified

6 Conclusions

Surface-level automation is changing how backfill

systems are managed. Centralizing control of pumps, boreholes, high-pressure and flush-water circuits, and dump lines removes most manual intervention and keeps people clear of high-risk areas. Experience from operating sites shows this approach can cut pour-change time from hours to minutes while improving safety and maintaining full control from the surface.

When paired with a clear, operator-driven decision tree, the system turns what was once a reactive process into a structured, consistent operation. It improves safety, reduces downtime, and gives operators better visibility into system performance.

Automation at the paste plant also sets the stage for the next step—fully integrated networks where sensors, valves, and control logic work together to detect problems and respond automatically. The goal remains simple: make backfill systems safer, more reliable, and easier to run by starting where it matters most—at the surface.

References

[1] T. Belem and M. Benzaazoua, "Design and application of underground mine paste backfill technology," *Geotechnical and Geological Engineering*, vol. 26, pp. 147–174, 2008.

[2] A. O'Neil. Operational Trigger–Action–Response Plan (TARP) for Paste Backfill Reticulation Systems. Agnico Eagle-Goldex Mine Operational Procedure, 2025.