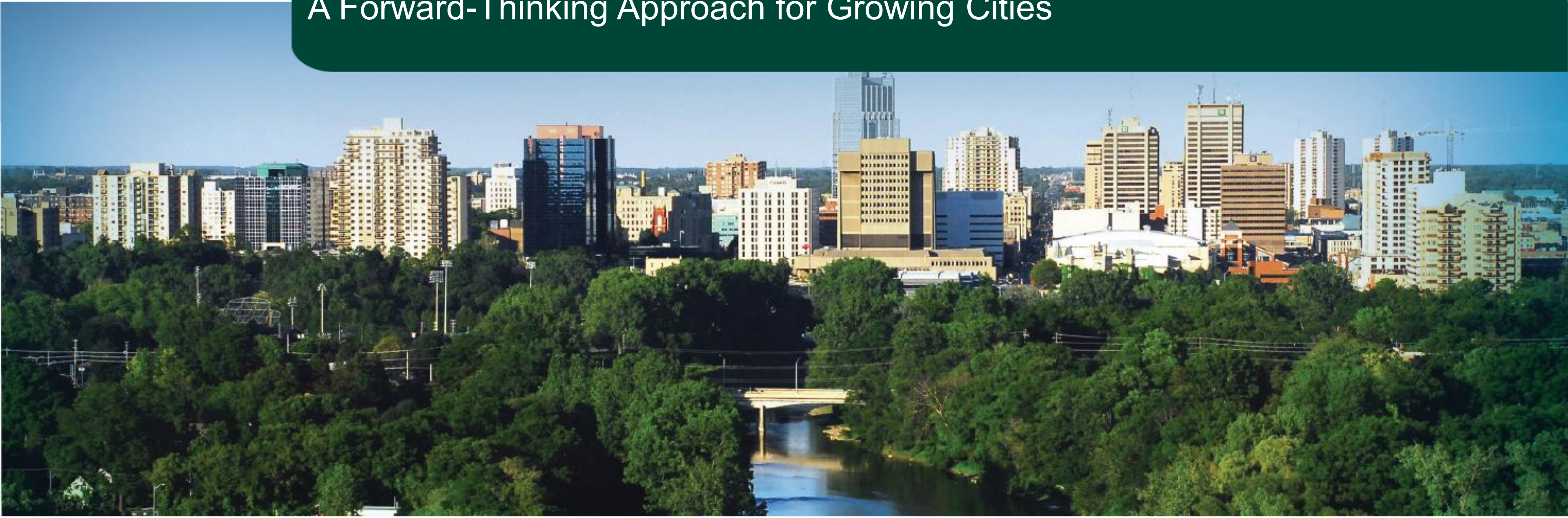

# Innovative Injection Methods for Sustainable Stormwater Management: A Forward-Thinking Approach for Growing Cities

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# Presentation Overview

- Growth of High-Rise Construction in City Environments
- Stormwater Management Issues Arising from Urbanization
- An Overview of Injection Wells
- Benefits of Using Injection Wells for Urban Stormwater Control
- Regulatory Framework for Underground Injection Wells
- Summary and Recommendations

# Urban Expansion & high-rise Development

- Increasing population and movement toward urban areas
- Scarcity of land within central urban zones
- Economic development and attraction of investments
- Development and enhancement of public transportation networks
- Government initiatives encouraging higher density living
- Objectives for environmental sustainability
- Evolving lifestyle choices
- Impact of globalization on real estate investments

# Stormwater Management Challenges from Urban Development

- **Elevated land costs and scarce available space** greatly impede effective runoff management and flood prevention strategies.
- **The expansion of impervious surfaces** leads to higher peak runoff volumes and diminished groundwater replenishment.
- **Absence of regulations on underground parking depths and unrestricted building heights** have together intensified groundwater depletion through extended foundation drainage.
- **Aging infrastructure and stormwater systems** remain major obstacles, necessitating upgrades and retrofits to address current demands.

