Groundwater Management in Vancouver:

A Review of Leading Practices for Local Governments

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Executive Summary

The City of Vancouver (the "City") is in the initiation stages of developing a groundwater management strategy. The intent of the strategy is to better understand, protect, and manage groundwater resources in Vancouver's city limits and beyond. This will likely include conducting hydrogeologic research, developing a collaborative approach to resource management through engagement, protecting aquifers from contamination and depletion, and where feasible, sustainably utilizing groundwater to enhance Vancouver's resilience to climate change and other emergencies.

The purpose of this report is to provide recommendations for potential actions that could be employed by the City to better understand, protect, and manage groundwater. These actions may help to address existing as well as emerging challenges around water in Vancouver.

To complete this project, a literature review of groundwater or water management plans/strategies/policies from other jurisdictions was conducted. Specific actions or policies that were included in those documents that may be suitable for Vancouver were initially shortlisted to a comprehensive list of approximately 180 actions. These actions were then assessed using a set of weighted evaluation criteria. After completing the evaluation, 12 actions are recommended for consideration to be included in the City's groundwater management strategy. Based on the author's professional opinion, an additional three actions are also recommended for consideration for the groundwater management strategy. These three additional actions are recommended as they help to address emerging as well as long-standing issues regarding groundwater for the City that are considered higher priority issues by the author.

Based on the results of the project, the 15 total actions that are recommended for inclusion in the City's groundwater management strategy would generally help the City to:

- Understand the current state of groundwater, including the mapping of different hydrostratigraphic units and monitoring their water levels and water quality, and determining how groundwater interrelates with surface water. Groundwater elevations in Vancouver must be characterized to understand how enhanced infiltration, groundwater diversion and extraction, sea-level rise, paving of recharge zones, and climate change may impact the groundwater

- Protect groundwater from new as well as existing potential threats such as saltwater intrusion or contamination as our built environment evolves
- Manage groundwater elevations by understanding baseline conditions, understanding the interaction between groundwater and surface water, and establishing water level trigger limits and/or groundwater extraction limits

1. Introduction

Groundwater is a valuable water resource found underground and hosted between grains of sand or other unconsolidated sediments or in cracks and fractures in bedrock. Globally, groundwater accounts for approximately 99% of the world's liquid freshwater (Government of Canada, 2013). In Canada, approximately 30% of the population depends on groundwater for potable and domestic water use (Government of Canada, 2013).

The occurrence, quality, and quantity of groundwater in the vicinity of Vancouver, British Columbia is generally poorly understood. In order to better understand, protect, and manage groundwater, the City of Vancouver (City) is developing a groundwater management strategy. The strategy will provide the framework to help inform the City's approach to groundwater management.

The purpose of this report is to compile a variety of groundwater related actions that have been included in groundwater management plans, strategies, or policies prepared in other jurisdictions. The groundwater actions that appear to be most suitable to Vancouver with regards to existing as well as emerging groundwater-related challenges are provided as actions to consider including in the groundwater management strategy.

1.1 Project Background

The City's awareness around groundwater has been increasing over the years, which has ultimately led to the initiation of the development of the groundwater management strategy. Other plans/strategies/policies developed by the City that are relevant to the groundwater management strategy include:

- *Greenest City Action Plan* (City of Vancouver, 2015): This plan has numerous goals, including to become the greenest city in the world by 2020, and a Clean Water goal to reduce potable water consumption by 33% compared to 2006 levels per capita.
- *Climate Change Adaptation Strategy* (City of Vancouver, 2012) and *Climate Change Adaptation Strategy 2018 Update and Action Plan* (City of Vancouver, 2018): The 2012 version of the strategy includes a number of actions to monitor and investigate groundwater quality and elevations around the coastline to understand the extent and/or migration of saltwater intrusion. The 2018 update includes updated information regarding what could be

expected with climate change (e.g. warmer more intense summers, and warmer winters). Based on the updated anticipated impacts of climate change, the action to prepare a groundwater management strategy was proposed to help improve the resiliency of Vancouver's water supply and water-related infrastructure. Other groundwater related actions in this strategy include completing integrated water modelling and identifying alternative water sources such as groundwater.

As indicated in Section 1, the documentation review and analysis carried out for this project will help to inform some of the actions that may be considered for inclusion in the groundwater management strategy

2. Setting

This section summarizes the regulatory setting including provincial legislation and the City's other plans/strategies/policies relevant to groundwater. An overview of the geologic/hydrogeologic setting in the vicinity of Vancouver is also provided in this section.

It is noted that the governance or traditions that local Indigenous Nations may have around water and groundwater use or protection are not documented in this report. There may be an opportunity for collaboration with the Tsleil-Waututh, Squamish, and Musqueam Nations to share their knowledge and groundwater management priorities with the City if the Nations express the desire to do so.

2.1 Provincial Regulatory Setting

The following provincial legislation relates to groundwater in various manners. A brief overview of how each piece of legislation applies to groundwater is provided below:

- *BC Environmental Assessment Act* (Province of British Columbia, 2021) – This act provides the framework for requirements around environmental assessments for major projects/developments.
- *BC Environmental Management Act* (Province of British Columbia, 2021) – One of the intents of this act is to define what a "contaminated site" is and the actions/requirements that apply to a contaminated site. A contaminated site is defined as "an area of the land in which the soil or any groundwater lying beneath it, or the water or the underlying sediment, contains a

prescribed substance in quantities or concentrations exceeding prescribed risk based or numerical (a) criteria, (b) standards, or (c) conditions" (Province of British Columbia, 2021). This Act also makes it unlawful to discharge contaminants to the environment at sufficient quantities that may cause pollution.

- *BC Water Protection Act* (Province of British Columbia, 2021) – The primary focus of this act is to assign groundwater and surface water allocation rights and governance to the Province of British Columbia.
- *BC Water Sustainability Act* (Province of British Columbia, 2014) – This act provides an updated policy framework for water resource licensing and protection activities. The act is supported by four regulations, including: the Groundwater Protection Regulation; Water Sustainability Regulation; Water Sustainability Fees, Rentals and Charges Tariff Regulation; and Dam Safety Regulation.
- BC Water Sustainability Regulation (Province of British Columbia, 2021) – This regulation outlines the specific requirements for applications to extract/divert groundwater or surface water.
- BC Groundwater Protection Regulation (Province of British Columbia, 2021) – The intent of this regulation is to protect groundwater by setting requirements for well construction, maintenance, decommissioning, etc. The regulation also indicates who is qualified to carry out well-related work.
- BC Contaminated Sites Regulation (Province of British Columbia, 2021) – The purpose of this regulation is to outline the required activities for investigating and remediating contaminated sites. The regulation includes numerical criteria for groundwater quality standards for various parameters and end users/receiving environments.

A key takeaway regarding the above legislation is that it is primarily enforced on a case-by-case or location-by-location basis rather than instating a methodology to protect or manage groundwater resources. Whereas with the groundwater management strategy, the City is likely to use a proactive approach to protect and manage groundwater that will compliment the legislation outlined above.

2.2 Relevant City Documentation

In recent years, the City has begun to take a more holistic approach to managing its water resources, including aiming to become a "water sensitive city". A water sensitive city is a concept originally developed in Australia (Cooperative Research Centre for Water Sensitive Cities, 2021). The three core pillars or principles of a water sensitive city are to:

- Use the city as a water catchment
- Support a healthy ecosystem and natural environment
- Empower citizens to make educated decisions about water

The City has embraced the pillars of a water sensitive city and has been integrating them throughout recent water-related plans and strategies. A sampling and brief description of the City's recent plans, strategies, or policies that have some relevance to water or groundwater are provided below:

- *Rain City Strategy* (City of Vancouver, 2019) – The Rain City Strategy sets out to reconfigure how the City manages surface water run-off by infiltrating precipitation close to where it falls rather than conveying it through conventional piped stormwater sewers to discrete outfalls. Appendix D of the Rain City Strategy outlines the 19 watersheds that have been identified within the city limits. Directly and indirectly related characteristics including sea level rise areas, land use, tree canopy cover, and impervious areas are also detailed for each watershed.
- *Coastal Adaptation Plan* (City of Vancouver, 2018) – This plan identifies issues that may arise with the occurrence of sea level rise. One of the noted issues is the mobilization of existing soil or groundwater contamination within the estimated sea level rise floodplain. An action identified in this plan is to remove/remediate contamination in in the vicinity of the shoreline of the city.
- *Resilient Vancouver Strategy* (City of Vancouver, 2019) – This strategy notes three priority areas to work in to improve Vancouver's resilience. Those areas include thriving neighbourhoods, a proactive collaborative city, and safe/adaptive buildings and infrastructure. In terms of relevance to water, the strategy notes that overland/coastal flooding may occur as a result of climate change and subsequent sea level rise.

- *Groundwater Management Bulletin* (City of Vancouver, 2020) – This document is intended to be used by groups or individuals submitting either a land rezoning or development permit application. This bulletin details what activities or proposals may require a hydrogeologic study and what should be included in that study. This bulletin does not provide a directive framework in the same way as the plans or strategies listed above, but rather it provides direction and outlines requirements for land developments.

From review of the above, there are multiple City documents that have some mention or insinuation of groundwater. The details of how groundwater will play a role in the plans/strategies/policies listed above has not been thoroughly documented to date. As the City works to break down its historically siloed approach to water management, opportunities to collaborate between the City's various departments and initiatives may become apparent.

2.3 Geologic/Hydrogeologic Setting

This section briefly describes the geologic and hydrogeologic setting in the Vancouver area. Other groundwater-related features found in the region are also outlined in this section.

2.3.1 Geologic Setting

The geologic strata found in the Vancouver area are briefly described in this section. The strata listed below are ordered from shallowest to deepest. Unless otherwise noted, the descriptions are adapted from the geologic map *Surficial Geology Vancouver British Columbia* (Geological Survey of Canada, 1979).

- Fill – Fill material was placed in the False Creek Flats area as well as the Vancouver port lands over the last century.
- Quaternary aged peat – pockets of peat up to 8 metres (m) thick are found in the Vancouver area, primarily in eastern Vancouver neighbourhoods such as Hastings-Sunrise, Riley Park, and Victoria-Fraserview
- Fraser River Sediments – The Fraser River sediments are composed of Quaternary aged silts and clay loam. These sediments are primarily found in southern Vancouver adjacent to the Fraser River.
- Capilano Sediments – The Capilano Sediments are composed of Pleistocene aged medium to coarse grained sands 1 to 5 m in thickness. Within the Vancouver city limits, the Capilano

Sediments are primarily found in Arbutus Ridge, Kitsilano, Shaughnessy, and southern Vancouver.

- Vashon Drift – The Vashon Drift deposits are widespread across in the Vancouver area. It is composed of glacial till with mixed sands, gravels, and glaciolacustrine stony silt lenses. In the Vancouver area it is at least 10 m thick.
- Quadra Sands – The Quadra Sands are composed of fluvial cross-bedded sands with silt and gravel lenses. Exposed portions of the Quadra Sands can be seen along the coastline bluffs around the perimeter of the University of British Columbia (UBC) grounds.
- Cascade volcanic rocks – Outcrops from Tertiary aged andesite lava flows can be found in some locations throughout Vancouver. The outcrops can be found in Queen Elizabeth Park, along Great Northern Way, and Siwash Rock in Stanley Park (Armstrong, 1990).
- Kitsilano Formation – The late Cenozoic to Tertiary aged Kitsilano Formation is composed of sandstones, shales, conglomerates, and siltstones.

2.3.2 Hydrogeologic Setting

The hydrogeologic features found in the Vancouver area are briefly described in this section. The features listed below are ordered from shallowest to deepest.

- Fraser River Sediments Aquifer – The Fraser River Sediments Aquifer is an unconfined aquifer that extends along the southern areas of Vancouver, Burnaby, and the westernmost corner of New Westminster. The Fraser River Sediments Aquifer is registered as Aquifer #45 in the Province of BC's Aquifer Classification System database. It is noted that this aquifer has moderate productivity and high vulnerability. (Province of British Columbia, 2007) (Province of British Columbia, 2020)
- Quadra Sands Aquifer – The Quadra Sands Aquifer is a confined aquifer that extends from the UBC grounds to Vancouver, Burnaby, Port Moody, and Coquitlam. Groundwater levels are found at depths ranging from 5 m to 87 m below ground surface (bgs). The Quadra Sands Aquifer is registered as Aquifer #49 in the Province of BC's Aquifer Classification System database. It is noted that this aquifer has moderate productivity and moderate vulnerability. (Province of British Columbia, 2007) (Province of British Columbia, 2020)
- Bedrock aquifer – The well construction report for Well Tag Number 114335 indicates the presence of a bedrock aquifer within the Kitsilano Formation. At this location, bedrock is

encountered at approximately 33.5 m bgs and the static groundwater level at the time of completing the well was approximately 32 m bgs. (Forasse, 2016) It does not appear that the extent or characteristics of this bedrock aquifer have been further investigated. This aquifer is also not included in the Province of British Columbia's aquifer database.

2.3.3 Other Hydrogeologic Features

The Vancouver area is also home to some other hydrogeologic features. The City has designated some of these features as areas of concern. These features include the Well Drilling Advisory Area, Sewershed within the Cambie Corridor, the Designated Floodplain, and Soft Soils. For each of these areas, a hydrogeologic assessment may be required as part of rezoning or development application submissions. The Vancouver area has also experienced and still experiences groundwater contamination events. Each of these groundwater related features is discussed further in this section.

In southern Vancouver, the Province of British Columbia has issued a drilling advisory for flowing artesian conditions. As mentioned above, the City has included this Well Drilling Advisory Area as one of its hydrogeologic areas of concern. The Well Drilling Advisory Area extends from the University Endowment Lands (UEL) along the southern coast of Vancouver, Burnaby, and New Westminster. The advisory area covers portions of both the Fraser River Sediments Aquifer and the Quadra Sands Aquifer. At least four borings have been advanced in this area where flowing artesian conditions were encountered (Province of British Columbia, 2017).

In the vicinity of Cambie Street, notable re-development of the area continues to occur likely due the proximity of the Canada Line rail-based rapid transit system. Due to this increased development, the sewer main along Cambie Street is nearing its capacity. As the sewer cannot handle additional unnecessary discharge such as groundwater from building foundations, the Sewershed within the Cambie Corridor is included as an area of concern (City of Vancouver, 2020).

