Enhancing climate resilience of Subdivision and Development Servicing (SDS) Bylaws in the Columbia Basin:

A guidance document

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Disclaimer

The content in this Guidance Document and companion Subdivision and Development Servicing (SDS) model bylaw for Columbia Basin communities is based on the authors' interpretation and understanding of best available knowledge and development practices for enhancing climate resilience of subdivisions. These materials have been developed with the intention of providing guidance to individual communities in the Canadian Columbia River Basin for updating their own SDS bylaws.

Though the authors are experienced professionals who have used their judgment to provide the best possible guidance, use of the information in these documents is at the sole discretion and responsibility of each community. Application of these findings to a specific community will require further professional judgment to ensure the bylaws, standards, and design criteria are appropriately tailored for each community's needs and local conditions. The authors and/or Columbia Basin Trust are not liable for any loss or damage, including without limitation, indirect or consequential loss or damage, arising from reliance upon the information within these documents.

About this Report

Evidence reliably shows that climate in the Columbia Basin has changed significantly over the last century. Future climate is expected to change even further with additional increases in air temperatures, varied changes in precipitation, and shifts in the intensity and frequency of extreme events. Such changes are expected to affect the infrastructure of Basin communities. Storm drainage systems will be affected by more intense rain events leading to possible culvert failures, washed out roadbeds, and other water damage to household, local government, and utility infrastructure. Water distribution systems will be affected by declines in precipitation leading to an increase in summer drought and impacts on community water supplies. Roads will be affected by temperature variations which can lead to frost heaving, thermal cracking, and thaw weakening.

Through its Communities Adapting to Climate Change Initiative, the Columbia Basin Trust has been working with communities in the Basin since 2008 to increase their resilience to the potential impacts of future climate. Subdivision and Development Servicing (SDS) bylaws have been identified as being out of date and a potential obstacle to enhancing community resilience.

This guidance document and a companion SDS model bylaw have been developed to address this need and help guide communities when updating their SDS bylaws. In particular, this work was primarily designed to help communities (1) become more resilient to existing and future climate conditions; and (2) minimize the long term costs associated with developing and operating infrastructure across its entire life or service cycle. Other objectives have also been considered, namely reducing energy consumption, conserving water resources, protecting natural watercourses, allowing for wildfire evacuation routes, and remaining attractive/competitive to private developers.

Four core tasks were undertaken to develop a model bylaw and guidance for enhancing climate resilience. First, an initial list of infrastructure priorities was developed based on a review of all components that could be within an SDS bylaw. Next, the best available evidence was reviewed to understand the potential exposure and sensitivity of infrastructure to a suite of climate impacts. For the most vulnerable infrastructure, provisions and good practices were then examined that have been applied elsewhere in British Columbia, North America, and around the world. Finally, this information was organized in the SDS model bylaw (to provide a template structure, language and procedure for provisions) and guidance document (to provide examples of good practices that are relevant to the provisions) so Columbia Basin communities can use this information when updating existing SDS bylaws.

Beyond an SDS bylaw, there are additional aspects that have an important influence on the context and degree of success of updates by communities. These aspects relate to climate impacts, other legal requirements, financing, and works and services outside the subdivision. The following climate impacts are identified as having the potential to affect infrastructure within Basin communities:

- Intense rain
- Total annual rainfall
- Seasonal rainfall
- Overland flooding
- Drought
- Extreme heat
- Temperature variations
- Rain vs. snow
- Blizzards
- Ice storms
- Wildfire
- Biodiversity
- Intense wind
- Pests / invasives
- Terrain stability
- Water quality

Given the current variation in climatic and environmental conditions, it is reasonable to expect that these climate impacts will also vary across the region. A consideration of variation is important when updating SDS bylaws because it can help clarify the degree of exposure of a community to a climate impact, expected sensitivity of a community's infrastructure, and effectiveness of a particular good practice. Available evidence also indicates there is varied confidence in predicting future climate impacts and in understanding which good practices will most successfully enhance resilience.