# Urban Expansion & high-rise Development

Groundwater Depletion

Storm Sewer Capacity Limitations

Sewer surcharge; Localize flooding; Basement flooding.

Consumes stormwater pond detention storage; Increase risk of Erosion.

# Case Study: City of Toronto, Foundation Drainage Policy

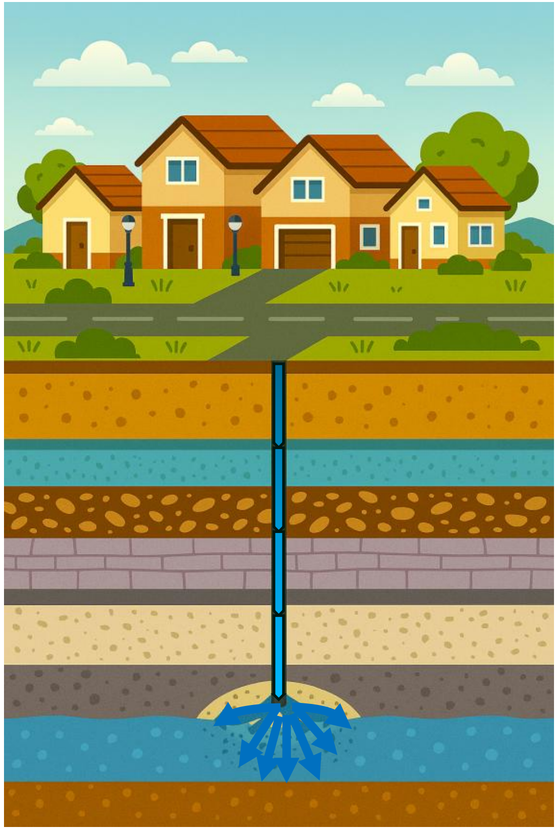

# Foundation Drainage: at Individual House Scale

| Preventive Method | Effectiveness / Considerations |
|---|---|
| **Sump Pump Technology** | Limited effectiveness when groundwater levels are high; challenges discharging water onto frozen yards. |
| **Gravity Connection to Storm Sewer** | Restricted by shallow sewer depth; not always feasible. |
| **Foundation Drainage Collector (FDC) / Third Pipe** | Provides reliable drainage, but involves high initial cost, ongoing O&M, and significant lifecycle replacement costs. |
| **Backflow Prevention Devices (Backwater Valves)** | Protect against sewer backup; ice jam or debris requires maintenance to remain functional. |
| **Downspout Disconnection** | Reduces inflow into foundation drainage and storm sewers; low-cost but effectiveness depends on lot grading and infiltration capacity. |

# What is Injection?

An **injection well** is a structure used to **place fluid underground into porous geologic formations**, which may include deep rock layers like sandstone or limestone, or shallow soil layers. Injected fluids might be water, wastewater, brine (salt water), or water mixed with chemicals.
*(Source: US EPA – Underground Injection Control Program, 40 CFR 144.3)*

While **injection technology** shouldn't be viewed as a **one-size-fits-all solution**, it provides a valuable means of **enhancing stormwater management** when applied strategically. Its effectiveness is maximized when **integrated with other best practices, policies, and infrastructure solutions**.