The City has also identified areas along the coastline as the Designated Floodplain, as these areas may be overtaken by sea level rise or storm surges if no preventative or mitigation actions are taken. The City is planning for 0.5 m of sea level rise by 2050 and an additional 0.5 m (1 m in total) of sea level rise by 2100. Some of the neighbourhoods most susceptible to rising sea levels includes Southlands, False Creek Flats, Port of Vancouver, and Spanish Banks/Jericho Beach areas (City of Vancouver, 2019). The lands within the Designated Floodplain are also more likely to

encounter significant quantities of groundwater, therefore the City has designated this area as a groundwater area of concern.

As well, pockets of soft soils can be found throughout Vancouver that could be impacted by changing water elevations. The City has designated specific locations as potential areas that may be susceptible to changing groundwater elevations. A majority of the locations included in this category of areas of concern are located in eastern Vancouver.

The locations of the Well Drilling Advisory Area, Sewershed within the Cambie Corridor, Designated Floodplain, and Soft Soils areas are illustrated in Appendix A.

Finally, given the urban setting of Vancouver, there have been multiple occurrences of groundwater contamination over the years. Some examples of contaminating activities include, but are not limited to, industrial operations resulting in contamination along Vancouver's shoreline in the early 1900s and point source contamination events from gas stations or dry-cleaning facilities throughout the 1900s and 2000s. Areas of known contamination should be managed in accordance with the BC Contaminated Sites Regulation to achieve either numerical or risk-based clean-up.

3. Research Approach

This section provides an overview of the methodology used to carry out this project. The steps taken to complete the project include a literature review, selection of evaluation criteria, and evaluation of the groundwater related actions found in the literature review. Following the evaluation of actions, some additional actions were also "hand-selected" by the author and provided as additional recommended actions. A description of each of these steps is provided in the following sub-sections.

3.1 Literature Review

The literature review was initiated by reviewing City of Vancouver plans, strategies, and other documents that have some relevance to water or groundwater. This was completed to understand the primary themes or issues that the City has prioritized regarding water. The plans and strategies that were reviewed are as follows:

- *Greenest City Action Plan* (City of Vancouver, 2015)
- *Climate Change Adaptation Strategy* (City of Vancouver, 2012)

- *Climate Change Adaptation Strategy 2018 Update and Action Plan* (City of Vancouver, 2018)
- *Rain City Strategy* (City of Vancouver, 2019)
- *Coastal Adaptation Plan* (City of Vancouver, 2018)
- *Resilient Vancouver Strategy* (City of Vancouver, 2019)
- *Groundwater Management Bulletin* (City of Vancouver, 2020)

The next portion of the literature review included the review of groundwater or water management plans, strategies, and/or policies that have been prepared in other jurisdictions. In April/May 2021 the City conducted a survey of groundwater subject matter experts (including consultants, academics, and government employee) and received 146 responses. One of the questions in the survey asked respondents to provide their suggestions for groundwater management plans/strategies/policies prepared for other jurisdictions. Some of the literature suggested by the subject matter experts was included in the literature review completed for this project. Other plans/strategies/policies were found through online research and were also reviewed for this project. Due to time limitations, not all of the groundwater related documentation available could be reviewed. The documentation that was selected for review demonstrated one or more of the following characteristics:

- The plan/strategy/policy was specific to an urban area
- The plan/strategy/policy was specific to a coastal marine area
- The plan/strategy/policy was specific to an area with a similar climatic setting
- The body that prepared the plan/strategy/policy is a known leader of water/groundwater management
- The body that prepared the plan/strategy/policy relies on groundwater as a primary water source

The documents that were selected for review are as follows:

- *South Westside Basin Groundwater Management Plan* (San Francisco Water, 2012)
- *Groundwater Basins Master Plan* (Water Replenishment District of Southern California, 2016)
- *Redmond-Bear Creek Valley Ground Water Management Plan* (Redmond Bear Creek Groundwater Management Committee, 1999)

- *Portland Water Bureau Strategic Plan* (Portland Water Bureau , 2019)
- *Columbia South Shore Well Field Wellhead Protection Area* (City of Portland, 2017)
- *Drinking Water and Watershed Protection Action Plan 2.0* (Regional District of Nanaimo, 2019)
- *Groundwater Protection Plan* (City of Chilliwack, 1997)
- *Aquifer Protection Plan* (Advisian, 2017)
- *Water Resources Protection Master Plan* (Region of Waterloo, 2008)
- *Planning for the future of the Assiniboine Delta Aquifer* (Assiniboine Delta Aquifer Management Planning Process, 2005)
- *Waterwise Perth Action Plan* (Western Austalia Government, 2020)
- *Central Region Sustainable Water Strategy* (Victoria Government, 2005)
- *Cockburn Groundwater Allocation Plan* (Western Australia Government, 2021)
- *Environmental Protection (Water Quality) Policy* (South Australia Government, 2015)
- *Basement Development* (Borough of Islington, 2016)
- *Management of the London Basin Chalk Aquifer* (Environment Agency, 2018)
- *The Environment Agency's Approach to Protecting Groundwater* (Environment Agency, 2018)
- *European Groundwater Directive* (European Union, 2006)
- *Establishing a Framework for Community Action in the Field of Water Policy* (European Union, 2000)
- *Urban Groundwater – Mobilising Stakeholders to Improve Monitoring* (International Association of Hydrogeologists, 2019)
- *Resilient Groundwater and Cities* (International Association of Hydrogeologists, 2015)
- *Blue-Green Infrastructure for Sustainable Urban Stormwater Management – Lessons from Six Municipality-Led Pilot Projects in Beijing and Copenhagen* (Liu, 2019)

During the review of the documentation listed above, actions related to improving the understanding of aquifers, groundwater protection, and groundwater management were shortlisted for further evaluation for this project. The actions that were selected for evaluation demonstrated one or more of the following characteristics:

- The action is something not currently being carried out by the City

- The action helps to rectify an issue that the City is working to address, but has not completely solved
- The action helps to rectify a known issue that the City is not currently addressing
- The action helps to rectify an emerging issue that the City is not currently addressing

In some cases, similar or complimentary actions were noted from different plans/strategies/policies. The similar actions were recorded separately as some of them have their own nuances that would otherwise be lost if they were not listed separately.

The shortlisted actions are discussed further in Section 4.1.

3.2 Evaluation Criteria Selection

Twelve evaluation criteria were used to assess the actions that were shortlisted from the literature review. The evaluation criteria were selected to provide a well-rounded set of criteria that includes technical, sociopolitical, and forward-thinking considerations. The City's initiative to take a more holistic stance with water management was also kept in top of mind to select the evaluation criteria. It is noted that these evaluation criteria were developed for this report specifically and are not necessarily intended to be used in the groundwater management strategy. The definitions for selected evaluation criteria are provided below:

1) Applicability to Vancouver – Is the action implementable in terms of the City's hydrogeologic and urbanized setting?
2) Innovative – Is the action a creative solution, or one that hasn't been implemented as frequently in other jurisdictions but is still promising?
3) Strategic – Does the action align with existing City policies as well as emerging priorities?
4) Collaborative – Will the action enable partnerships and/or information sharing with groundwater experts, other local or senior governments, and the various City departments interested in groundwater? Stakeholder involvement is a key component of successful groundwater management.
5) Integrated – Groundwater, rainwater, surface water, drinking water, wastewater, and receiving water bodies are inextricably linked; therefore actions should ideally consider them holistically.

6) **Efficient** – Due to a limited City budget, cost-effective actions that have the largest impact should be prioritized. Emphasis will also be given to elegant solutions that address a number of threats, have synergies with other actions, or that produce additional co-benefits.
7) **Sustainable** – Ecosystem health is a key consideration, and actions should ideally aim to protect aquifers from contamination and depletion while also supporting urban streams, receiving water bodies, trees, and wildlife – all of which are dependent on, or are impacted by, groundwater.
8) **Resilient** – Because groundwater has implications for water security and community well-being, actions will be prioritized that can contribute to the city's resilience, including to climate change and in emergencies such as earthquakes.
9) **Awareness and education** – Does the action have the potential to help educate residents, businesses, City staff, or other stakeholders about groundwater and how to protect it?
10) **Evidence based** – Is the action informed by the best available science, high quality data, or traditional ecological knowledge?
11) **Address emerging issues** – Is the action proactive in addressing emerging issues such as saltwater intrusion, "iceberg"[1] houses, geo-exchange systems, or stormwater infiltration water quality?
12) **Effectiveness** – How successful is the action likely to be in achieving its objective and/or meeting the City's overall groundwater goals?

The criteria listed above were also weighted using a scale of 1 to 3. Criteria that align best with the City's priorities and interests were scored 3 and less pertinent criteria were scored 1. The weighting for each criterion is summarized below:

Criterion	Weighting	Criterion	Weighting
Applicability to Vancouver	3	Sustainable	3
Innovative	1	Resilient	3
Strategic	3	Awareness and education	2
Collaborative	2	Evidence based	2

[1] Iceberg houses are single-family homes that have basements that may be greater than 1 storey in depth, have a lateral extent greater than the ground-level footprint of the house, or both (The Tyee, 2021)

Integrated	2	Address emerging issues	2
Efficient	2	Effectiveness	3

3.3 Action Evaluation

Once the evaluation criteria were selected and weighted, the shortlisted actions were then assessed. To evaluate each of the shortlisted actions, the actions were compared against each criterion described in Section 3.2 and scored "Yes" or "No". In total, of 2,160 scoring decisions (180 actions x 12 criteria) were made to complete the evaluation. During the evaluation process it was noted that the scoring was somewhat subjective at times, making it difficult to definitively score an action against the criteria. Furthermore, during the development of the groundwater management strategy, a different set of evaluation criteria may be used which will have an effect on how relevant or applicable the actions recommended in this report may be for the strategy.

The best possible score for an action (i.e. if the action scored "Yes" for all of the criteria) was 28. For the purpose of this project, actions that scored greater than 24 were put forwards as actions for further consideration. Twenty-four was used as the cut-off score as these actions scored at least 85% and kept the number of recommended actions reasonable given the time constraints of this project. It should be noted that the actions recommended are not intended to provide a comprehensive list of all the actions that should be included in the City's groundwater management strategy; the intent was instead to recommend leading or particularly relevant actions to the City. It is also noted that the actions that scored less than 24 are not considered "bad" actions; they simply did not meet as many of the selected criteria.

Three additional actions are also provided as recommendations to be considered for the groundwater management strategy. These additional actions are based on the author's professional opinion in terms of relevance to Vancouver and creating a larger impact with a smaller action.

4. Results

This section describes the results of the literature review and the evaluation of the actions selected from the literature review.

4.1 Actions Summary

The actions that were selected from the literature review were compiled in a single document. Each action is labelled to indicate if the primary aim of the action is to understand, manage, or protect groundwater. The actions, source documents, and developer of the water management plan/strategy/policy are summarized in Appendix B. It is noted that the actions listed in Appendix B are paraphrased from their original document unless they are surrounded by quotation marks (“ “).

4.2 Actions Scoring

The score that each action received is noted in Appendix B. From review of Appendix B, a total of 22 actions scored 24 or greater. Some of the actions that scored 24 or higher were similar or complimentary to each other; therefore those actions were combined together and sometimes paraphrased to create a hybrid action. As some of the actions used to create the hybrid actions were complimentary rather than similar, these actions may not necessarily have the same score, but still scored greater than 24. Only the actions that scored greater than 24 were used in the hybrid actions. In some cases, the wording of the action has been adjusted between the Appendix B and Appendix C so the action better suits Vancouver’s setting. From the scoring evaluation, 12 actions made it to the list of recommended actions. Appendix C lists these 12 of the recommended actions and also notes which actions from Appendix B were combined to create the hybrid actions.

4.3 Recommended Actions Based on Evaluation Criteria Score

Below are the 12 actions (in italics, and in no particular order) that are recommended based on their score from the evaluation process. The corresponding action number(s) from Appendix B is also noted with each action, along with the action’s score out of 28. For the actions where multiple actions were combined to create a hybrid action a range of scores is noted where applicable. The bullet below each action provides additional rationale or a description for why the action is relevant to Vancouver.

Actions 4, 6, 10, 18, 20 (score: 24 to 28) – Create a tiered system to permit the construction of green infrastructure for stormwater infiltration (i.e. infiltrating stormwater from building roofs may have less stringent requirements than stormwater from roads, parking lots, etc.). For new green infrastructure systems, a stormwater assessment should be completed to determine what

constituents of concern may be present and if pre-treatment is needed. For the use of green infrastructure, the suitability of the near surface conditions must be evaluated. In addition to the use of green infrastructure, review areas where stormwater is noted to infiltrate naturally near roadways, parking lots, etc. and complete stormwater management upgrades (e.g. pre-treatment system) as needed to prevent the infiltration of potentially contaminated water. (San Francisco Water, 2012) (Environment Agency, 2018) (Redmond Bear Creek Groundwater Management Committee, 1999) (Liu, 2019)

- The usage of green infrastructure in Vancouver is becoming more common for managing stormwater from roads or other impervious surfaces. The intent behind this is to help fulfill the goal of infiltrating as much precipitation as possible close to where it falls. It also has been demonstrated that the use of green infrastructure prevents contaminants such as tire particulates, heavy metals, and petroleum hydrocarbons that tend to be found in roadway run-off from reaching the receiving body at the sewer outfall (e.g. False Creek or the Fraser River). However, some green infrastructure systems have been noted to be more effective than others; therefore, there is the possibility that less effective green infrastructure systems could unintentionally convey contaminants to underlying aquifers. To protect Vancouver's groundwater, it is pertinent to understand to what extent the stormwater may be contaminated and how much pre-treatment is required prior to infiltration. Furthermore, the infiltration capacity of the native underlying soils should be investigated to determine if it can handle the estimated volume of stormwater to be infiltrated. This investigation should also include geotechnical considerations to ensure that existing structures such as building foundations or underground parking will not be negatively impacted by the increased stormwater infiltration. The required maintenance schedule for each green infrastructure system should also be developed and followed to ensure the designed contaminant removal ability of the system remains consistent.

Action 2 (score: 26) – If grey water is used for irrigation, ensure it is not used in wellhead protection areas. Complete groundwater monitoring in areas where wastewater is used for irrigation. (International Association of Hydrogeologists, 2019)

- Some of the green infrastructure systems include a component that irrigates urban trees along roadways (City of Vancouver, 2019). If the City someday plans to use groundwater as a supplementary water source, the potential well locations should be targeted prior to planning

or constructing any green infrastructure systems in those areas. Alternatively, if a groundwater extraction well is installed downgradient of a green infrastructure irrigation system an adequate buffer zone with groundwater monitoring wells should be designated. The size of the buffer zone should be based on the local estimated groundwater travel times. This is not a particularly prominent issue for the City at this time, however this framework for establishing wellhead protection areas/buffer zones can be developed to proactively manage groundwater in Vancouver.