Beyond updating SDS bylaws, communities should also consider the package of laws and policies flowing from the *Local Government Act* and *Community Charter* within which an SDS bylaw is situated. It is the collection of requirements that will affect the site selection, density of uses, design, and construction of a subdivision or development, and ultimately affect the resilience of a community to future climate. The suite of legal requirements beyond an SDS bylaw includes:

- Official community plans;
- Zoning;
- Development permit areas for hazards;
- Development permit areas for water conservation;
- Drainage bylaws;
- Runoff control and impermeable surfaces;
- Landscaping bylaws;
- Watercourse protection bylaws;
- Water conservation bylaws;
- Floodplain bylaws; and
- Development cost charges.

The cost of climate resilience is likely another key concern of local governments. Though the fiscal benefits of climate resilience are unclear at this time, a recent study on smart growth development found that costs are on average one-third less for upfront infrastructure, ongoing delivery of services is on average 10 percent less, and tax revenues per acre can be 10 times higher than conventional suburban development.

Various offsite works and services have the potential to be affected by future climate and can be either directly or indirectly linked to an SDS bylaw. These works and services include: offsite stormwater management; water resources, treatment, and storage; potable water and wastewater distribution systems; and other existing infrastructure associated with roads and private utilities. The responsibility for developing and maintaining these works and services may rest with developers, local governments or private utility companies and will similarly require a consideration of good practices that support climate resilience beyond what may be included in an SDS bylaw.

The goal of the SDS model bylaw is to require owners who are subdividing property or require a building permit to make an application under the bylaw. The SDS model bylaw sets out the procedural requirements for applying and obtaining approval from the local government and directs attention to designing subdivisions and developments using good practices with a view to addressing potential climatic impacts. In addition to directing applicants and their consultants to Schedule B, which contains the engineering design specifications for works and services, it includes landscaping as a work to reflect its importance towards building resilience. The SDS model bylaw specifically lists good practices documents and other local government policies and bylaws that applicants must consider in subdivision design, and requires an integrated design meeting between the applicant's professionals and local government staff. Staff are empowered to request additional information, such as climate adaptation, wildfire interface, and landscaping plans, in support of the application. Under the model bylaw the local government may retain security deposits for up to two years post-substantial completion to ensure that the works, including climate resilient works and landscaping as green infrastructure, are functioning. Finally, a two year post-substantial completion monitoring or testing requirement allows local government to obtain information about the performance of works.

Local authorities usually append a Schedule to the SDS bylaw that outlines prescriptive or performance-based design criteria, specifications, drawings, standards and deliverables that support the bylaw provisions. These requirements are intended to guide developers and their consulting professionals in preparing subdivision application submissions to the local authority. This review focused on identifying provisions and good practices that can enhance resiliency of storm drainage systems, water distribution systems, sanitary sewage collection and disposal systems, connectivity, highways and active transportation, landscaping, and utilities that would be contained in such a Schedule.

These schedules strive to ensure that public infrastructure left to the local authority after construction will be well built and remain easy to maintain. Schedule B in the model bylaw has been collated from a number of bylaws, codes and ordinances from around the world. The trend in communities across Canada and abroad is to keep bylaw Schedules simple and refer to good practices in manuals and guidelines that are housed elsewhere. With the SDS model bylaw that is companion to this guidance document, a detailed set of provisions have been provided so that Basin communities can pick and choose the wording and provisions they would like to include when updating their own SDS Bylaws. Examples of structural good practices are referenced throughout this guidance document which could be further specified in a Schedule B. These examples include, among others:

- alternative stormwater management practices which include overland flood routes to create wetlands that attenuate storm flows, reductions in impervious paved surfaces, and the use of landscaping, bioretention areas, and rain gardens (among other) to detain and treat runoff from roads and roofs;
- Low Impact Development (LID) practices to create subdivisions that are more sustainable and livable by preserving natural watercourses and creating wildfire evacuation routes;
- methods to analyze and implement water conservation and water demand management strategies;
- consideration of the effective and safe use of 'greywater' in conserving water resources; and
- consideration of future technologies in subdivision design (e.g., upsizing electrical infrastructure to charge electric vehicles and allow net-metering or selling locally generated alternative energy back into the power grid).