# Key advantages of Stormwater Injection Wells for Urban High-Rise

**Space & Construction Efficiency:**

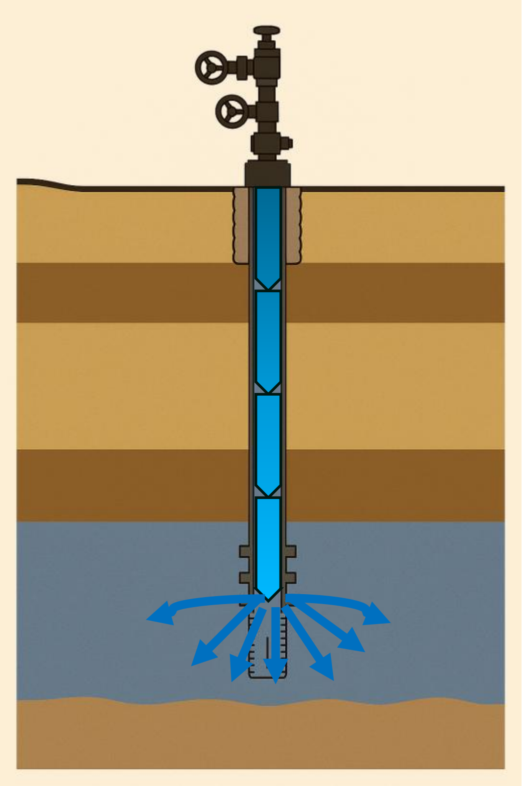
- Minimal Surface Footprint
- Rapid Installation

**Operation & Economic Benefits:**

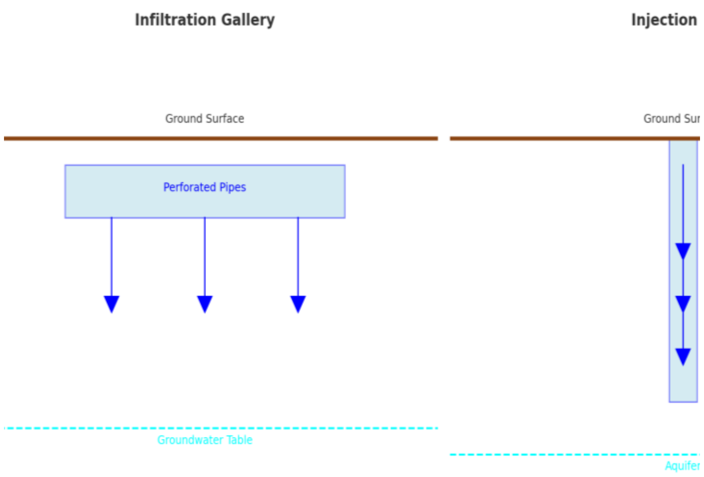
- Targeted Source Control
- Cost-Effective

**Environmental and Resilience Value**

- Groundwater Recharge
- Climate Resilience
- Water Quality Improvement



# Comparison of Infiltration Galleries and Injection Well




**Groundwater Table Sensitivity**

**Vulnerability to Contamination**

**Soil Type Compatibility**

**Necessary Building Setback Distances**

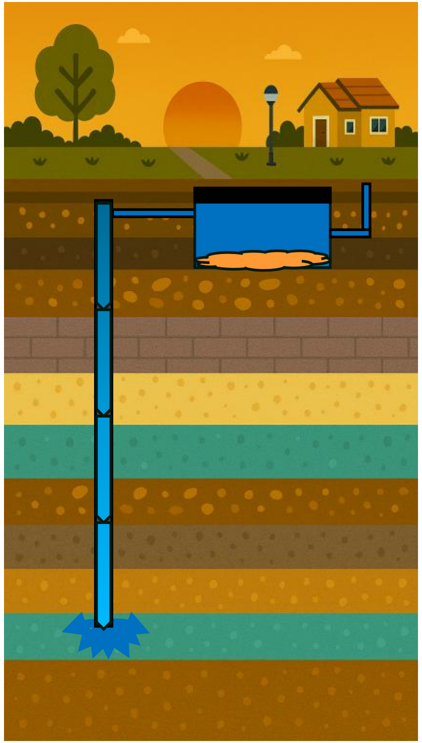
**Excavation Factors and Aquifer Connectivity**