Actions 8, 9 (score: 26) – Source water must be of acceptable quality before being used to recharge an aquifer via managed injection[2]. A permit must be granted before a managed injection site can be constructed. Applications for a managed injection site must have a hydrogeologic assessment, risk assessment, and operating plan. A component of the operating plan must include a monitoring plan. Managed injection sites may be used for ensuring surface water levels remain at acceptable levels, mitigating saltwater intrusion, "disposal" of treated wastewater, and/or re-injection of groundwater diverted from underground developments. (Western Austalia Government, 2020)

- Managed water injection sites in Vancouver do not appear to be widely used at this time, however there also does not appear to be any legislation prohibiting the use of injection wells. It appears the primary use of injection wells around Vancouver is to divert groundwater from underground developments (e.g. parking garages) and re-injecting that water downgradient of the development. There may be the opportunity for the City to designate specific zones or areas where groundwater injection is allowed. Furthermore, this may be an opportunity of the City to develop protocols to require the long-term operation of injection wells rather than these wells being used as a temporary measure. On a similar note, the Vancouver Building By-law could be amended to include requirements for groundwater diversion and/or injection.

Actions 3, 5, 7 (score: 26) – Identify areas sensitive to saltwater intrusion and set groundwater elevation limits for the interface based on the sensitive area locations. Monitor the salinity of

[2] Injection is the process of using pressure to drive water directly into an aquifer via a well (i.e. the water is injected beneath the water table)

shallow/coastal groundwater in addition to groundwater elevations. Develop a saltwater intrusion management plan if needed. (San Francisco Water, 2012) (Victoria Government, 2005) (Western Australia Government, 2021)

- Sea levels are anticipated to increase by 1 m by 2100 (City of Vancouver, 2019). In order to mitigate the potential implications that sea level rise may have on the built environment, a baseline understanding of the groundwater elevations and salinity along the coastline must first be developed. Once the baseline understanding has been established, the effects of sea level rise on groundwater elevations should be modelled to assist with the development of a saltwater intrusion management plan. The plan should also include the potential effects of rising groundwater levels and salinity due to saltwater intrusion on existing structures as well as mitigation or adaptation strategies. A similar action to monitor groundwater near the shoreline has been put forth in the City's Coastal Adaptation Plan; therefore there may be the opportunity for cross-department/branch collaboration within the City.

Action 22 (score: 24) – Create a standard groundwater elevation and geochemistry monitoring program. Share the groundwater monitoring data with other government bodies or stakeholders (San Francisco Water, 2012)

- Groundwater elevations and flow directions in the Vancouver area are not well understood. A rule of thumb is to assume the groundwater flow direction and elevations generally mirror ground surface topography; however a significant portion of the city is covered with impervious surfaces which may have altered the natural groundwater flow pattern. There is also a limited understanding of the geochemistry of groundwater in the Vancouver area. Groundwater monitoring in Vancouver should be undertaken create a baseline understanding of the groundwater regime in the area. Seasonal fluctuations in groundwater elevations as well as groundwater geochemistry should be included in this monitoring program. The Province of BC manages an observation well network; however there are currently no observation wells located in Vancouver's city limits (Province of British Columbia, n.d.). There may be the opportunity to partner with the Province to share monitoring costs and to contribute to the observation well network.

Action 15 (score: 25) – Create water level limits based on minimum levels needed in surface water bodies in the area as well as where the freshwater/seawater interface is within the groundwater near the shore (Western Australia Government, 2021)

- To create water level limits, a water level monitoring program for surface water bodies will need to be employed in conjunction with the groundwater elevation monitoring program. The relationship between surface water bodies and groundwater (e.g. whether the stream is a gaining or losing stream) should be characterized. The water level limits may seasonally fluctuate based on the relationship between groundwater and surface water. It is understood the City is exploring the option of daylighting historic streams and creeks that are currently conveyed through piped infrastructure. If this comes to fruition, creating the water level limits to protect surface water bodies will be especially relevant.

Action 17 (score: 25) – Consider both groundwater and surface water when completing works that are intended to affect one of these bodies. (i.e. work done to isolate surface water movement may have unintended consequences for groundwater movement, and vice versa) (International Association of Hydrogeologists, 2019)

- Similar to the action above, groundwater and surface water are intrinsically linked; therefore the relationship between groundwater and surface water needs to be well understood to understand how current and new developments affect both of these water sources. As noted above, the City may opt to uncover historic streams that are currently flowing in piped systems. The implications to groundwater elevations that re-naturalizing these streams might have should be considered in this investigation.

Action 21 (score: 24) – Review groundwater allocation limits regularly and make adjustments if needed (Assiniboine Delta Aquifer Management Planning Process, 2005)

- If groundwater extraction and use becomes more widespread in Vancouver, it may be pertinent for the City to work with the Province to designate specific areas with groundwater extraction limits based on characteristics such as the sustainable yield of the aquifer, proximity to surface water bodies, or land use. These groundwater extraction limits could be time-sensitive based on a short-term seasonal approach, a long-term land development approach, or both. If possible, the City should work with the Province to include specific end

dates or renewal dates for the groundwater extraction licenses to allow the City and the Province to review if the groundwater extraction rates are still appropriate.

Actions 12, 13, 14, 16 (score: 25) – Incorporate groundwater protection and water policy into long-term city plans/legislation such as the Official Community Plan or local by-laws. Zoning by-laws should also be amended to limit or prohibit hazardous activities (in terms of groundwater contamination) in vulnerable groundwater areas. This could be done by changing the land use rules or the land use itself. (Advisian, 2017) (City of Chilliwack, 1997) (Victoria Government, 2005) (Regional District of Nanaimo, 2019)

- A strong measure that can be used to protect groundwater quality is to zone certain land uses to restrict potentially harmful activities in vulnerable groundwater areas. This measure could be used to designate groundwater protection areas, groundwater extraction areas, groundwater injection areas, restrict boring in the well drilling advisory area, or to restrict groundwater extraction if the groundwater is contaminated. A more specific requirement that could be included in the zoning by-law is to require a certain percentage of permeable area for new developments.

Action 1 (score: 28) – Educate City staff about the importance of protecting groundwater and how it can be done. (City of Chilliwack, 1997)

- The City of Vancouver employs thousands of staff throughout various departments or branches. By educating other City staff about groundwater and groundwater protection in Vancouver, the opportunity may arise to collaborate with other City departments to meet the groundwater projection objectives. The City may also have the opportunity to then educate the public about groundwater at some point in the future. Furthermore, City staff can be empowered to pass along this knowledge to their family, friends, and colleagues to further disseminate the message about the need for groundwater protection.

Action 19 (score: 24) – Collaborate with Indigenous Nations to ensure that the groundwater strategy aligns with social, spiritual, and customary objectives (Victoria Government, 2005)

- Indigenous Nations are known to have their own unique relationships with water and groundwater. As part of the City's efforts to reconcile with local Indigenous peoples, the

Musqueam, Squamish, and Tsleil-Waututh nations should be consulted to collaborate on groundwater protection strategies.

Action 11 (score: 24) – Work with the fire department to phase out the use of fluorinated fire-fighting foam. An example of the phasing out sequence could start with no longer using the foams for training exercises, then banning the sale of the foams, then ceasing the use of fluorinated foams altogether (South Australia Government, 2015)

- Per- and polyfluoroalkyl substances (PFAS) is a group of chemicals that have many applications including water repellant clothing or packaging, fire retardants, and fire-fighting foams. PFAS are considered "forever chemicals" as they are known carcinogens that bioaccumulate in plant and animal tissue (Government of Canada, 2021). PFAS have been found accumulating in groundwater as well as ice caps, drinking water, sediment, and the ocean (Ottawa Citizen, 2020). In Canada, certain types of PFASs have been banned from fire-fighting foams; however other PFASs may still be in use (Government of Canada, 2018). Other jurisdictions in the United States and Australia have enacted legislation banning the use of PFAS-containing fire-fighting foams. In Vancouver, the local fire department has the opportunity to become a local leader by being the first municipal jurisdiction in Canada to prohibit the use of all PFAS-containing fire-fighting foams. Furthermore, as the City is exploring the option of using groundwater as a drinking water resource it is in the City's best interest to prevent PFAS contamination from entering local aquifers.

4.4 Additional Recommended Actions Based on Professional Opinion

In addition to the 12 actions provided in Section 4.2, three additional actions are recommended to be considered for the groundwater management strategy. The actions did not score high enough to be included in Section 4.2, but are recommended based on the author's professional opinion. These additional actions may help to address emerging as well as long-standing issues with regards to groundwater protection.

The additional actions are listed below (in no particular order) in italics and are further expanded upon in the bullet below each action. The corresponding action number from Appendix B is also noted with each action. These actions are also listed in Appendix C.

Action 110, 125 (score: 17) – Require land sellers to disclose the location of unused wells. Require the disclosure of the location and status of wells on the property for rezoning/land use applications. Locate and record the position and condition of abandoned wells. Create a grant program for land/well owners to access to help fund decommissioning activities for abandoned, irreparably damaged, or unused wells. (San Francisco Water, 2012) (Redmond Bear Creek Groundwater Management Committee, 1999)

- For land redevelopment applications, Phase 2 Environmental Site Assessments (ESA) are often required for the land owner to secure bank loans or insurance. Completing a Phase 2 ESA can include monitoring well installation to determine if groundwater contamination is present. Under the BC Groundwater Protection Regulation, it is not required to register monitoring wells with the Province's well database or decommission monitoring wells within a certain period of time, therefore there may be hundreds if not thousands of unaccounted for monitoring wells in Vancouver. Secondly, prior to the instatement of the BC Groundwater Protection Regulation, domestic well owners were not required to register their wells with the Province (Province of British Columbia, 2021). There may be a chance that older domestic wells in Vancouver have been abandoned as properties have been sold and purchased over the history of the city. Both these abandoned domestic and monitoring wells have the potential to serve as conduits for contaminates to enter the aquifer. To help mitigate the risk of groundwater contamination via unused wells, the wells should be decommissioned in accordance with the BC Groundwater Protection Regulation.

Action 91 (score: 18) – Enact a by-law that indicates a basement and/or other structures should cumulatively occupy less than 50% of the original garden/unbuilt upon area, and be smaller in area than the original footprint of the dwelling, whichever the lesser. A basement should not involve excavation of more than one (1) storey below the lowest original habitable floor level. The height of a basement should not exceed 3 m floor to ceiling height. (Borough of Islington, 2016)

- "Iceberg homes" are single-family homes with large basements that can have multiple levels and/or extend laterally outside of the ground surface footprint of the house. These houses have become a known issue in London, England and are beginning to appear in Vancouver (The Tyee, 2021). If these oversized basements extend below the groundwater table, they may adversely influence the groundwater flow patterns in the vicinity of the house. As the construction of an oversized basement only provides benefit to the few inhabitants of a

single-family home (as opposed to a similarly deep excavation for a high-density condominium development), it is pertinent to enact legislation that prevents the construction of oversized basements before it becomes a larger issue.

Action 46 (score: 21) – In open-loop geo-exchange heating/cooling systems, the temperature of "injection" water cannot be 10 ℃ greater than the natural groundwater temperature or greater than the maximum threshold of 25 ℃ [whichever is less] (Environment Agency, 2018)

- In open-loop geo-exchange systems, groundwater is extracted, run through a heat pump and re-injected to the same aquifer. When the geo-exchange system is in the cooling mode, the temperature of the re-injected groundwater will be greater than the ambient aquifer temperature. To prevent excessive heating of the aquifer, temperature limits for the injection water should be put in place

5. Limitations & Other Observations

Through completing the literature review, some limitations were encountered and observations regarding groundwater management in other jurisdictions were noted. The limitations and observations are further described below:

- The plans/strategies/policies that were reviewed were limited to documents available in English. For example, Copenhagen and Tokyo are both jurisdictions suggested by the survey respondents described in Section 3.1, however the literature review undertaken for this project was limited to journal articles and/or presentations in English rather than the jurisdiction's groundwater management document.
- In many cases, the groundwater management plans are often prepared for jurisdictions that use groundwater as a drinking water resource. Generally speaking, the groundwater that those management plans are protecting is of good quality in terms of contamination. As noted in Section 2.3.3 there are multiple areas of groundwater contamination throughout Vancouver; therefore particular attention will be required when assigning groundwater protection and use measures. This appears to put the City in a unique position if it elects to harvest its groundwater as it may only be possible to extract smaller pockets of groundwater rather than drawing on a large groundwater zone.

- During the initial review of groundwater management plans available, it was noted that some management plans are specific to an aquifer or watershed rather than being limited to a city boundary. As the City works to develop its groundwater management strategy, extra coordination will be needed between the City and the other local governments that overlie the same aquifers to ensure each other's actions/activities are not counter-productive.
- The responsibility to take a proactive approach to protect/manage water resources sometimes falls on higher levels of government in other countries. For example, in 2000 the European Union (EU) instated a directive for all member states to develop watershed management plans. In most cases, either the federal or provincial/state governments of the EU member states took the lead in developing the watershed management plans; therefore a city or municipal level groundwater management strategy is less common in this part of the world.

6. Summary & Conclusions

Based on the results of the project, the actions that are recommended to be considered for inclusion in the City's groundwater management strategy generally address the following considerations:

- Understand the current state of groundwater, including the mapping of different hydrostratigraphic units and monitoring their water levels and water quality, and determining how groundwater interrelate with surface water. Groundwater elevations in Vancouver must be characterized to understand how enhanced infiltration, groundwater diversion and extraction, sea-level rise, paving of recharge zones, and climate change may impact the groundwater
- Manage groundwater elevations by understanding baseline conditions, understanding the interaction between groundwater and surface water, and establishing water level trigger limits and/or groundwater extraction limits
- Protect groundwater from new as well as existing potential threats such as saltwater intrusion or contamination as our built environment evolves

From the results of this project, there are countless strong and proven actions used in other jurisdictions to help understand, protect, and manage groundwater resources. To successfully

implement the management and protection groundwater actions, a strong understanding of the hydrogeologic setting of the area of interest is essential. As the occurrence and quality of groundwater in Vancouver is poorly understood, the next course of action is to characterize the groundwater regime in the Vancouver area. This includes groundwater elevations, groundwater quality, groundwater temperature, and seasonal fluctuations for each of these characteristics. This could also include an investigation of the apparent bedrock aquifer in the Kitsilano Formation.

