Appendix – Example Mitigations

As noted in the body of the report, a multitude of technological, material, design, and engineering options exist to address common risks involved in transporting produced water via layflat. A suite of options will likely be required to address identified risks for Higher Risk Activities. Several of these options are listed below as examples. This is not intended to be an exhaustive list or endorsement of any one approach. Example mitigations include:

- improve the quality of water being transported via treatment, possibly blending;
- utilize alternative materials and designs to reduce leaks at common locations, such as:
    - pumps with improved seals;
    - alternative coupling/connection materials to reduce drips (e.g. flanged couplings);
    - couplings which have low risk of separation from hose;
    - drip trays at couplings; and
    - systems with fewer (or no) couplings.
- where appropriate, install containment within right of ways;
- increase inspections frequency (by both operators and regulators);
- utilize leak detection technologies and pressure transmitters;
- utilize automated, remote, real-time monitoring and control systems to minimize volumes spilled and optimize performance;
- install pressure relief systems;
- implement approaches to manage freezing (e.g. install bypasses to enable controlled emptying of produced water following end of use);
- develop and utilize quality control and assurance processes for conveyance materials (e.g. pressure testing with freshwater, verifying purchased materials are received);
- assess the complete transportation network to identify high pressure points (e.g. at the bottom of slopes) and revise system design to ensure pressures do not exceed material ratings;
- reduce the volume which can be spilled due to a failure (e.g. shutoff valves at short intervals);
- maintain material safety data sheets nearby to where produced water is transported so spills can be managed and communicated properly; and
- develop and maintain an emergency response and spill cleanup plan.

Appendix – Combined Jurisdictional Review Table

Jurisdiction	Relevant regulatory instruments	Approval mechanisms	Regulatory barriers	Risks	Risk mitigation	Common technologies & materials	Differences from Alberta
Alberta	Pipeline Rules Directive 058: Oilfield Waste Management Requirements for the Upstream Petroleum Industry Oil and Gas Conservation Act & Regulation Directive 056: Energy Development Applications and Schedules Directive 058: Transportation and Storage of Oilfield Wastes *(indirect impact*)	*Pipeline Rules* - A licence for pipeline construction must be obtained via application to the AER in accordance with *Directive 056* for transportation of water via temporary hose where the source water contains produced or process affected water (note: this includes blended waters). No application is required for freshwater transportation through temporary pipeline. Applications do not need to be made for pipelines constructed within the facility lease boundary.	Applications for transport of produced water through temporary pipelines are not approved by the AER given, the high risks associated with leaks from layflat. Produced water spills contravene the *Environmental Protection and Enhancement Act,* leading to severe fines for operators (see Apache pipeline spill 2013). Produced water is defined as non-hazardous oilfield waste by Directive 058. Storage of produced water away from the well site requires regulatory approval as a waste facility, which is burdensome. The barriers to produced water storage mean conveyance by pipeline or layflat is less likely to be undertaken.	The AER has concerns over the risks to groundwater and fresh surface water sources, plants, and aquatic life from layflat leakages at connectors and catastrophic failures resulting in large volume releases of water.	**Leaks and Spills** The AER mitigates risks by only allowing transportation of produced water through pipelines meeting the CSA standards laid out in the *Pipeline Rules.* Truck transport of produced water is also permitted. For pipelines, pressure testing must be conducted to the CSA Z662 standard. **Additional Requirements** Surface pipelines must have additional features, such as temperature monitoring if the material has operational temperature limits.	**Materials** Steel and fibreglass pipelines are often used for transporting produced water in Alberta in non-temporary, licenced pipelines. There is recognition that corrosion issues exist with steel pipeline. From a regulatory perspective, it is possible to use HDPE for above-ground transfer of produced water. **Materials Standards** Pipelines regulated under the *Pipeline Rules,* including produced water transfer lines, must meet the following standards: - CSA Z245.11, Steel Fittings - CSA Z245.12, Steel Flanges - CSA Z245.15, Steel Valves - CSA Z662, Oil and Gas Pipeline Systems The *Pipeline Rules* state materials deviating from these standards can be used at the discretion of the Regulator; technical specifications regarding the construction materials, components, or maintenance methods must be provided.	N/A