Though the focus of this review is on identifying provisions and good practices that will reduce the sensitivity of a community's "hard" or engineered infrastructure, enhancing adaptive capacity can also be important for increasing a community's resilience. Related efforts are focused on enhancing a community's "soft" infrastructure – its institutions, networks, and knowledge base. Given gaps in understanding future climate impacts and effectiveness of good practices, a recommended focus for enhancing adaptive capacity is on innovation and learning. This focus will help Basin communities reduce the potential for overinvestment or under-investment in infrastructure changes. "Learning by doing" or Adaptive Management is ideally suited to enhancing adaptive capacity given its ability to help communities implement innovative practices and learn about which will provide the greatest benefits in the face of the large unknowns. The Basin also seems like an ideal place for its use given lessons learned elsewhere.

Before updating an SDS bylaw to enhance climate resilience it will be important for communities to remember the following take home messages:

- Local governments will be asking for more information about the impacts of a development up front and the SDS model bylaw requires applicants to invest more in studies to justify design approaches rather than business as usual.
- Local governments will increasingly be holding applicants responsible for ensuring that their infrastructure is functioning properly, for example by requiring an applicant to provide security before commencing development, and may also require monitoring of new infrastructure.
- Prescriptive provisions will require a large amount of information in a Schedule, similar and potentially more than is contained in the SDS model bylaw. This approach may be less attractive to some consulting professionals and developers, who are ultimately responsible for the design and construction of subdivisions. Such an approach may also open up legal dilemmas.

- Performance-based provisions can lead to more streamlined Schedules with references being made to manuals and guidelines that are provided elsewhere. A large portion of bylaws, ordinances, codes and development rules from around the world are moving towards such an approach.
- There are many technical good practice guides available that provide direction to consulting professionals designing new developments and for the staff that are reviewing applications for development. A determination of the most appropriate good practices for a particular community will depend on local conditions and how different practices balance the above competing objectives compared to the status quo. This guidance document summarizes some of these measures, the details of which could be included into existing bylaws and the specifications of which could be drawn from available manuals / guides.

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Abbreviations

AM	Adaptive Management
BEC	Biogeoclimatic Ecological Classification
CACCI	Communities Adapting to Climate Change Initiative
CBT	Columbia Basin Trust
CC	Community Charter
DCCs	Development Cost Charges
DPAs	Development Permit Areas
IDF	Intensity Duration Frequency
LGA	Local Government Act
LID	Low Impact Development
MMCD	Master Municipal Construction Documents
OCP	Official Community Plan
PCIC	Pacific Climate Impacts Consortium
PIEVC	Public Infrastructure Engineering Vulnerability Committee
SDS	Subdivision and Development Servicing

1.0 Introduction

Why update Subdivision and Development Servicing bylaws in the Columbia Basin?

Through its Communities Adapting to Climate Change Initiative (CACCI), the Columbia Basin Trust (CBT) has been working with communities in the Basin since 2008 to increase their resilience to the potential impacts of future climate. Recently, communities have identified Subdivision and Development Servicing (SDS) bylaws as being out of date (in some instances decades old) and a potential obstacle to implementing adaptation measures in response to future climate conditions.[1]

The motivation for updating SDS bylaws is based, in part, on evidence which reliably shows that climate in the Columbia Basin has changed over the last century.[2] Across the Basin, average annual air temperatures have increased from 0.7 to 1.7˚C with total precipitation increasing across seasons (by as much as 4% per decade), though less perceptibly at some locations. Future changes are expected to intensify historic trends and occurrence of extreme events leading to higher seasonal temperatures including hotter summers and a greater frequency of hot spells, higher wintertime and nighttime lows, a longer period of frost-free days, as well as increased precipitation in the fall and winter with more precipitation falling as rain at low elevations (as opposed to snow), more frequent and intense rain events in the fall, and decreased precipitation in the summer.[3]

As the intensity and frequency of extreme events escalate, conventional SDS bylaws will become increasingly less effective at creating subdivisions that can withstand the related impacts. Most SDS bylaws manage for specific environmental conditions using hard infrastructure, the capacity of which is based on predictable environmental conditions, and results in a relatively uniform subdivision layout. For example, a stormwater management system is designed to carry the volume of water that falls as rain away from buildings and streets through pipes and into natural watercourses. The pipes are sized to handle a predictable 1 in 100 or 1 in 200 year storm event. As these events become more severe, hard infrastructure has no adaptability built into its single use design and function – it generally works in the same way under all conditions. As the volume and velocity of water flowing through the system increases, it will cause flooding, damage natural watercourses, and have an impact on water quality.[4] This approach to moving water off the landscape also alters hydrology, which affects the ability of a watershed to support important environmental services such as adequate flows for fish in drier months and recharge of aquifers and other water sources.