Vancouver has historically been on the forefront of sustainability issues, including on climate change and rainwater management. The City now has an opportunity to become a leader on urban groundwater protection, and to advance a collaborative and holistic approach to aquifer management. This type of approach would allow the City to minimize groundwater-related risks, support ecosystem health, enable sustainable groundwater use, and contribute to Vancouver's resilience. Moving forward, it is hoped that some of the recommendations and examples from other jurisdictions in this report will assist the City as it develops its groundwater management strategy.

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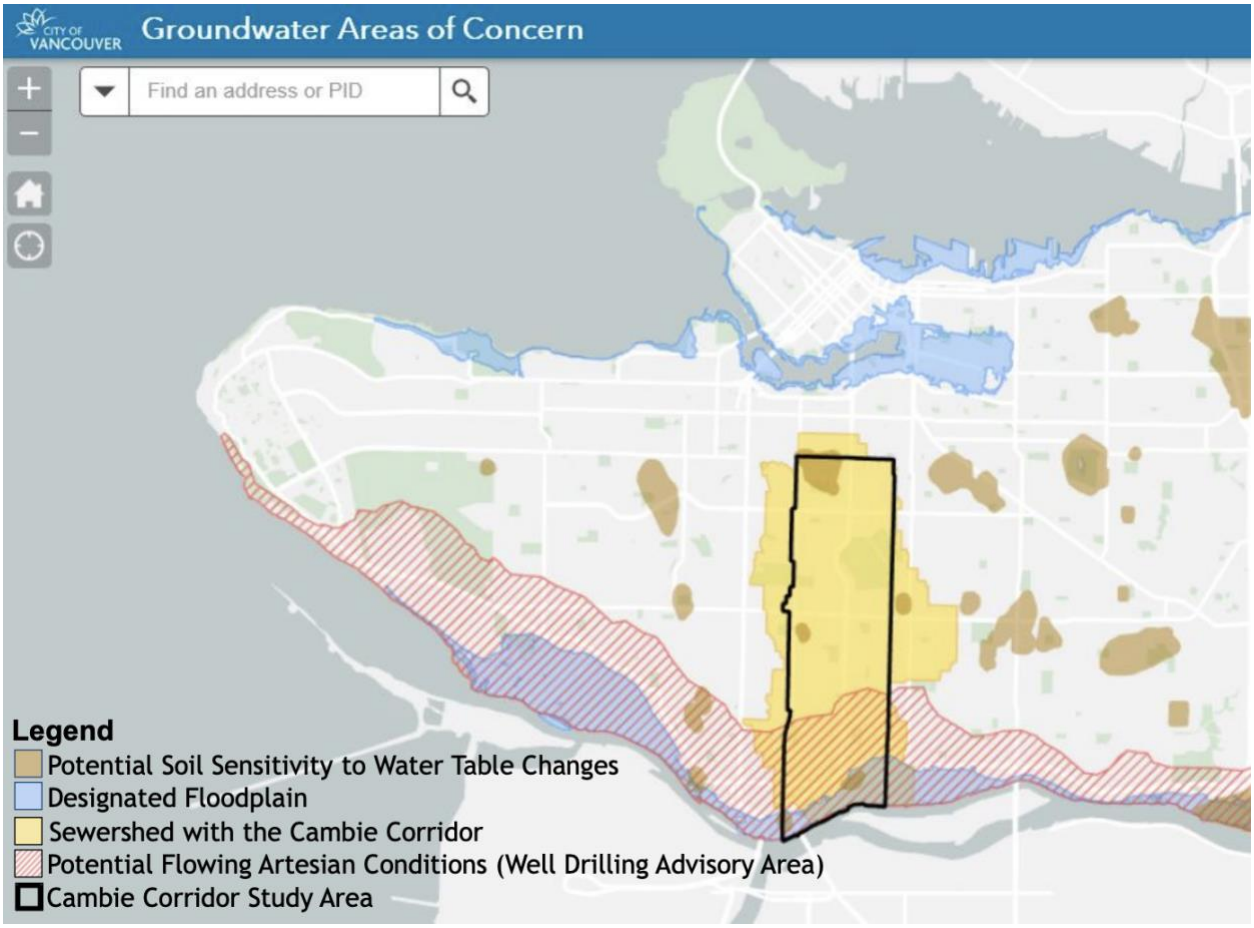
Appendix A – Groundwater Areas of Concern



Source: https://maps.vancouver.ca/portal/apps/webappviewer/index.html?id=ba64dbf9a80341aa8527538fe55da80e (City of Vancouver, 2020)

Appendix B – Actions Summary

Action #	Goal/action	Primary Aim (understand/ protect/ manage)	Document Name	Location or Source	Evaluation Criteria (and weighted point value)												Total Score (Out of 28)	Link
					Applicability to Vancouver (3)	Innovative (1)	Strategic (3)	Collaborat -ive (2)	Integrated (2)	Efficient (2)	Sustainable (3)	Resilient (3)	Awareness and Education (2)	Evidence based (2)	Address emerging issues (2)	Effective-ness (3)		
1	Educate City staff about the importance of protecting groundwater and how it can be done.	Protect	Groundwater Protection Plan	Chilliwack, BC	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	**28**	https://www.chilliwack.com/main/attachments/Files/2400/Goundwater%20Protection%20Plan%20District%20of%20Chilliwack.pdf
2	If wastewater is used for irrigation, ensure it is not used in wellhead protection areas. Complete groundwater monitoring in areas where wastewater is used for irrigation	Protect	Urban Groundwater – Policies and Institutions for Integrated Management	Global Water Partnership article	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	**26**	https://www.gwp.org/globalassets/global/toolbox/publications/perspective-papers/05-urban-groundwater---policies-and-institutions-for-integrated-management.pdf
3	Develop a saltwater intrusion management plan if needed	Manage	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	**26**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104
4	Determine the suitability of near surface conditions for the use of green infrastructure and stormwater infiltration	Protect	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	**26**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104
5	Monitor salinity of shallow/coastal groundwater	Understand	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	**26**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central

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6	For sustainable drainage infiltration systems that collect run-off from roads, parking areas, or public areas the following is required: 1) meet UK standards/guidelines 2) complete a hydrogeologic risk assessment to determine if contaminants may be present and what pre-treatment is needed	Protect	UK The Environment Agency's Approach to Protecting Groundwater	United Kingdom	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	**26**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/692989/Envirnment-Agency-approach-to-groundwater-protection.pdf
7	Identify areas sensitive to seawater migration and set groundwater elevation limits for the interface based on the sensitive area locations	Manage	Cockburn Groundwater Allocation Plan	Perth, Western Australia, Australia	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	**26**	https://www.wa.gov.au/sites/default/files/2021-01/Cockburn%20groundwater%20allocation%20plan.pdf
8	Source water must be of acceptable quality before being used to recharge an aquifer via managed infiltration or injection	Protect	Water and Environmental Considerations for Managed Aquifer Recharge Operations in Western Australia	Western Australia, Australia	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	**26**	https://www.wa.gov.au/sites/default/files/2021-01/Guideline-Water-and-environmental-considerations-for-MAR-in-WA.pdf

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9	Applications for a managed infiltration/injection site must have a hydrogeologic assessment, risk assessment, and operating plan. The operating plan must include a monitoring plan. Managed infiltration/injection sites may be used for ensuring wetland water levels remain at acceptable levels, mitigating saltwater intrusion, or "disposal" of treated wastewater	Manage	Water and Environmental Considerations for Managed Aquifer Recharge Operations in Western Australia	Western Australia, Australia	Y	Y	Y	Y	y	Y	Y	Y	N	Y	Y	Y	**26**	https://www.wa.gov.au/sites/default/files/2021-01/Guideline-Water-and-environmental-considerations-for-MAR-in-WA.pdf
10	Review areas where stormwater is noted to infiltrate naturally near roadways, parking lots, etc. and complete stormwater management upgrades (e.g. pre-treatment system or diversion) as needed to prevent the infiltration of potentially contaminated water	Understand	Redmond Bear Creek Valley Groundwater Management Plan	Seattle, Washington, USA	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	**26**	https://your.kingcounty.gov/dnrp/library/1999/kcr146/kcr146_Mgmt-Plan.pdf
11	Ban on fluorinated firefighting foams enacted in January 2018 with a 2 year grace period for users to find alternatives	Protect	Environment Protection (Water Quality) Policy 2015	South Australia, Australia	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	**26**	https://www.epa.sa.gov.au/environmental_info/perfluorinated-compounds#:~:text=PFAS%20in%20South%20Australia,the%20Environment%20Protection%20Act%201993.
12	Incorporate groundwater protection into Official Community Plan or zoning bylaw	Protect	Aquifer Protection Plan	White Rock, BC	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	**25**	https://www.whiterockcity.ca/DocumentCenter/View/2017/2018-Aquifer-

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																		Protection-Plan-PDF?bidId=
13	Revise the Official Community Plan to limit potentially hazardous activities (in terms of groundwater contamination) to less vulnerable groundwater areas	Manage	Groundwater Protection Plan	Chilliwack, BC	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	**25**	https://www.chilliwack.com/main/attachments/Files/2400/Goundwater%20Protection%20Plan%20District%20of%20Chilliwack.pdf
14	Integrate water policy with other long term city plans (e.g. Official Community Plan)	Manage	Drinking Water and Watershed Protection Action Plan 2.0 2020-2030	Nanaimo, BC	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	**25**	https://www.rdn.bc.ca/sites/default/files/inline-files/DIGITAL%20SINGLE%20PAGES_RDN-action-plan31.pdf
15	Create water level limits based on minimum levels need in wetlands and lakes in the area as well as where the freshwater/seawater interface is within the groundwater near the shore	Manage	Cockburn Groundwater Allocation Plan	Perth, Western Australia, Australia	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	**25**	https://www.wa.gov.au/sites/default/files/2021-01/Cockburn%20groundwater%20allocation%20plan.pdf
16	Change land use rules or the land use itself to protect water resources	Manage	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	**25**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central

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17	Consider both groundwater and surface water elevations when completing works that are intended to affect the water level in one of these bodies. (as work done to isolate surface water movement may have unintended consequences for groundwater movement)	Manage	Urban Groundwater – Mobilizing Stakeholders to Improve Monitoring	International Water Association	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	**25**	https://www.thesourcemagazine.org/urban-groundwater-mobilising-stakeholders-to-improve-monitoring/
18	Implement green/blue infrastructure by collecting stormwater, detaining it, and slowly releasing the water to the sewer system. Characterize stormwater quality prior to reusing stormwater for non-potable uses	Manage	Blue-Green Infrastructure for Sustainable Urban Stormwater Management—Lessons from Six Municipality-Led Pilot Projects in Beijing and Copenhagen	Copenhagen, Denmark	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	**24**	https://www.researchgate.net/publication/336137780_Blue-Green_Infrastructure_for_Sustainable_Urban_Stormwater_Management-Lessons_from_Six_Municipality-Led_Pilot_Projects_in_Beijing_and_Copenhagen
19	Collaborate with Indigenous Nations to ensure conservation strategies align with social, spiritual, or customary objectives	Manage	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	**24**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central

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20	Only permit infiltration through green infrastructure for stormwater that is collected from roofs.	Protect	Blue-Green Infrastructure for Sustainable Urban Stormwater Management—Lessons from Six Municipality-Led Pilot Projects in Beijing and Copenhagen	Denmark	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	**24**	https://www.researchgate.net/publication/336137780_Blue-Green_Infrastructure_for_Sustainable_Urban_Stormwater_Management-Lessons_from_Six_Municipality-Led_Pilot_Projects_in_Beijing_and_Copenhagen
21	Review groundwater allocation limits regularly and make adjustments if needed	Manage	Assiniboine Delta Aquifer Management Plan	Manitoba	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	**24**	http://digitalcollection.gov.mb.ca/awweb/pdfopener?smd=1&did=12371&md=1
22	Create a standard groundwater elevation monitoring program. Share the groundwater elevation data with other government bodies or stakeholders	Understand	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	**24**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104
23	Review land use in susceptible areas, particularly high recharge areas or areas more sensitive to contamination	Understand	Redmond Bear Creek Valley Groundwater Management Plan	Seattle, Washington, USA	Y	N	Y	Y	Y	Y	Y	Y	N	Y	N	Y	**23**	https://your.kingcounty.gov/dnrp/library/1999/kcr146/kcr146_Mgmt-Plan.pdf

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24	Establish groundwater protection zones in groundwater capture areas and make them into parks	Manage	Resilient Groundwater and Cities	International Association of Hydrogeologists article	Y	N	Y	Y	Y	Y	Y	Y	N	Y	N	Y	**23**	https://iah.org/wp-content/uploads/2015/12/IAH-Resilient-Cities-Groundwater-Dec-2015.pdf
25	Provide landowners in recharge areas with incentives to minimize development on their property (e.g. density transfer agreements)	Protect	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	**23**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104
26	Protect against climate change by developing groundwater protection plans to address low flow scenarios	Manage	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	**23**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central
27	Protect groundwater dependent ecosystems	Protect	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	**23**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central
28	Principles for water extraction should be created to extract water sustainably	Manage	Establishing a Framework for Community Action in the Field of Water Policy	Europe	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	**23**	https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF

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29	Treated effluent from sewage treatment plants is encouraged to be infiltrated to the shallow subsurface rather than directly discharged to a surface water body to help replenish the aquifer. The infiltration area must be appropriately designed	Protect	UK The Environment Agency's Approach to Protecting Groundwater	United Kingdom	N	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	**23**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/692989/Envirnment-Agency-approach-to-groundwater-protection.pdf
30	Establish both trigger limits and maximum/minimum requirements for acceptable groundwater elevations. A series of trigger limits can be established with escalating actions as the max/min limits are approached.	Protect	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	Y	N	N	Y	Y	Y	Y	Y	N	Y	Y	Y	**22**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104
31	Work with adjacent municipalities that overlie the same aquifer to coordinate groundwater protection efforts (e.g. same limitations on CSR Schedule 2 activities)	Manage	Aquifer Protection Plan	White Rock, BC	Y	N	N	Y	Y	Y	Y	Y	N	Y	Y	Y	**22**	https://www.whiterockcity.ca/DocumentCenter/View/2017/2018-Aquifer-Protection-Plan-PDF?bidId=
32	Minimize pollutant discharge to groundwater recharge areas	Protect	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	Y	N	N	Y	Y	Y	Y	Y	N	Y	Y	Y	**22**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104
33	Place signs around well capture zones marking 5-year, 10 year, etc. travel times around groundwater extraction wells.	Protect	Groundwater Protection Plan	Chilliwack, BC	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	**22**	https://www.chilliwack.com/main/attachments/Files/2400/Goundwater%20Protection%20Plan%20District%20of%20Chilliwack.pdf