**Potential for Clogging and Maintenance Needs**

**Impact of Surface Activities**

# Stormwater Storage and Injection Well

- **Stormwater Storage Options**
  - Stormwater Management Pond
  - Subsurface Storage Tank
  - Rooftop Storage Systems (blue roofs)
- **Injection Well Benefits**
  - Reduces storage volume requirements and lowers erosion risk
  - Removes the necessity for permanent pools and prolonged detention times
  - Promotes direct groundwater recharge
  - Enables focused source control on rooftops and/or paved areas
  - Improves water quality
  - Limits thermal impacts
  - Cost-effective solution




# Other Applications for Injection Well

Upgrading SWM Infrastructure

- Retrofitting SWM Ponds
- Addressing basement flooding and disconnecting downspouts
- Managing sewer surcharge

Snow Disposal Facilities – brine injection

Municipal Drinking Water – Aquifer Storage and Recovery

Injection of Treated Sewage –Sea Water Intrusion

# US EPA –Underground Injection Well Classification

**Class I Wells**:

- These wells are intended for the injection of **hazardous and non-hazardous wastes** into **deep, isolated geological formations**, primarily to safeguard underground sources of drinking water (USDWs).

**Class II Wells**:

- These wells are employed for injecting fluids associated with **oil and natural gas production**, playing a crucial role in enhanced oil recovery and reservoir management.

**Class III Wells**:

- Designed for **solution mining**, these wells inject fluids to dissolve and extract minerals from underground deposits.

**Class IV Wells**:

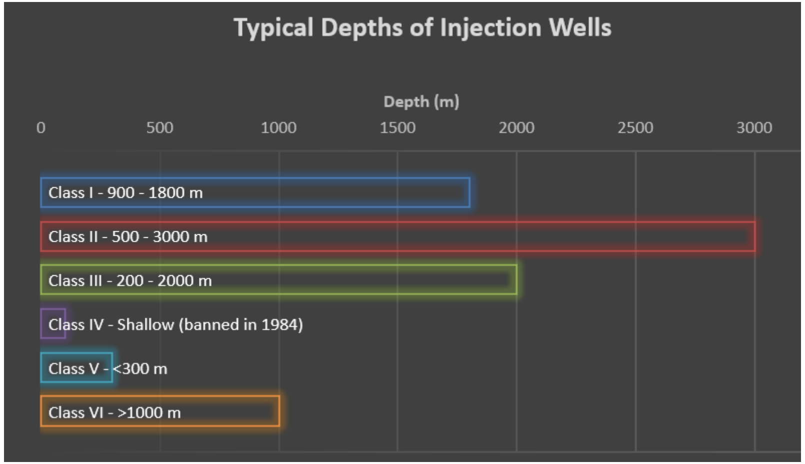
- These **shallow wells** (banned in 1984) were used to inject **hazardous or radioactive wastes** into or above geological formations that contain USDWs.

**Class V Wells**:

- Covering a wide range of applications, Class V wells inject **non-hazardous fluids** below the surface.

**Class VI Wells**:

- Specifically constructed for **carbon dioxide ($CO_2$) injection**, these wells target deep subsurface rock formations for carbon sequestration.



# Historical Perspective & Regulatory Context of Class V - Injection Wells

**Regulatory Framework**

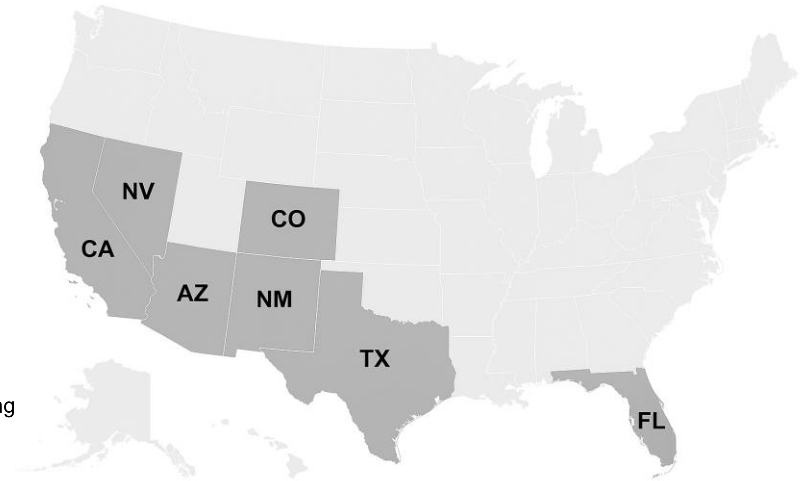
- **EPA Class V UIC Program** (covers most recharge & ASR wells):
  - Recharge wells → stormwater, surface water, treated wastewater.
  - ASR wells → storing treated water for later recovery.