Hence, building adaptability into SDS bylaws requires a new approach to dealing with water. In particular, new approaches will allow for the design of subdivisions with rainwater management systems that slow movement of water across the landscape and allow it to infiltrate into soil using a variety of design features, not just pipes and natural watercourses, which behave differently under various conditions. This approach to development will also direct the layout of subdivisions to be better shaped by ecological features, such as watercourses and biodiversity corridors.

How might future climate affect Columbia Basin communities?

Evidence indicates that infrastructure in Basin communities is likely to be affected in the following ways:[5]

- Storm drainage systems will be affected by more intense rain events in the spring / fall and increases in the frequency of rain on snow leading to possible culvert failures, washed out roadbeds, and damage to private, municipal, and utility infrastructure. Earlier and higher peak flows can lead to flooding as a result of overland runoff along impervious surfaces and watercourses spilling their banks.
- Water distribution systems will be affected by a decline in precipitation leading to an increase in summer drought and impacts on community water supplies.
- Sanitary sewage collection and disposal systems will be affected by changes in the intensity, duration and frequency of rain events leading to sewer overflows and flooding of basements.
- Connectivity, highways and active transportation corridors and their foundations will be affected by temperature variations (extreme heat, changes in freeze-thaw cycles) which can lead to frost heaving, thermal cracking, and thaw weakening and alterations to weight restrictions and maintenance schedules.
- Landscaping will be affected by increasing water scarcity and warmer summer air temperature which will increase pressures on residential demand and irrigation requirements, as well as lead to greater conflicts in water allocations among residential, agricultural, industrial, and other needs.

Given the interconnected nature of municipal infrastructure, impacts on one component have the potential to cascade into other failures or losses within the system. For instance, poor performance of the storm drainage system can lead to impacts on roads, bridges and culverts. The potential for cascading failures is only expected to increase as these systems were developed to accommodate historic conditions in climate and hydrology, which no longer apply.[6] Commitments of local governments in the Columbia Basin to the Climate Action Charter[7] demonstrate the further need to improve energy efficiency and reduce emissions of greenhouse gases through infrastructure development and community growth. Thus, it is becoming increasingly clear that sustainable development for local governments requires changes to past approaches of planning, designing, and constructing municipal infrastructure to better withstand the projected range of future climate conditions and better respond to the increasing interest in mitigating impacts on future climate.[8]

What objectives will help Columbia Basin communities enhance resilience of their SDS bylaws?

Based on the above reasoning, updates to SDS bylaws are clearly necessary. However, changes will only be adopted and effective if grounded in the reality that local governments need to balance both today's AND tomorrow's interests. As a result, the primary objectives of updating SDS bylaws to adapt to future climate should be to help communities:

(1) Become more resilient (see Box 1) to existing and future climate conditions; and
(2) Minimize the long term costs associated with developing and operating infrastructure across its entire life or service cycle.

Communities pursue sustainable development with other considerations in mind, however, so updates should also be designed to help communities meet the following secondary objectives:

(3) Reduce energy consumption and greenhouse gas emissions;
(4) Conserve water resources;
(5) Protect natural water courses;
(6) Ensure appropriate evacuation routes and emergency response; and
(7) Remain attractive and competitive for businesses.

Updates to SDS bylaws that seek to represent the breadth of these objectives are more likely to lead to 'no regrets' measures that serve the multiple interests of local governments today and tomorrow.

Box 1. Understanding resilience

In adaptation planning there is an increasing reference to the need to become more "resilient" to future climate.[9] A common view is that resilience refers to the "*capacity of a system to absorb disturbance and reorganize while undergoing changes so as to still retain essentially the same function, structure, identity, and feedbacks*".[10] Though useful as a concept, others have noted challenges in applying it[11] and measuring progress[12] which may be due to confusion around its use and definition.[13] "*Diversity, flexibility, sustainability, adaptability, self-organization, and the ability to evolve and learn*" are seen as key features that describe a resilient community so that it can "*withstand, cope with, manage, and rapidly recover their stability after a variety of crises*".[14] The Stockholm Resilience Centre provides useful insights that can serve as guiding principles for enhancing community resilience:[15]

- Transformation can involve both incremental and abrupt changes;
- Entrepreneurship and leadership have important roles in transformation;
- Crises and opportunities are important for enabling transformations;
- Informal networks of people have an important role in developing new solutions to problems;
- Innovations can break self-reinforcing and undesirable behaviours; and
- Resilience thinking supports long lasting solutions by considering both the social and ecological implications of decisions.