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34	Add green fees on water supply and sanitation services to persuade people to use less water	Manage	On the Implementation of the Water Framework Directive 2000/60/EC River Basin Management Plans	Denmark	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	N	**22**	https://ec.europa.eu/environment/water/water-framework/pdf/3rd_report/CWD-2012-379_EN-Vol3_DK.pdf
35	Establish baseline required flows[/levels] for rivers [or aquifers] and maintain those at a minimum	Manage	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	N	**22**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central
36	Limits on quantities of hazardous materials that can be brought into the well field area	Protect	Columbia South Shore Well Field Wellhead Protection Area Reference Manual	Portland, Oregon, USA	Y	N	Y	Y	Y	Y	Y	N	N	Y	Y	Y	**22**	https://www.portland.gov/sites/default/files/2020/referencemanualupdatefinal2017.pdf
37	Use zoning to control the following: location of hazardous waste facilities, underground storage tanks, septic systems, pesticides or fertilizer use	Protect	Redmond Bear Creek Valley Groundwater Management Plan	Seattle, Washington, USA	Y	N	Y	Y	Y	Y	Y	N	N	Y	Y	Y	**22**	https://your.kingcounty.gov/dnrp/library/1999/kcr146/kcr146_Mgmt-Plan.pdf
38	The improved understanding of local groundwater system should be integrated with city planners' development plans/process	Manage	Urban Groundwater – Mobilizing Stakeholders to	International Water Association	Y	N	Y	Y	Y	Y	Y	N	N	Y	Y	Y	**22**	https://www.thesourcemagazine.org/urban-groundwater-mobilising-

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			Improve Monitoring															stakeholders-to-improve-monitoring/
39	Create zoning by-laws that require that groundwater stays at a certain level (or range of levels).	Manage	Groundwater Protection Plan	Chilliwack, BC	Y	N	N	Y	Y	Y	Y	Y	N	Y	Y	Y	**22**	https://www.chilliwack.com/main/attachments/Files/2400/Goundwater%20Protection%20Plan%20District%20of%20Chilliwack.pdf
40	Limit certain activities (e.g. BC Contaminated Site Regulation Schedule 2 activities) in vulnerable groundwater areas	Protect	Aquifer Protection Plan	White Rock, BC	Y	N	N	Y	Y	Y	Y	Y	N	Y	Y	Y	**22**	https://www.whiterockcity.ca/DocumentCenter/View/2017/2018-Aquifer-Protection-Plan-PDF?bidId=
41	Encourage pumping from shallow aquifers (as opposed to deep aquifers, or high quality drinking water sources) for irrigation in the vicinity of the irrigated area	Manage	Urban Groundwater – Policies and Institutions for Integrated Management	Global Water Partnership article	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	**21**	https://www.gwp.org/globalassets/global/toolbox/publications/perspective-papers/05-urban-groundwater---policies-and-institutions-for-integrated-management.pdf
42	Update the curriculum in schools and workshops/field trips to promote groundwater protection and water stewardship	Protect	Drinking Water and Watershed Protection Action Plan 2.0 2020-2030	Nanaimo, BC	Y	N	Y	Y	Y	Y	Y	N	Y	Y	Y	N	**21**	https://www.rdn.bc.ca/sites/default/files/inline-files/DIGITAL%20SINGLE%2

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																		0PAGES_RDN-action-plan31.pdf
43	Manage low flows and climate change by understanding climate change affects by monitoring the groundwater. Undertake restoration efforts to improve resiliency of streams, etc.	Manage	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	N	**21**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central
44	Limit how groundwater in near coastal areas can be used based on salinity	Manage	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	N	**21**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central
45	Only "non consumptive" loops permitted for geothermal heating	Protect	Management of the London Basin Chalk Aquifer	London, United Kingdom	Y	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	**21**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/735451/2018_Final.pdf
46	In geothermal systems, the temperature of "injection" water cannot be greater than 25 C or 10 C greater than the natural groundwater temperature	Protect	Management of the London Basin Chalk Aquifer	London, United Kingdom	Y	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	**21**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/735451/2018_Final.pdf

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47	Work with adjacent municipalities that overlie the same aquifer to have similar/the same strategy for integrated water management (e.g. same water quality limits for stormwater infiltration)	Manage	Aquifer Protection Plan	White Rock, BC	Y	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	**21**	https://www.whiterockcity.ca/DocumentCenter/View/2017/2018-Aquifer-Protection-Plan-PDF?bidId=
48	Collaborate between municipalities to create a common groundwater quality monitoring program. If there are gaps in the monitoring network, install additional monitoring wells.	Manage	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	Y	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	**21**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104
49	Only issue water licenses if water protection can be proven	Manage	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	N	**21**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central
50	Review impact to groundwater infiltration with new developments (review groundwater/surface water interaction)	Manage	Redmond Bear Creek Valley Groundwater Management Plan	Seattle, Washington, USA	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	N	**21**	https://your.kingcounty.gov/dnrp/library/1999/kcr146/kcr146_Mgmt-Plan.pdf
51	Review every river basin [watershed] for chemical analysis, human activities, and economic analysis of water use within 13 years, do the same review every 6 years afterwards	Understand	Establishing a Framework for Community Action in the Field of Water Policy	Europe	Y	N	Y	Y	Y	N	Y	Y	N	Y	N	Y	**21**	https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF

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52	Create a river basin management plan for each river basin. This must be completed within 15 years of this directive and updated every 6 years after that	Manage	Establishing a Framework for Community Action in the Field of Water Policy	Europe	Y	N	Y	Y	Y	N	Y	Y	N	Y	N	Y	**21**	https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF
53	Educate the public about the relationship between inappropriate waste disposal and groundwater contamination	Protect	Redmond Bear Creek Valley Groundwater Management Plan	Seattle, Washington, USA	Y	N	Y	Y	Y	Y	Y	N	Y	Y	Y	N	**21**	https://your.kingcounty.gov/dnrp/library/1999/kcr146/kcr146_Mgmt-Plan.pdf
54	"Deep" discharge of treated effluent via a borehole directly to an aquifer is not preferred as the vadose zone is bypassed so no attenuation can occur. A permit is needed for "deep" discharge	Protect	UK The Environment Agency's Approach to Protecting Groundwater	United Kingdom	N	Y	N	Y	Y	Y	Y	Y	N	Y	Y	Y	**20**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/692989/Envirnment-Agency-approach-to-groundwater-protection.pdf
55	Target locations to educate young people about the importance of groundwater protection and methods for protecting groundwater (school visits, Science World, park field trips, etc.)	Manage	Groundwater Protection Plan	Chilliwack, BC	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	N	**20**	https://www.chilliwack.com/main/attachments/Files/2400/Goundwater%20Protection%20Plan%20District%20of%20Chilliwack.pdf
56	Work with adjacent municipalities that overlie the same aquifer to create similar signage with groundwater protection messages	Manage	Aquifer Protection Plan	White Rock, BC	Y	Y	N	Y	N	Y	Y	N	Y	Y	Y	Y	**20**	https://www.whiterockcity.ca/DocumentCenter/View/2017/2018-Aquifer-

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																		Protection-Plan-PDF?bidId=
57	Work with schools within groundwater capture zones to understand their lawn care routine and chemicals used. Encourage the execution of more eco-friendly lawn care activities.	Protect	Groundwater Protection Plan	Chilliwack, BC	Y	N	N	Y	Y	N	Y	Y	Y	Y	N	Y	**20**	https://www.chilliwack.com/main/attachments/Files/2400/Goundwater%20Protection%20Plan%20District%20of%20Chilliwack.pdf
58	Update the groundwater management plan as more information becomes available (e.g. refined estimate of well capture zones)	Manage	Groundwater Protection Plan	Chilliwack, BC	Y	N	N	Y	Y	Y	Y	Y	N	Y	N	Y	**20**	https://www.chilliwack.com/main/attachments/Files/2400/Goundwater%20Protection%20Plan%20District%20of%20Chilliwack.pdf
59	Limit groundwater extraction to 35% of annual recharge volumes	Protect	On the Implementation of the Water Framework Directive 2000/60/EC River Basin Management Plans	Denmark	Y	N	N	N	Y	Y	Y	Y	N	Y	Y	Y	**20**	https://ec.europa.eu/environment/water/water-framework/pdf/3rd_report/CWD-2012-379_EN-Vol3_DK.pdf
60	Establish criteria for increasing trends in groundwater chemistry for constituents of concern	Manage	European Groundwater Directive	Europe	Y	N	N	N	Y	Y	Y	Y	N	Y	Y	Y	**20**	https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:372:0019:0031:EN:PDF

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61	Inventory areas where groundwater extraction could be done without adverse impact to environment	Manage	Assiniboine Delta Aquifer Management Plan	Manitoba	Y	N	N	N	Y	Y	Y	Y	N	Y	Y	Y	**20**	http://digitalcollection.gov.mb.ca/awweb/pdfopener?smd=1&did=12371&md=1
62	Limit groundwater extraction	Manage	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	N	Y	N	Y	Y	Y	N	N	Y	Y	Y	**20**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central
63	Develop targets to maintain watershed function	Manage	Drinking Water and Watershed Protection Action Plan 2.0 2020-2030	Nanaimo, BC	Y	N	Y	Y	Y	N	Y	Y	N	Y	Y	N	**20**	https://www.rdn.bc.ca/sites/default/files/inline-files/DIGITAL%20SINGLE%20PAGES_RDN-action-plan31.pdf
64	Innovate policies to improve sustainability – water protection policies and best practices	Manage	Drinking Water and Watershed Protection Action Plan 2.0 2020-2030	Nanaimo, BC	Y	N	Y	Y	Y	N	Y	Y	N	Y	Y	N	**20**	https://www.rdn.bc.ca/sites/default/files/inline-files/DIGITAL%20SINGLE%20PAGES_RDN-action-plan31.pdf
65	Start an annual free hazardous waste collection day to prevent citizens from keeping hazardous waste they no longer need	Protect	Groundwater Protection Plan	Chilliwack, BC	Y	N	N	Y	Y	N	Y	Y	Y	N	Y	Y	**20**	https://www.chilliwack.com/main/attachments/Files/2400/Goundwater%20Protection%20Plan%20District%20of%20Chilliwack.pdf

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66	Provide rebates for: rainwater collection, using greywater, soil improvements, low water needs landscaping, irrigation efficiently, rain garden/infiltration swales, water meters for well owners, wellhead protection upgrades, water well testing	Manage	Drinking Water and Watershed Protection Action Plan 2.0 2020-2030	Nanaimo, BC	Y	N	Y	Y	Y	N	Y	Y	Y	Y	N	N	**20**	https://www.rdn.bc.ca/sites/default/files/inline-files/DIGITAL%20SINGLE%20PAGES_RDN-action-plan31.pdf
67	Groundwater in London must be extracted to protect building foundations/tube etc., but not too much so that the groundwater level is at unacceptable levels. During groundwater extraction license reviews the following is evaluated: - is there a long term trend of groundwater decline in the area? - What are the groundwater levels relative to the confining London Clay formation? - Any recent extraction in the area? How have groundwater levels been affected by the extraction? If changes haven't been observed yet a license cannot be granted until existed impacts are measured - Any proposals in the area that have been refused in the last 5 years? - Proximity to artificial recharge areas?	Manage	Management of the London Basin Chalk Aquifer	London, United Kingdom	N	Y	N	Y	Y	Y	Y	Y	N	Y	Y	Y	**20**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/735451/2018_Final.pdf

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68	Establish a groundwater management group with representatives from various levels of government and other major stakeholders. The group must have the power and financial means to improve urban groundwater monitoring and protection	Manage	Urban Groundwater – Policies and Institutions for Integrated Management	Global Water Partnership article	Y	N	N	Y	N	Y	Y	Y	N	Y	Y	Y	**20**	https://www.gwp.org/globalassets/global/toolbox/publications/perspective-papers/05-urban-groundwater---policies-and-institutions-for-integrated-management.pdf
69	To develop a sound groundwater management strategy there is a baseline level of knowledge needed 1) Map human-made and natural areas of discharge and recharge 2) Map saltwater/freshwater interface 3) Any areas of contaminated or saline water 4) Any perched aquifers 5) Inventory of wells 6) Economic modelling of supplementing water supply using different water sources 7) Evaluate surface water for municipal water use 8) Adequate data to understand/model the impacts of pumping on the aquifer	Understand	Urban Groundwater – Policies and Institutions for Integrated Management	Global Water Partnership article	Y	N	N	Y	Y	N	Y	Y	N	Y	Y	Y	**20**	https://www.gwp.org/globalassets/global/toolbox/publications/perspective-papers/05-urban-groundwater---policies-and-institutions-for-integrated-management.pdf

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70	Components of urban water management plan 1) Establish management body with representatives from all levels of govt and municipalities that would have some stake to claim over the aquifer 2) Current groundwater quality/quantity and trends 3) Potential future services that will use groundwater 4) Water allocation agreements 5) Adequate monitoring networks 6) Institutional provision, capacity and effectiveness 7) Complete cost-benefit analysis for potential future options 8) Propose incentives to reduce demand 9) ID tasks and institutional and financial needs 10) Strategy for stakeholder participation 11) Develop adaptive strategy	Manage	Urban Groundwater – Policies and Institutions for Integrated Management	Global Water Partnership article	Y	N	N	Y	Y	Y	Y	Y	N	Y	N	Y	**20**	https://www.gwp.org/globalassets/global/toolbox/publications/perspective-papers/05-urban-groundwater---policies-and-institutions-for-integrated-management.pdf
71	Member states sharing groundwater resources with other countries/jurisdictions should coordinate monitoring and protection efforts	Manage	European Groundwater Directive	Europe	Y	N	Y	Y	Y	Y	Y	N	N	Y	N	Y	**20**	https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:372:0019:0031:EN:PDF
72	Collaborate with the Geological Survey with their groundwater quality monitoring program to share data	Understand	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	Y	Y	N	Y	N	Y	Y	Y	N	Y	N	Y	**19**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104