Jurisdiction	Relevant regulatory instruments	Approval mechanisms	Regulatory barriers	Risks	Risk mitigation	Common technologies & materials	Differences from Alberta
British Columbia	Oil and Gas Activities Act (OGAA) British Columbia Water Act Pipeline Regulation Drilling and Production Regulation	Temporary above ground pipelines designed to carry *freshwater* do not fall under the definition of a pipeline, as defined by the OGAA, and do not require a permit unless transported over Crown Land. Although a permit is not required, BCOGC approval is still required for these pipelines. The Pipeline Regulation legislates transport of fluids beyond the lease boundary. Under the Pipeline Regulation, all oilfield water must be transported by pipeline meeting CSA Z662 Oil and Gas Pipeline standard*. Temporary over ground pipelines are not regulated under the Pipeline Regulation. The *Drilling and Production Regulation* (DPR) legislates transport of fluids within the lease boundary. Under the DPR, all fluids within the lease boundary must be transported in pipelines meeting either the CSA Z662 or ASME B31.3 standards. Under the OGAA, a permit is required to transport oilfield water by pipeline. The BCOGC has approved the use of spoolable RTP for produced water transportation in certain projects where risks are deemed appropriately mitigated. Where materials used do not meet CSAZ662, engineering sign off is required from a B.C. registered Professional Engineer that the materials used are appropriate for the activity.	Under the OGAA, a pipeline definition includes the transportation of produced and flowback waters. *The Pipeline Regulation* states pipelines must also meet the design and construction requirements laid out in CSA Z662. The BCOGC has been working with industry to pilot projects using spoolable RTP, such as Primus Line, that meets different materials engineering standards, such as API 15S, for the over ground transportation of produced water. These require engineering sign off. Engineering sign off for alternative materials is permitted under clause 5.1.6 of CSA Z662.	The BCOGC recognizes there are risks posed by the transportation of alternative water in the form of contamination of freshwater sources, vegetation, and wildlife from spills and leaks. The BCOGC recognizes these risks exist to a lesser extent when transporting produced water via permitted pipeline conforming to the CSA Z662 standard.	**Leaks and Spills** The BCOGC mitigates the risks associated with the transport of produced water by only allowing off-lease transport through permitted pipeline meeting the CSA Z662 standard. Within the lease boundary, the risk of leaks occurring unnoticed is reduced. The BCOGC recognizes this and allows pipelines to meet the ASME B31.3 standard for certain activities. Truck transport is also permitted, as this is deemed lower risk. There is evidence the BCOGC works collaboratively with industry to implement new risk mitigation approaches (e.g. spoolable RTP). This is enabled by a more risk-based regulatory environment. **Monitoring** The OGAA states that monitoring must be undertaken to verify the integrity of a pipeline.	**Materials** The most common transport method in B.C. is trucking of produced water, though permitted pipelines and water hubs are becoming more popular. Common construction materials include HDPE. Engineered layflat has also been piloted and approved in some cases (RTP). **Materials Standards** Under the *Pipeline Regulation,* off-lease pipelines must meet CSA Z662. Under the *Drilling and Production Regulation,* on-lease pipelines must meet either CSA Z662 or ASME B31.3.	**Climate** Similar to Alberta; water is subjected to sub-zero temperatures. **Topography** Similar to Alberta; high pressure pumping is required to transport water over hills. **Water availability** Northeastern B.C. is subject to water withdrawal restrictions due to drought. **Disposal availability** Fewer disposal wells are available in B.C. compared to Alberta, generally speaking. This has encouraged the reuse and storage of produced water in B.C. **Risk tolerance** As in Alberta, there is low tolerance for spills or leaks resulting in environmental damage.

Jurisdiction	Relevant regulatory instruments	Approval mechanisms	Regulatory barriers	Risks	Risk mitigation	Common technologies & materials	Differences from Alberta
Colorado	The Colorado Oil and Gas Conservation Commission (COGCC) 900 series for governing the management of exploration and production of waste Flowline Rulemaking	Off-lease flowlines must be registered with a designated Director or as part of a produced water transfer system.	Under the Flowline Rulemaking document 1100, it is possible to use flexible above ground piping with the written agreement of landowners if that pipeline meets the materials standards of ASME B31.3 or API 15S and the required pressure testing is undertaken. There is evidence operators utilize double-jacketed layflat materials with improved couplings for produced water transfer (e.g. TETRA Steel) under existing regulations. These materials may or may not comply with existing API or ASME standards, though vendors have internal quality control procedures.	Colorado produced water varies by formation. Many, though not all, formations have low TDS (< 10,000 mg/L), meaning there is less concern over salinity impacts to ground and surface water. Produced water reuse occurs, for example for irrigation and dust suppression.	**Depth of flowlines** Flowlines are to be installed below ground at a sufficient depth to protect them, except in cases where written agreement from surface owner can be secured to install flowlines with minimal cover or above ground. **Marking** Markings indicating the location of flowlines are required in Designated Setback Locations and at crossings with public/utility rights of way. **Leak and Corrosion prevention** Operators are required to prevent failures, leakage, and corrosion of pipelines by taking reasonable precautions.	**Materials** Materials must be compatible with transported fluids, of sufficient structural integrity for planned operations, and compliant with one applicable standard (of which there are six approved in the regulation). Double-jacketed layflat has been used in some cases. **Materials standards** Applicable standards for produced water transport approved in Colorado are: - ASME B31.3 Process Piping Guide; and - API 15S Spoolable Reinforced Plastic Line Pipe. **Pressure** Operating pressures cannot exceed manufacturer's specifications for any piece of equipment in the transportation system. **Monitoring** Automated, remote, real-time monitoring and control systems have been installed to reduce spill volumes and optimize performance	**Climate** Warmer climate with lower freezing risk. **Topography** Changes in topography are greater in closer proximity to the Rocky Mountains. Higher operating pressures may be required to overcome changes in elevation in the region. Eastern Colorado is flatter, potentially accommodating lower operating pressures. **Water Availability** Water scarcity in the state creates a high drive for reuse and alternative uses for produced water, such as road maintenance and crop irrigation. **Disposal Availability** Disposal well availability varies regionally, leading to local variations in the intensity of reuse. **Risk Tolerance** Salinity and TDS concentrations in some parts of Colorado are lower than in Texas and Alberta, enabling more management options, such as reuse.