Despite the range of views, at its core resilience is about an outcome – a community that is able to withstand, cope, and rapidly recover from a disturbance – and about the characteristics that allow it to achieve that outcome – flexible, responsive, entrepreneurial, innovative, and focused on the long-term.

How will this guidance document help Columbia Basin communities achieve these objectives?

This guidance document and a companion SDS model bylaw[16] have been developed to help communities enhance their climate resilience by explicitly incorporating future climate projections and examining provisions and good practices (see Box 2) that have been applied elsewhere in British Columbia, North America, and around the world. The focus of these documents is on infrastructure related to storm drainage systems, water distribution systems, sanitary sewage collection and disposal systems, connectivity, highways and active transportation, landscaping, and utilities in new and existing subdivisions across Columbia Basin communities.

The Subdivision and Development Servicing model bylaw serves as a core reference by providing the template structure, language and procedures for provisions that Columbia Basin communities can use when updating existing SDS bylaws. It serves as a compendium from which communities can choose the appropriate provisions and within which good practices can be specified and tailored for local conditions.

> **Box 2. Good practices vs. best practices**
>
> Throughout this document the term "good practices" is used synonymously with "innovative practices" or "adaptation measures" to refer to the innovations, engineering design standards, technologies, and procedures that could be implemented by communities in the Columbia Basin to help minimize the adverse effects of climate change. Due to the uncertainty in understanding effectiveness of infrastructure improvements, the term "good practices" is used instead of "best practices" or "best management practices" because there remain many things to learn about which practices are truly the most effective in responding to climate change.

This guidance document serves as a manual to the model bylaw by providing the supporting context, analysis, rationale, and examples of good practices that have been applied elsewhere. In particular, this document is organized into the following five sections:

Section 1 introduces this work and describes the approach for developing the guidance document and SDS model bylaw.
Section 2 sets this work within the context of relevant considerations that are not explicitly included in an SDS bylaw, yet have an influence on how well updates will enhance climate resilience for a community.
Section 3 provides the supporting rationale related to the process requirements in the model bylaw.
Section 4 provides the supporting rationale and examples of good practices related to the design criteria and specifications in Schedule B of the model bylaw.
Section 5 concludes with a few final considerations for communities updating their own SDS bylaws.

This document is intended to be used alongside the model bylaw so Columbia Basin communities can examine options for improving resilience of their infrastructure, select among these options to meet their individual needs, and update their SDS bylaws as efficiently as possible.

1.1 Approach

This guidance document and accompanying model bylaw were developed by considering the following sequence of questions:

(1) What is the scope of relevant infrastructure for the SDS model bylaw?
(2) What infrastructure is vulnerable to future climate impacts?
(3) What good practices have been used elsewhere to enhance resilience to climate impacts?
(4) What information is needed to guide Columbia Basin communities?

What is the scope of relevant infrastructure for the SDS model bylaw?

An initial list of considerations was developed based on a reasonably comprehensive representation of all components (water distribution system, sanitary system, storm drainage system, roads and sidewalks, landscaping, and utilities) and engineering elements (pumping stations, reservoirs, water mains, curbs and gutters, culverts, inlet / outlet structures) that could be contained within an SDS bylaw. This initial list was then prioritized based on: (1) priority concerns identified by CBT and partner communities; (2) anticipated sensitivity of engineering elements to potential climate impacts; (3) anticipated resilience of engineering good practices; and (4) availability of evidence to understand climate impacts that might affect infrastructure. The resulting scope of relevant infrastructure is outlined in Table 1. Since the SDS model bylaw was drafted to guide developers working within the jurisdiction of a local government, these priorities did not include considerations that may be relevant for other levels of government.

What infrastructure is vulnerable to future climate impacts?