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73	Work with Canadian National Rail (CN) to develop a right-of-way spill response plan for vulnerable groundwater areas	Protect	Groundwater Protection Plan	Chilliwack, BC	Y	N	N	Y	Y	Y	Y	N	N	Y	Y	Y	**19**	https://www.chilliwack.com/main/attachments/Files/2400/Goundwater%20Protection%20Plan%20District%20of%20Chilliwack.pdf
74	Make the public who live around aquifer aware of it and its sensitivities	Protect	Assiniboine Delta Aquifer Management Plan	Manitoba	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	N	**19**	http://digitalcollection.gov.mb.ca/awweb/pdfopener?smd=1&did=12371&md=1
75	Promote environmental stewardship to residents within vulnerable groundwater areas (e.g. hazardous chemical storage)	Protect	Aquifer Protection Plan	White Rock, BC	Y	N	Y	Y	Y	Y	Y	N	Y	Y	N	N	**19**	https://www.whiterockcity.ca/DocumentCenter/View/2017/2018-Aquifer-Protection-Plan-PDF?bidId=
76	Establish a regional groundwater committee. The committee should be led or endorsed by FLNRORD. The committee will plan, develop, and monitor the monitoring well network for the aquifer; develop a regional climate change strategy to protect groundwater; and conduct a recharge study to understand the effects of green infrastructure stormwater infiltration	Manage	Aquifer Protection Plan	White Rock, BC	Y	N	N	Y	Y	Y	Y	N	N	Y	Y	Y	**19**	https://www.whiterockcity.ca/DocumentCenter/View/2017/2018-Aquifer-Protection-Plan-PDF?bidId=
77	Involve stakeholders and create a groundwater protection taskforce	Manage	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	Y	N	N	Y	Y	Y	Y	N	Y	N	Y	Y	**19**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104

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78	Reach out to individual groundwater users/well owners to educate them about protecting groundwater/their well	Protect	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	Y	N	N	Y	Y	N	Y	N	Y	Y	Y	Y	**19**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104
79	Reach out to individual groundwater users/well owners to potentially have them join the taskforce	Manage	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	Y	N	N	Y	Y	Y	Y	N	Y	N	Y	Y	**19**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104
80	Results of the groundwater elevation monitoring program should be compiled in a groundwater model. If groundwater levels decline, use the model to determine if it's because of a low recharge year or other causes	Understand	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	Y	Y	N	N	Y	N	Y	Y	N	Y	Y	Y	**19**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104
81	Collaborate with other basin/aquifer committees or levels of government to share lessons learned and to ensure that protection regulations align	Manage	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	Y	N	N	Y	Y	Y	Y	N	N	Y	Y	Y	**19**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104
82	Educate the public about groundwater vulnerability, particularly operations with potentially groundwater contaminating activities in well capture zones. E.g. send flyers to residents and businesses within well capture zones	Protect	Groundwater Protection Plan	Chilliwack, BC	Y	N	N	Y	Y	N	Y	Y	Y	Y	Y	N	**19**	https://www.chilliwack.com/main/attachments/Files/2400/Goundwater%20Protection%20Plan%20District%20of%20Chilliwack.pdf
83	Do an inventory of private wells and educate owners of protecting their wells. Encourage decommissioning if the well is not in use	Manage	Groundwater Protection Plan	Chilliwack, BC	Y	N	N	Y	Y	N	Y	N	Y	Y	Y	Y	**19**	https://www.chilliwack.com/main/attachments/Files/2400/Goundwater%20Protection%20Plan%20District%20of%20Chilliwack.pdf

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84	Form a groundwater protection committee with city staff, representatives from the Province, representatives from the Federal government, and private stakeholders	Manage	Groundwater Protection Plan	Chilliwack, BC	Y	N	N	Y	Y	Y	Y	N	N	Y	Y	Y	**19**	https://www.chilliwack.com/main/attachments/Files/2400/Goundwater%20Protection%20Plan%20District%20of%20Chilliwack.pdf
85	Groundwater steering committee must the follow actions 1) Improve communication between steering committee and other relevant groups 2) Review staffing levels and asset needs to ensure the committee can deliver its service effectively 3) Prioritize maintenance/repairs 4) Focus on work that will make the groundwater distribution system more reliable	Manage	Portland Water Bureau Strategic Plan	Portland, Oregon, USA	N	N	N	Y	Y	Y	Y	Y	N	Y	Y	Y	**19**	https://www.portland.gov/sites/default/files/2020/sp-brochure2019-web-spreads-2.pdf
86	No permit needed for sustainable drainage infiltration systems for run-off collected from roofs	Protect	UK The Environment Agency's Approach to Protecting Groundwater	United Kingdom	Y	Y	Y	N	Y	Y	Y	Y	N	Y	N	N	**19**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/692989/Envirnment-Agency-approach-to-groundwater-protection.pdf
87	Try to encourage sustainable remediation techniques to protect groundwater	Manage	UK The Environment Agency's Approach to Protecting Groundwater	United Kingdom	Y	N	Y	Y	Y	Y	Y	N	N	Y	Y	N	**19**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/692989/Envirnment-Agency-

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																		approach-to-groundwater-protection.pdf
88	Establish water use (purpose and volume) allocations for each watershed	Protect	Water Resources Protection Master Plan	Waterloo, Ontario	Y	N	N	Y	Y	Y	Y	Y	N	Y	Y	N	**19**	https://www.regionofwaterloo.ca/en/living-here/resources/Documents/water/plans/RMOW-water-resources-protection-master-plan-summary-AODA.pdf
89	Delineate vulnerable areas and develop a specific set of rules for them (e.g. more stringent wellhead protection)	Understand/Protect	Water Resources Protection Master Plan	Waterloo, Ontario	Y	N	N	N	Y	N	Y	Y	N	Y	Y	Y	**18**	https://www.regionofwaterloo.ca/en/living-here/resources/Documents/water/plans/RMOW-water-resources-protection-master-plan-summary-AODA.pdf
90	Quantify natural assets (e.g. aquifers, streams, wetlands, etc.)	Understand	Drinking Water and Watershed Protection Action Plan 2.0 2020-2030	Nanaimo, BC	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	N	**18**	https://www.rdn.bc.ca/sites/default/files/inline-files/DIGITAL%20SINGLE%20PAGES_RDN-action-plan31.pdf

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91	A basement and/or other structures should cumulatively occupy less than 50% of the original garden/unbuilt upon area, and be smaller in area than the original footprint of the dwelling, whichever the lesser.	Manage	Basement Development	Borough of Islington, London, UK	Y	Y	N	Y	N	Y	N	Y	N	Y	Y	Y	**18**	https://democracy.islington.gov.uk/documents/s6637/Appendix%201%20-%20Basement%20Development%20SPD%20FINAL.pdf
92	Decrease stormwater run-off in groundwater recharge areas by decreasing paved areas. Avoid oil/fuel and other car related contamination from run-off from paved areas	Protect	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	Y	Y	N	Y	Y	Y	Y	Y	N	N	Y	N	**18**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104
93	Educate the public about hazardous waste/chemical disposal options (e.g. BCUOMA, Return-it depots)	Protect	Groundwater Protection Plan	Chilliwack, BC	Y	N	Y	Y	N	N	Y	Y	Y	N	Y	N	**18**	https://www.chilliwack.com/main/attachments/Files/2400/Goundwater%20Protection%20Plan%20District%20of%20Chilliwack.pdf
94	Conduct groundwater monitoring near stormwater infiltration areas	Understand	Groundwater Protection Plan	Chilliwack, BC	Y	N	Y	Y	Y	N	Y	N	N	Y	N	Y	**18**	https://www.chilliwack.com/main/attachments/Files/2400/Goundwater%20Protection%20Plan%20District%20of%20Chilliwack.pdf
95	Create a zoning by-law that prohibits gas stations or other potentially groundwater contaminating activities from being located within 1 year groundwater capture zone.	Protect	Groundwater Protection Plan	Chilliwack, BC	Y	N	N	Y	Y	N	Y	Y	N	Y	N	Y	**18**	https://www.chilliwack.com/main/attachments/Files/2400/Goundwater%20Protection%20Plan%20District%20of%20Chilliwack.pdf

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96	Determine what allocation limit (e.g. volume of water to extract) is acceptable for the aquifer	Understand	Assiniboine Delta Aquifer Management Plan	Manitoba	Y	N	N	N	Y	N	Y	Y	N	Y	Y	Y	**18**	http://digitalcollection.gov.mb.ca/awweb/pdfopener?smd=1&did=12371&md=1
97	Establish "reserve zones" of groundwater	Understand	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	N	N	N	N	Y	Y	Y	N	Y	Y	Y	**18**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central
98	Establish general managing rules for groundwater resources/aquifer that are being underused that may not have a separate management plan	Manage	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	Y	N	N	Y	Y	Y	Y	N	Y	Y	N	**18**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central
99	Prioritize more at-risk aquifers/watersheds	Protect	Drinking Water and Watershed Protection Action Plan 2.0 2020-2030	Nanaimo, BC	Y	N	Y	N	Y	Y	Y	N	N	Y	N	Y	**18**	https://www.rdn.bc.ca/sites/default/files/inline-files/DIGITAL%20SINGLE%20PAGES_RDN-action-plan31.pdf
100	Set annual total allocation/extraction limits for specific aquifer areas	Manage	Cockburn Groundwater Allocation Plan	Perth, Western Australia, Australia	Y	N	N	N	Y	N	Y	Y	N	Y	Y	Y	**18**	https://www.wa.gov.au/sites/default/files/2021-01/Cockburn%20groundwater%20allocation%20plan.pdf
101	Establish limits for groundwater elevation decline	Manage	Redmond Bear Creek Valley	Seattle, Washington, USA	Y	N	N	N	N	Y	Y	Y	N	Y	Y	Y	**18**	https://your.kingcounty.gov/dnrp/library/1999/kcr146/kcr146_Mgmt-Plan.pdf

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			Groundwater Management Plan															
102	Create a groundwater management committee that will lead the implementation of the actions in the plan	Manage	Redmond Bear Creek Valley Groundwater Management Plan	Seattle, Washington, USA	Y	N	N	Y	N	Y	Y	Y	N	Y	N	Y	**18**	https://your.kingcounty.gov/dnrp/library/1999/kcr146/kcr146_Mgmt-Plan.pdf
103	Issue advisories to drilling companies regard areas with non-potable groundwater	Manage	Resilient Groundwater and Cities	International Association of Hydrogeologists article	Y	Y	N	N	N	Y	Y	N	Y	Y	Y	Y	**18**	https://iah.org/wp-content/uploads/2015/12/IAH-Resilient-Cities-Groundwater-Dec-2015.pdf
104	Send out advisories to water well drillers to inform them about non-potable groundwater areas or sensitive areas	Protect	Urban Groundwater – Policies and Institutions for Integrated Management	Global Water Partnership article	Y	Y	N	N	N	Y	Y	N	Y	Y	Y	Y	**18**	https://www.gwp.org/globalassets/global/toolbox/publications/perspective-papers/05-urban-groundwater---policies-and-institutions-for-integrated-management.pdf

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105	Recharge the aquifer using stormwater.	Manage	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	Y	N	N	Y	Y	N	Y	Y	N	N	Y	Y	**18**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104
106	Basements must not be greater than 1 storey in depth and cannot take up more than 50% of the garden space	Protect	Local Plan 2019 Chapter 22.3.51	Boroughs of Kensignton and Chelsea, London, England	Y	Y	N	Y	N	Y	N	Y	N	Y	Y	Y	**18**	https://www.rbkc.gov.uk/sites/default/files/atoms/files/2019%20LOCAL%20PLAN%20SECTION%202%20DELIVERY%20STRATEGY.pdf
107	A basement should not involve excavation of more than one (1) storey below the lowest original habitable floor level. The height of a basement should not exceed 3m floor to ceiling height.	Manage	Basement Development	Borough of Islington, London, UK	Y	Y	N	Y	N	Y	N	Y	N	Y	Y	Y	**18**	https://democracy.islington.gov.uk/documents/s6637/Appendix%201%20-%20Basement%20Development%20SPD%20FINAL.pdf

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108	Use both groundwater and surface as potable or non-potable water sources and manage both in a sustainable manner. (i.e.) move to a decentralized system for water sources with smaller water sources that serve smaller areas of the population	Manage	Urban Groundwater – Policies and Institutions for Integrated Management	Global Water Partnership article	N	N	Y	Y	Y	N	Y	Y	N	N	Y	Y	**18**	https://www.gwp.org/globalassets/global/toolbox/publications/perspective-papers/05-urban-groundwater---policies-and-institutions-for-integrated-management.pdf
109	EU members must have their own plan/legislation that enforces the directive by 2009. Lobby for the BC Government to require all municipalities to create a groundwater management plan by [DATE]	Manage	European Groundwater Directive	Europe	N	N	N	Y	Y	N	Y	Y	N	Y	Y	Y	**17**	https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:372:0019:0031:EN:PDF
110	Locate and record the position and condition of abandoned wells. Create a grant program for land/well owners to access to help fund decommissioning activities for abandoned or irreparably damaged wells	Protect	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	Y	N	N	Y	Y	N	Y	N	N	Y	Y	Y	**17**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104
111	Conduct annual reporting on compliance with baseline flows/levels	Understand	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	N	Y	N	Y	Y	Y	N	N	Y	Y	N	**17**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central

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112	Enact a bylaw restricting lawn/garden chemicals that contaminate groundwater	Protect	Water Resources Protection Master Plan	Waterloo, Ontario	Y	N	Y	Y	Y	Y	Y	N	N	Y	N	N	**17**	https://www.regionofwaterloo.ca/en/living-here/resources/Documents/water/plans/RMOW-water-resources-protection-master-plan-summary-AODA.pdf
113	Complete an inventory of potentially groundwater contaminating activities located within well capture zones	Protect	Groundwater Protection Plan	Chilliwack, BC	Y	N	N	Y	N	Y	N	Y	N	Y	Y	Y	**17**	https://www.chilliwack.com/main/attachments/Files/2400/Goundwater%20Protection%20Plan%20District%20of%20Chilliwack.pdf
114	Engage with owners of gas stations and auto repair shops to educate them that they are within the capture zone/vulnerable groundwater zone. Inform these operations of their obligations to protect groundwater (e.g. no dumping oil, secondary containment around chemical containers)	Protect	Groundwater Protection Plan	Chilliwack, BC	Y	N	N	Y	Y	N	Y	N	Y	Y	N	Y	**17**	https://www.chilliwack.com/main/attachments/Files/2400/Goundwater%20Protection%20Plan%20District%20of%20Chilliwack.pdf