**Early Adoption (by State & Era)**

- **California (Late 1800s):** First treated wastewater injection to combat seawater intrusion.
- **Florida (Mid-1900s):** Aquifer Storage & Recovery (ASR) for seasonal storage.
- **Texas (1950s–1980s):** Surface infiltration, later ASR injection projects.
- **Arizona (1980s):** Infiltration basins & shallow sumps for stormwater recharge.
- **New Mexico, Nevada, Colorado (2000s+):** Gradual adoption, slowed by regulatory hurdles.

**State-Level Variations**

- **Arizona & Texas:** Supportive with state-specific permitting.
- **New Mexico:** Stricter review, tied to water rights & monitoring.
- **California:** State laws (like SGMA) actively **incentivize and fund** projects, including providing **pumping credits** to landowners.




**EPA sets Class V rules, but states shape how projects are implemented.**

Source: Moore, S. J. (2018). *Managed recharge – Beyond the ASR well*. Texas Groundwater Summit, San Antonio, TX.

# Alberta - Underground Injection Well Classification

**Class Ia Wells:**

- Oilfield/industrial waste –these wells are used to dispose oilfield or industrial waste fluids and waste streams

**Class Ib Wells:**

- Produced water /specified waste – acidic or alkaline solutions, amine filter backwash, aqueous liquid fraction, boiler blowdown water etc.

**Class II Wells:**

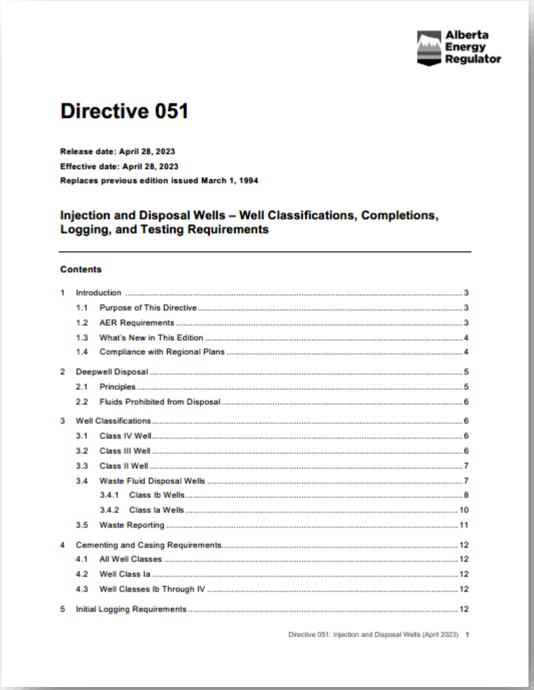
- Produced water/brine equivalent – these wells are used to inject or dispose of produced water (brine) or brine-equivalent fluids

**Class III Wells:**

- Hydrocarbon/inert/scour gases – these wells are used to inject hydrocarbons, inert gases, or other gases for enhanced recovery or storage in a reservoir

**Class IV Wells:**

- Steam/potable water – these wells are used to inject potable water (with no expectation of its conversion to produced water) or steam made from either potable water or recycled water into reservoir



Alberta Energy Regulator

**Directive 051**

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Replaces previous edition issued March 1, 1994