Jurisdiction	Relevant regulatory instruments	Approval mechanisms	Regulatory barriers	Risks	Risk mitigation	Common technologies & materials	Differences from Alberta
Texas	Texas Administrative Code Texas Railroad Commission (RRC) – Responsible for disposal and recycling and fluid wastes associated with oil and gas operations, but not layflat transportation of produced water Texas Department of Transportation (TxDOT) – Responsible for leasing right of way for saltwater pipelines	There is no distinct approval/authorization process for layflat, unless it is placed in a state-owned right of way (ROW). In these cases, TxDOT handles approvals. There are two types of licences issued by TxDOT for produced water pipelines: 1. Short term (90-180 days), above ground, not intended to carry produced water. Water with a TDS > 10,000 mg/L cannot be transported through above ground temporary pipelines (typical Texas produced water exceeds 100,000 mg/L TDS). 2. Long term (90+ days), underground, intended to carry produced water.	The TxDOT regulations appear to prohibit transportation of water with TDS concentrations > 10,000 mg/L in above ground temporary pipelines. Conversations with individuals active in Texas suggest transportation of produced water in above ground temporary HDPE pipelines is common. Pipeline diameters are restricted to 12'' (30 cm), while layflat is typically 8-10'' (20-25cm) in state-owned ROWs. The Texas Administrative Code requires operating pressures of temporary pipelines not to exceed 60 psi (~413 kPa) at any point in state-owned ROWs. There is evidence operators utilize double-jacketed layflat materials with improved couplings for produced water transfer (e.g. TETRA Steel) under existing regulations. These materials may or may not comply with existing API or ASME standards, though vendors have internal quality control procedures.	There are concerns regarding operators incorrectly siting temporary pipelines in state-owned ROWs, exposing them to damage and interfering with other activities (e.g. road maintenance). Vandalism is a significant risk for above ground pipelines. Texas has produced water with high salinity (typically > 100,000 mg/L TDS), producing greater consequences for plants and wildlife. However, some areas have relatively sparse vegetation and wildlife. Use of metal pipelines are no longer permitted due to frequency of damage and leaks. Operators have noted traditional (single-jacketed) layflat is prone to leaks, particularly at couplings.	**Anchoring** Use metal stakes instead of wooden stakes for securing and anchoring above ground pipelines. **Ramps and Manifolds** Ramps and manifolds are used at property entrance crossings. These must be sufficient to hold vehicles. **Use of Culverts** Guidelines use a table to specify how many temporary pipelines can pass through a culvert at any given time. **Pressure Testing** All temporary pipelines should be pressure tested prior to operation. **Inspection Procedures, Salinity Basis** The guidelines specify varying inspection protocols depending on the salinity classification of the water (fresh, slightly saline, moderately saline, or saline). **Depth of Cover** The minimum depth of cover for saltwater pipelines is 48'' (122 cm). Pipelines are encased at right of way crossings.	**Materials** The TxDOT regulations appear to require buried HDPE for produced water, but practice (based on talking to colleagues familiar with the regions) suggests above ground HDPE is in use for produced water. As well, double-jacketed layflat with leak-reducing couplings has been used in some cases. Standard layflat hose can be used for water with TDS concentrations < 10,000 mg/L, which precludes typical Texas produced water. Metal pipeline materials, such as aluminum and steel, are not permitted for above ground temporary piping. **Monitoring** Automated, remote, real-time monitoring and control systems have been installed to reduce spill volumes and optimize performance	**Climate** Warmer climate; the risk of pipes freezing is very low. **Topography** A flat topography over great distances allows for the use of lower operating pressures. **Water Availability** Water scarcity in the state creates a high drive for water reuse. **Disposal Availability** Disposal in Texas is currently relatively inexpensive compared to disposal in Alberta. **Risk Tolerance** Regulations on the use of above ground temporary pipelines for produced water are strict. However, our conversations suggest operators are still using HDPE for moving produced water above ground. Notably, operators would not be comfortable using layflat to transport produced water, even if it were permitted, due to high TDS concentrations (often > 100,000 mg/L).