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115	Make efforts to achieve “good” status in terms of ecological and chemical standings Achieve “good” ecological potential and “good” chemical status of surface water within 15 years of issuing the directive Achieve “good” groundwater status within 15 years. Find balance between extraction and recharge Achieve “good” status for protected areas	Protect	Establishing a Framework for Community Action in the Field of Water Policy	European Union	Y	Y	Y	N	Y	N	Y	N	N	Y	N	Y	**17**	https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF
116	Use groundwater efficiently, ensure users are not interfering with each other	Manage	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	N	N	N	Y	Y	Y	N	N	Y	Y	Y	**17**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central
117	Monitor groundwater that interacts with surface water bodies, marshes, etc.	Understand	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	N	Y	Y	Y	N	Y	N	N	Y	Y	N	**17**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central
118	Create a list of agencies that can assist with implementation and work with them (e.g. municipalities, water district bodies, state government)	Manage	Redmond Bear Creek Valley Groundwater Management Plan	Seattle, Washington, USA	Y	N	Y	Y	Y	Y	Y	N	N	Y	N	N	**17**	https://your.kingcounty.gov/dnrp/library/1999/kcr146/kcr146_Mgmt-Plan.pdf

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119	Create incentives for brownfield redevelopment rather than developing greenfields near harvested groundwater resources	Protect	Water Resources Protection Master Plan	Waterloo, Ontario	N	Y	Y	Y	Y	Y	Y	N	N	Y	Y	N	**17**	https://www.regionofwaterloo.ca/en/living-here/resources/Documents/water/plans/RMOW-water-resources-protection-master-plan-summary-AODA.pdf
120	Reduce road salt usage and replace with other less harmful substances	Protect	Water Resources Protection Master Plan	Waterloo, Ontario	Y	N	Y	Y	Y	Y	Y	N	N	Y	N	N	**17**	https://www.regionofwaterloo.ca/en/living-here/resources/Documents/water/plans/RMOW-water-resources-protection-master-plan-summary-AODA.pdf
121	Develop an education program for safe handling of fuel/chemical handling and storage that prevents water contamination	Protect	Water Resources Protection Master Plan	Waterloo, Ontario	Y	N	Y	N	Y	Y	Y	N	Y	Y	N	N	**17**	https://www.regionofwaterloo.ca/en/living-here/resources/Documents/water/plans/RMOW-water-resources-protection-master-plan-summary-AODA.pdf
122	Create incentive program to get farmers [or other major water users] to use water more efficiently (e.g. swapping fixtures for low flow)	Manage	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	N	Y	Y	Y	Y	Y	Y	N	Y	Y	N	N	**17**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central

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123	Provide incentives for sewer main maintenance to prevent leakage and contamination to groundwater	Protect	Water Resources Protection Master Plan	Waterloo, Ontario	Y	N	Y	Y	Y	N	Y	N	Y	Y	N	N	**17**	https://www.regionofwaterloo.ca/en/living-here/resources/Documents/water/plans/RMOW-water-resources-protection-master-plan-summary-AODA.pdf
124	Encourage home heating oil tank removal or maintenance	Protect	Redmond Bear Creek Valley Groundwater Management Plan	Seattle, Washington, USA	Y	N	Y	Y	N	Y	Y	N	Y	Y	N	N	**17**	https://your.kingcounty.gov/dnrp/library/1999/kcr146/kcr146_Mgmt-Plan.pdf
125	Require land sellers to disclose the location of unused wells. Require disclosure of location and status of wells on property for rezoning/land use applications. Create funding program to help offset costs for well decommissioning for private owners	Manage	Redmond Bear Creek Valley Groundwater Management Plan	Seattle, Washington, USA	Y	N	N	N	Y	Y	Y	N	N	Y	Y	Y	**17**	https://your.kingcounty.gov/dnrp/library/1999/kcr146/kcr146_Mgmt-Plan.pdf
126	Use a common end-date for groundwater licenses so water use can be reviewed all at once when licenses are up for re-renewal.	Manage	London Abstraction Licensing Strategy	London, United Kingdom	N	Y	N	N	Y	Y	Y	Y	N	N	Y	Y	**16**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/865039/CAMS-London-abstraction-licensing-strategy.pdf

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127	Geothermal systems should be used for both heating and cooling to prevent unacceptable long-term heating of groundwater	Protect	UK The Environment Agency's Approach to Protecting Groundwater	United Kingdom	Y	Y	N	N	N	Y	Y	N	N	Y	Y	Y	**16**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/692989/Envirnment-Agency-approach-to-groundwater-protection.pdf
128	Identify areas where groundwater quality is a concern and monitor it	Manage	Assiniboine Delta Aquifer Management Plan	Manitoba	Y	N	Y	Y	N	N	Y	N	N	Y	N	Y	**16**	http://digitalcollection.gov.mb.ca/awweb/pdfopener?smd=1&did=12371&md=1
129	Complete regular groundwater monitoring to ensure groundwater level and quality requirements are being met or if remedial actions are needed	Understand	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	N	N	N	Y	N	Y	Y	N	Y	N	Y	**16**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central
130	Designate zones where groundwater is available and not available for extraction	Manage	London Abstraction Licensing Strategy	London, United Kingdom	Y	Y	N	N	N	Y	Y	Y	N	Y	Y	N	**16**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/865039/CAMS-London-abstraction-licensing-strategy.pdf

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131	Include a minimum groundwater elevation limit that must be maintained by the groundwater extractor.	Manage	London Abstraction Licensing Strategy	London, United Kingdom	Y	Y	N	N	N	Y	Y	Y	N	Y	Y	N	**16**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/865039/CAMS-London-abstraction-licensing-strategy.pdf
132	Create different levels of protection areas 1) "Drinking Water Protected Area" is a groundwater or surface water body used for drinking water 2) Source Protection Zone (SPZ) is a radius around a groundwater well used for drinking water. Private wells have a default radius length for SPZs. Activities are limited/restricted for the different protection areas	Manage	UK The Environment Agency's Approach to Protecting Groundwater	United Kingdom	N	N	Y	N	N	N	Y	Y	N	Y	Y	Y	**16**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/692989/Envirnment-Agency-approach-to-groundwater-protection.pdf
133	Groundwater extraction licenses should be time sensitive i.e. they expire after a certain period of time so at the time of re-application the government has the opportunity to re-evaluate the water use	Manage	Urban Groundwater – Policies and Institutions for Integrated Management	Global Water Partnership article	Y	Y	N	N	N	Y	Y	Y	N	Y	Y	N	**16**	https://www.gwp.org/globalassets/global/toolbox/publications/perspective-papers/05-urban-groundwater---policies-and-institutions-for-integrated-management.pdf
134	Improve the characterization efforts of the aquifer and conduct ongoing monitoring for key issues	Understand	Aquifer Protection Plan	White Rock, BC	Y	N	N	N	Y	N	Y	N	N	Y	Y	Y	**15**	https://www.whiterockcity.ca/DocumentCenter/View/2017/2018-Aquifer-

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	(e.g. saltwater intrusion, contamination, agriculture)																	Protection-Plan-PDF?bidId=
135	Develop groundwater use reduction measures for the aquifer	Protect	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	N	N	N	Y	Y	N	Y	Y	N	N	Y	Y	**15**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104
136	Work with the Ministry of the Environment on sites with Pollution Prevention Orders and Remediation Orders	Manage	Groundwater Protection Plan	Chilliwack, BC	Y	N	N	Y	N	N	Y	N	N	Y	Y	Y	**15**	https://www.chilliwack.com/main/attachments/Files/2400/Goundwater%20Protection%20Plan%20District%20of%20Chilliwack.pdf
137	Determine the sustainable yield for the aquifer	Understand	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	N	N	N	Y	N	Y	N	N	Y	Y	Y	**15**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central
138	Existing facilities are not grandfathered in and must abide by hazardous material limits. If an existing facility is found to be non-compliant, a compliance plan must be submitted.	Protect	Columbia South Shore Well Field Wellhead Protection Area Reference Manual	Portland, Oregon, USA	Y	Y	N	Y	Y	Y	Y	N	N	Y	N	N	**15**	https://www.portland.gov/sites/default/files/2020/referencemanualupdatefinal2017.pdf
139	Review impacts along street rights-of-way for treatment chemicals (e.g. road salts, or pesticides on greenway boulevards) and identify alternatives	Understand	Redmond Bear Creek Valley Groundwater Management Plan	Seattle, Washington, USA	Y	N	Y	Y	Y	N	Y	N	N	Y	N	N	**15**	https://your.kingcounty.gov/dnrp/library/1999/kcr146/kcr146_Mgmt-Plan.pdf

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140	All treated sewage/wastewater effluent discharges to groundwater greater than 2 m3/day must have a permit	Protect	UK The Environment Agency's Approach to Protecting Groundwater	United Kingdom	Y	Y	N	Y	Y	N	Y	N	N	Y	Y	N	**15**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/692989/Envirnment-Agency-approach-to-groundwater-protection.pdf
141	Limit heavy truck traffic along streets that are within vulnerable groundwater areas	Protect	Groundwater Protection Plan	Chilliwack, BC	Y	Y	Y	Y	Y	N	Y	N	N	N	N	N	**14**	https://www.chilliwack.com/main/attachments/Files/2400/Goundwater%20Protection%20Plan%20District%20of%20Chilliwack.pdf
142	Report on the implementation of the groundwater management plan every 2 years.	Manage	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	Y	N	N	N	Y	Y	N	N	N	Y	Y	Y	**14**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104
143	Obtain public feedback on the groundwater management plan	Manage	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	Y	N	N	Y	Y	N	Y	N	Y	N	Y	N	**14**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104
144	Work with relevant government bodies to ensure that contaminated sites are prioritized and remediated	Manage	UK The Environment Agency's Approach to Protecting Groundwater	United Kingdom	Y	N	Y	Y	Y	Y	N	N	N	Y	N	N	**14**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/692989/Envirnment-Agency-approach-to-groundwater-protection.pdf

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145	Conduct targeted monitoring to aquifers specific to their use and identified threats to the aquifer	Understand	Climate change: the utility groundwater role in supply security	Hamburg, Germany - International Association of Hydrogeologists article	Y	N	N	N	Y	Y	N	N	N	Y	Y	Y	**14**	https://www.thesourcemagazine.org/climate-change-the-utility-groundwater-role-in-supply-security/
146	If it is determined that too much groundwater is being extracted, set legislated requirements for groundwater replenishment	Manage	South Westside Basin Groundwater Management Plan	San Francisco, California, USA	N	Y	N	N	Y	N	Y	Y	N	Y	Y	N	**13**	https://sfwater.org/Modules/ShowDocument.aspx?documentid=3104
147	Understand volume, use, and impacts of using water to the aquifer	Understand	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	N	Y	N	Y	N	Y	N	N	Y	N	N	**13**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central
148	For sewer pipes below the water table - install impermeable seals around sewer pipes to prevent preferential flow of potentially leaking sewage through the granular backfill (inadvertently contaminating groundwater along the sewer line)	Protect	Redmond Bear Creek Valley Groundwater Management Plan	Seattle, Washington, USA	Y	Y	N	Y	Y	N	Y	N	N	Y	N	N	**13**	https://your.kingcounty.gov/dnrp/library/1999/kcr146/kcr146_Mgmt-Plan.pdf
149	Monitor groundwater elevations and link the monitoring location to the number of extraction wells in its vicinity. The number of days that extraction in this area is permitted should also be noted.	Understand	London Abstraction Licensing Strategy	London, United Kingdom	N	Y	N	N	N	Y	Y	N	N	Y	Y	Y	**13**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/865039/CAMS-London-abstraction-licensing-strategy.pdf

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150	Develop an inventory of sites that may be a threat to groundwater	Understand	Water Resources Protection Master Plan	Waterloo, Ontario	Y	N	N	Y	Y	Y	N	N	N	Y	Y	N	**13**	https://www.regionofwaterloo.ca/en/living-here/resources/Documents/water/plans/RMOW-water-resources-protection-master-plan-summary-AODA.pdf
151	Map extraction well density and estimated groundwater recharge conditions. Create groundwater extraction restrictions where over extraction has occurred	Manage	Climate change: the utility groundwater role in supply security	Sao Paulo, Brazil - International Association of Hydrogeologists article	N	N	N	N	N	Y	Y	Y	N	Y	N	Y	**13**	https://www.thesourcemagazine.org/climate-change-the-utility-groundwater-role-in-supply-security/
152	Map susceptible areas for groundwater contamination (e.g. shallow unconfined areas) and raise citizens' and decision makers' awareness/education	Protect	Redmond Bear Creek Valley Groundwater Management Plan	Seattle, Washington, USA	Y	N	N	Y	N	Y	N	N	Y	Y	Y	N	**13**	https://your.kingcounty.gov/dnrp/library/1999/kcr146/kcr146_Mgmt-Plan.pdf
153	Target existing operations (e.g. gas stations) in high sensitivity areas and work with them to ensure groundwater protection measures are being adequately implemented	Protect	Aquifer Protection Plan	White Rock, BC	Y	N	N	N	Y	N	Y	N	Y	Y	N	N	**12**	https://www.whiterockcity.ca/DocumentCenter/View/2017/2018-Aquifer-Protection-Plan-PDF?bidId=
154	Monitor precipitation and how it affects or doesn't affect groundwater elevations	Understand	Cockburn Groundwater Allocation Plan	Perth, Western Australia, Australia	Y	N	Y	Y	Y	N	N	N	N	Y	N	N	**12**	https://www.wa.gov.au/sites/default/files/2021-01/Cockburn%20groundwa

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																		ter%20allocation%20plan.pdf
155	Add a term to groundwater licenses that indicates that a reduced extraction volume can be enforced during low rainfall/recharge years.	Manage	London Abstraction Licensing Strategy	London, United Kingdom	N	Y	N	N	Y	Y	Y	N	N	Y	Y	N	**12**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/865039/CAMS-London-abstraction-licensing-strategy.pdf
156	Underground storage tanks must be outside of SPZ and provide a hydrogeologic assessment to justify its position	Protect	UK The Environment Agency's Approach to Protecting Groundwater	United Kingdom	N	N	N	N	N	Y	Y	N	N	Y	Y	Y	**12**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/692989/Envirnment-Agency-approach-to-groundwater-protection.pdf
157	Monitor groundwater elevation in areas where groundwater extraction occurs	Understand	Water Resources Protection Master Plan	Waterloo, Ontario	Y	N	N	N	Y	N	N	N	N	Y	Y	Y	**12**	https://www.regionofwaterloo.ca/en/living-here/resources/Documents/water/plans/RMOW-water-resources-protection-master-plan-summary-AODA.pdf