**Injection and Disposal Wells – Well Classifications, Completions, Logging, and Testing Requirements**

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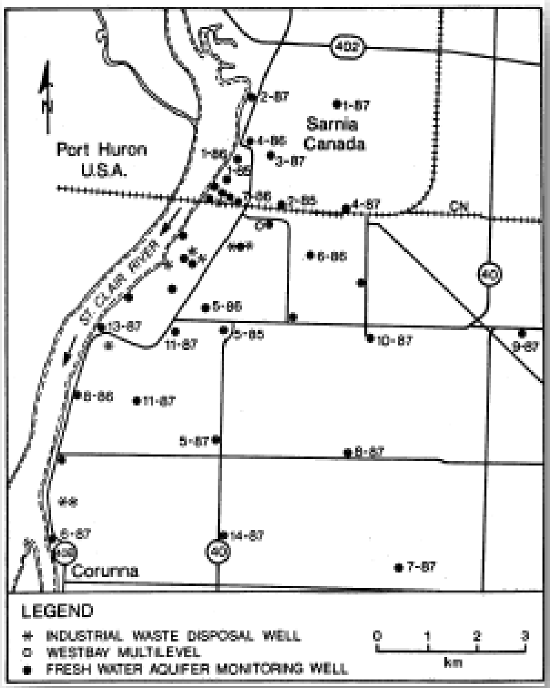
Directive 051: Injection and Disposal Wells (April 2023) 1

Source: Alberta Energy Regulator – Directive 051 – Injection and Disposal Wells – Well Classifications, Completions, Logging, and Testing Requirements.

# Subsurface Injection in Ontario, Canada

- The first industrial waste injection well near Sarnia was established in **1958**, with several more drilled later, mostly within the Detroit River Group at depths under 300 meters.
- From **1958 to 1974**, about **6.4 million cubic meters** of liquid industrial waste from oil refining and petrochemical plants were injected into bedrock in Sarnia.
- The waste had high levels of **phenols, sulfides, ammonia**, and a pH above 9.
- Disposal occurred **177 to 274 meters** deep in the Devonian-era Lucas Formation dolomite.
- Injection pressures reached **450 psi**, with rates of **50 to 100** gallons per minute.
- In **1970**, Ontario banned hazardous waste injection into shallow formations.




Source: Monitoring Shallow Ground Water For Injected Liquid Industrial Waste, Sarnia, Canada, Rivers Research Branch, National Water Research Institute Canada Centre for Inland Waters, October 1989.

# Legislation & Regulations Governing Class II Injection Wells in Ontario

| Regulation & Act | Scope related to Injection Wells |
| --- | --- |
| **Oil, Gas and Salt Resources Act (Section 11)** | Requires injection permits; referral procedures near gas storage areas |
| **Provincial Operating Standards – Part 2** | Sets detailed application, design, and integrity requirements for injection wells |
| **R.R.O. 1990, Reg. 341 – Deep Well Disposal** | Covers standards for liquid industrial waste disposal into deep wells; notes oil field brine exemption |
| **Ontario Water Resources Act & Wells Regulation** | Governs well construction and abandonment standards, relevant for integrity assurance |
| **Environmental Protection Act** | Controls the discharge of contaminants via environmental compliance approvals |

# Summary

Injection well technology has been applied worldwide for over a century in oil, gas, and water management.

In the U.S., injection and aquifer recharge methods are widely used in seven states (FL, CA, AZ, CO, NV, NM, TX).

Practices are governed by strict laws, regulations, and monitoring to safeguard potable aquifers.

Proven opportunity to adapt this technology for **sustainable stormwater management in growing cities**.

# Recommendations

**Encourage adoption** of injection methods for stormwater management through government funding and tax incentives.

**Support pilot projects and empirical studies**, following U.S. models, to assess Canadian applicability.

**Share research outcomes** in a format accessible to designers and regulators.

**Eliminate technical and regulatory barriers** with clear guidelines and evidence-based practices.

# Questions?