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158	Establish a monitoring program for the aquifer. Collect data through the program over the next 3-5 years to understand groundwater flow/recharge/discharge conditions and quality	Understand	Assiniboine Delta Aquifer Management Plan	Manitoba	Y	N	N	N	N	N	Y	N	N	Y	N	Y	**11**	http://digitalcollection.gov.mb.ca/awweb/pdfopener?smd=1&did=12371&md=1
159	Report on the results of the groundwater monitoring program every 3-5 years	Understand	Assiniboine Delta Aquifer Management Plan	Manitoba	Y	N	N	N	N	N	Y	N	N	Y	N	Y	**11**	http://digitalcollection.gov.mb.ca/awweb/pdfopener?smd=1&did=12371&md=1
160	Inform the public about best management practices for owning/maintaining wells including sealing abandoned wells	Protect	Assiniboine Delta Aquifer Management Plan	Manitoba	Y	N	N	N	Y	Y	N	N	Y	Y	N	N	**11**	http://digitalcollection.gov.mb.ca/awweb/pdfopener?smd=1&did=12371&md=1
161	Make existing and future commercial/industrial operations undertake a groundwater contamination assessment (pathways, risk, potential constituents of concern), a groundwater monitoring program	Protect	Urban Groundwater – Policies and Institutions for Integrated Management	Global Water Partnership article	N	Y	Y	N	Y	N	Y	N	N	Y	N	N	**11**	https://www.gwp.org/globalassets/global/toolbox/publications/perspective-papers/05-urban-groundwater---policies-and-institutions-for-integrated-management.pdf
162	A permit is required for open-loop geothermal systems, but not for closed loop	Manage	UK The Environment Agency's Approach to Protecting Groundwater	United Kingdom	Y	Y	N	Y	N	Y	Y	N	N	N	N	N	**11**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/692989/Envirnment-Agency-approach-to-groundwater-protection.pdf

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163	Map extent of water bodies and monitor water quality to characterize it.	Understand	Establishing a Framework for Community Action in the Field of Water Policy	Europe	Y	N	N	N	Y	N	N	N	N	Y	N	Y	**10**	https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF
164	Identify water basins where more than 10m3/day of water is extracted and serves more than 50 people	Manage	Establishing a Framework for Community Action in the Field of Water Policy	Europe	N	Y	N	N	Y	Y	Y	N	N	Y	N	N	**10**	https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF
165	Restrict sub-grade storage tanks that are below/straddling the groundwater table	Protect	UK The Environment Agency's Approach to Protecting Groundwater	United Kingdom	Y	N	N	N	N	Y	N	N	N	Y	N	Y	**10**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/692989/Envirnment-Agency-approach-to-groundwater-protection.pdf
166	Partner with local university to continue wetland mapping	Understand	Drinking Water and Watershed Protection Action Plan 2.0 2020-2030	Nanaimo, BC	Y	N	N	Y	Y	Y	N	N	N	N	N	N	**9**	https://www.rdn.bc.ca/sites/default/files/inline-files/DIGITAL%20SINGLE%20PAGES_RDN-action-plan31.pdf

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					Applicability to Vancouver (3)	Innovative (1)	Strategic (3)	Collaborat-ive (2)	Integrated (2)	Efficient (2)	Sustainable (3)	Resilient (3)	Awareness and Education (2)	Evidence based (2)	Address emerging issues (2)	Effective-ness (3)		
167	Education and assistance with private well owners with wellhead protection	Protect	Redmond Bear Creek Valley Groundwater Management Plan	Seattle, Washington, USA	Y	N	N	Y	N	N	N	N	Y	Y	N	N	**9**	https://your.kingcounty.gov/dnrp/library/1999/kcr146/kcr146_Mgmt-Plan.pdf
168	Develop a monitoring program to understand how pervious versus impervious surfaces have impacted groundwater infiltration and groundwater elevations	Understand	Water Resources Protection Master Plan	Waterloo, Ontario	Y	Y	Y	N	Y	N	N	N	N	N	N	N	**9**	https://www.regionofwaterloo.ca/en/living-here/resources/Documents/water/plans/RMOW-water-resources-protection-master-plan-summary-AODA.pdf
169	Undertake a desktop survey of past and current commercial/industrial activities and estimate the likelihood of contamination (if not already known)	Understand	Urban Groundwater – Policies and Institutions for Integrated Management	Global Water Partnership article	N	N	Y	N	Y	Y	N	N	N	Y	N	N	**9**	https://www.gwp.org/globalassets/global/toolbox/publications/perspective-papers/05-urban-groundwater---policies-and-institutions-for-integrated-management.pdf
170	Monitor known contamination sources: In-situ sanitation, leaking sewers, industrial effluent disposal, spills, mobilization of existing contamination, pesticides, herbicides, fertilizers. Instate “trigger limits” for groundwater contamination before regulated limits are exceeded. Increase awareness of emerging	Protect	Urban Groundwater – Mobilizing Stakeholders to Improve Monitoring	International Water Association	N	N	Y	N	Y	Y	N	N	N	Y	N	N	**9**	https://www.thesourcemagazine.org/urban-groundwater-mobilising-stakeholders-to-improve-monitoring/

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					Applicability to Vancouver (3)	Innovative (1)	Strategic (3)	Collaborat-ive (2)	Integrated (2)	Efficient (2)	Sustainable (3)	Resilient (3)	Awareness and Education (2)	Evidence based (2)	Address emerging issues (2)	Effective-ness (3)		
	contaminants and incorporate them into monitoring plans																	
171	Work with water utilities/water district to add a fee into user fees to help fund these groundwater initiatives	Manage	Redmond Bear Creek Valley Groundwater Management Plan	Seattle, Washington, USA	N	Y	Y	Y	Y	N	N	N	N	N	N	N	**8**	https://your.kingcounty.gov/dnrp/library/1999/kcr146/kcr146_Mgmt-Plan.pdf
172	Monitor metered groundwater use	Understand	Cockburn Groundwater Allocation Plan	Perth, Western Australia, Australia	N	Y	N	N	N	N	Y	N	N	Y	Y	N	**8**	https://www.wa.gov.au/sites/default/files/2021-01/Cockburn%20groundwater%20allocation%20plan.pdf
173	Create a baseline database of groundwater temperatures to assist with licensing geothermal heating systems and to support long term groundwater temperature monitoring	Understand	Management of the London Basin Chalk Aquifer	London, United Kingdom	Y	Y	N	N	N	N	N	N	N	Y	Y	N	**8**	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/735451/2018_Final.pdf
174	Water quality monitoring for typical and selected parameters	Understand	Drinking Water and Watershed Protection Action Plan 2.0 2020-2030	Nanaimo, BC	Y	N	N	N	Y	N	N	N	N	Y	N	N	**7**	https://www.rdn.bc.ca/sites/default/files/inline-files/DIGITAL%20SINGLE%20PAGES_RDN-action-plan31.pdf

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					Applicability to Vancouver (3)	Innovative (1)	Strategic (3)	Collaborat-ive (2)	Integrated (2)	Efficient (2)	Sustainable (3)	Resilient (3)	Awareness and Education (2)	Evidence based (2)	Address emerging issues (2)	Effective-ness (3)		
175	Complete compliance reporting for all groundwater uses/users	Manage	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	N	N	N	N	N	N	N	N	Y	N	N	**5**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central
176	Compile and distribute groundwater water quality reports to public	Manage	Assiniboine Delta Aquifer Management Plan	Manitoba	Y	N	N	N	N	N	N	N	Y	N	N	N	**5**	http://digitalcollection.gov.mb.ca/awweb/pdfopener?smd=1&did=12371&md=1
177	Existing well records may not be accurate for the volume of water being extracted. Complete an inventory of wells to understand current groundwater extraction rates	Understand	Redmond Bear Creek Valley Groundwater Management Plan	Seattle, Washington, USA	Y	N	N	N	N	N	N	N	N	Y	N	N	**5**	https://your.kingcounty.gov/dnrp/library/1999/kcr146/kcr146_Mgmt-Plan.pdf
178	Complete an inventory of private wells and the volume of water extracted at each well	Understand	Climate change: the utility groundwater role in supply security	Sao Paulo, Brazil - International Association of Hydrogeologists article	Y	N	N	N	N	N	N	N	N	Y	N	N	**5**	https://www.thesourcemagazine.org/climate-change-the-utility-groundwater-role-in-supply-security/
179	Require all commercial, industrial, and multi-resident private wells to be registered	Manage	Urban Groundwater – Policies and Institutions for Integrated Management	Global Water Partnership article	N	N	N	N	N	Y	N	N	N	Y	N	N	**4**	https://www.gwp.org/globalassets/global/toolbox/publications/perspective-papers/05-urban-groundwater---policies-and-institutions-for-integrated-management.pdf

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					Applicability to Vancouver (3)	Innovative (1)	Strategic (3)	Collaborat -ive (2)	Integrated (2)	Efficient (2)	Sustainable (3)	Resilient (3)	Awareness and Education (2)	Evidence based (2)	Address emerging issues (2)	Effective- ness (3)		
180	Inventory groundwater uses/users that do not require licenses	Understand	Sustainable Water Strategy Action to 2055	Central Region (Melbourne area), Victoria, Australia	Y	Y	N	N	N	N	N	N	N	N	N	N	**4**	https://www.water.vic.gov.au/planning/long-term-assessments-and-strategies/sws/central

Appendix C – Recommended Actions

Action	Appendix B Action #	Primary Aim (understand/ protect/ manage)	Document Name
Create a tiered system to permit the construction of green infrastructure for stormwater infiltration (i.e. infiltrating stormwater from building roofs may have less stringent requirements than stormwater from roads, parking lots, etc). For new green infrastructure systems, a stormwater assessment should be completed to determine what constituents of concern may be present and if pre-treatment is needed. For the use of green infrastructure, the suitability of the near surface conditions must be evaluated. In addition to the use of green infrastructure, review areas where stormwater is noted to infiltrate naturally near roadways, parking lots, etc. and complete stormwater management upgrades (e.g. pre-treatment system) as needed to prevent the infiltration of potentially contaminated water	4, 6, 10, 18, 20	Protect	South Westside Basin Groundwater Management Plan UK The Environment Agency's Approach to Protecting Groundwater Redmond Bear Creek Valley Groundwater Management Plan Blue-Green Infrastructure for Sustainable Urban Stormwater Management – Lessons from Six Municipality-Led Pilot Projects in Beijing and Copenhagen
If grey water is used for irrigation, ensure it is not used in wellhead protection areas. Complete groundwater monitoring in areas where wastewater is used for irrigation.	2	Protect	Urban Groundwater – Policies and Institutions for Integrated Management
Source water must be of acceptable quality before being used to recharge an aquifer via managed injection. A permit must be granted before a managed injection site can be constructed. Applications for a managed injection site must have a hydrogeologic assessment, risk assessment, and operating plan. A component of the operating plan must include a monitoring plan. Managed injection sites may be used for ensuring surface water levels remain at acceptable levels, mitigating saltwater intrusion, "disposal" of treated wastewater, and/or re-injection of groundwater diverted from underground developments	8, 9	Protect	Water and Environmental Considerations for Managed Aquifer Recharge Operations in Western Australia
Identify areas sensitive to saltwater intrusion and set groundwater elevation limits for the interface based on the sensitive area locations. Monitor the salinity of shallow/coastal groundwater in addition to groundwater elevations. Develop a saltwater intrusion management plan if needed	3, 5, 7	Manage	South Westside Basin Groundwater Management Plan Sustainable Water Strategy Action to 2055 Cockburn Groundwater Allocation Plan

Action	Appendix B Action #	Primary Aim (understand/ protect/ manage)	Document Name
Create water level limits based on base levels needed in surface water bodies in the area as well as where the freshwater/seawater interface is within the groundwater near the shore	15	Manage	Cockburn Groundwater Allocation Plan
Consider both groundwater and surface water when completing works that are intended to affect one of these bodies. (i.e. work done to isolate surface water movement may have unintended consequences for groundwater movement, and vice versa)	17	Manage	Urban Groundwater – Mobilizing Stakeholders to Improve Monitoring
Review groundwater allocation limits regularly and make adjustments if needed	21	Manage	Assiniboine Delta Aquifer Management Plan
Incorporate groundwater protection and water policy into long-term city plans/legislation such as the Official Community Plan or local by-laws. Zoning by-laws should also be amended to limit or prohibit hazardous activities (in terms of groundwater contamination) in vulnerable groundwater areas. This could be done by changing the land use rules or the land use itself.	12, 13, 14, 16	Protect	Aquifer Protection Plan Groundwater Protection Plan Sustainable Water Strategy Action to 2055 Drinking Water and Watershed Protection Action Plan 2.0 2020-2030
Educate City staff about the importance of protecting groundwater and how it can be done	1	Protect	Groundwater Protection Plan
Collaborate with Indigenous Nations to ensure that the groundwater strategy aligns with social, spiritual, and customary objectives	19	Manage	Sustainable Water Strategy Action to 2055

Action	Appendix B Action #	Primary Aim (understand/ protect/ manage)	Document Name
Work with the fire department to phase out the use of fluorinated fire-fighting foam. An example of the phasing out sequence could start with no longer using the foams for training exercises, then banning the sale of the foams, then ceasing the use of fluorinated foams altogether	11	Protect	Environment Protection (Water Quality) Policy 2015
Create a standard groundwater elevation and geochemistry monitoring program. Share the groundwater monitoring data with other government bodies or stakeholders	22	Understand	South Westside Basin Groundwater Management Plan
Additional Actions			
Require land sellers to disclose the location of unused wells. Require the disclosure of the location and status of wells on the property for rezoning/land use applications. Locate and record the position and condition of abandoned wells. Create a grant program for land/well owners to access to help fund decommissioning activities for abandoned, irreparably damaged, or unused wells	110, 125	Protect	South Westside Basin Groundwater Management Plan Redmond Bear Creek Valley Groundwater Management Plan
Enact a by-law that indicates a basement and/or other structures should cumulatively occupy less than 50% of the original garden/unbuilt upon area, and be smaller in area than the original footprint of the dwelling, whichever the lesser. A basement should not involve excavation of more than one (1) storey below the lowest original habitable floor level. The height of a basement should not exceed 3 m floor to ceiling height	91	Manage	Basement Development
In open-loop geo-exchange heating/cooling systems, the temperature of “injection” water cannot be 10 °C greater than the natural groundwater temperature or greater than the maximum threshold of 25 °C [whichever is less]	46	Protect	Management of the London Basin Chalk Aquifer