Although a general understanding of the vulnerability (see Box 3) of Basin communities to future climate is already available,[19] it was not possible to characterize the vulnerability of subdivisions and infrastructure for all communities.[20] An understanding of vulnerability was necessary, however, to help identify the good practices that would be most effective at improving a community's climate resilience. Infrastructure that is most sensitive to future climate will likely be the most prone to failures in operation, potentially leading to a direct loss of infrastructure (e.g., washed out culverts) or indirect impacts on other parts of the built environment (e.g., flooding of homes). Good practices that help a community respond to a climate impact with a high degree of exposure (e.g., intense rainfall events) will likely require more robust design criteria compared to climate impacts for which exposure is expected to be less (e.g., extreme heat events).

Box 3. Vulnerability to future climate

The emerging and dominant view is that the vulnerability of human communities and ecosystems can be described as "*a function of the character, magnitude and rate of climate change and the variation to which a system is exposed, its sensitivity and its adaptive capacity*".[17]

Thus, three measures are used to describe vulnerability to future climate. Exposure is a measure of the severity, extent and duration over which a community will be affected by a climate impact. Sensitivity is a measure of the degree to which a community may be affected after being exposed to a climate impact. Adaptive capacity is a measure of the potential (e.g., human, financial, technical capacity) within a community for decreasing its exposure or sensitivity to a climate impact.[18]

Given this need, the best available evidence was used to develop a summary of the expected exposure and sensitivity to future climate impacts across the Columbia Basin (provided in Section 2.1). An understanding of exposure was based on a review of existing summaries of climate impacts,[21] projections of future climate conditions,[22] analyses or modelling of changes in local environmental conditions,[23] as well as analyses, studies or reviews of environmental changes from elsewhere in British Columbia.[24] A sensitivity matrix was then used to represent the potential interactions between a community's infrastructure and expected climate impacts.[25]

What good practices have been used elsewhere to enhance resilience to climate impacts?

Responses of communities to future climate can include actions that address mitigation, adaptation or both.[26] Given the emphasis on enhancing the climate resilience of communities, this review was focused on identifying bylaw provisions and good practices that support adaptation with mitigation considered as a secondary benefit. Three criteria guided the review of other SDS bylaws, provisions, and good practices. The priority was to identify good practices that were leading examples, have been implemented, and relevant to the mountainous setting and climate impacts affecting Basin communities. Although Table 1 was used as the basis for prioritizing this review, a more comprehensive set of provisions was included in the model bylaw. Additional provisions were included to reflect current thinking from around the world regarding resilience, regardless of whether future climate impacts directly affect these provisions. The results of this review are included in the SDS model bylaw and in Sections 3 and 4 of this guidance document.

What information is needed to guide Columbia Basin communities?

Not surprisingly, it is very difficult to develop an SDS model bylaw that comprehensively captures all the necessary elements for guiding developers across all Basin communities. The 2011 draft SDS bylaw from the District of Elkford[27] was used as an initial template for the model bylaw. Additional provisions were necessary to provide the framework into which appropriate good practices could be included. As such, the authors drew upon provisions from the District of North Vancouver, the City of Kamloops and other municipalities to produce a fairly comprehensive example of a 'model bylaw'. This comprehensive approach is in contrast to many jurisdictions around the world in which an SDS bylaw is kept brief with references made to checklists and detailed guidelines provided elsewhere (e.g., BC Stormwater Design Guidelines). The Cities of Calgary and Toronto are good examples.[28]

The intention in developing the model bylaw in this way is that it could be used by local governments to choose the subset of relevant provisions and good practices when updating their own SDS bylaw. In some places in the model bylaw, provisions are ambiguous without reference to a specific good practice since no single approach is seen as being appropriate across all Basin communities. References to a range of good practices that are relevant to the SDS model bylaw are provided in this guidance document (page numbers in section headings of Sections 3 and 4 of this guidance document refer to the relevant locations to which a section applies in the SDS model bylaw). A local government's choice about the provisions and good practices to implement will require a consideration of the trade-offs among costs (up front and operating), benefits (economic competitiveness, environmental protection) and effectiveness (degree of climate protection and reliability of technology) of these measures. A set of established criteria are available for understanding the trade-offs among options and tailoring the suite of provisions and good practices to local conditions (see Table 2). These criteria directly align with the primary and secondary objectives of Basin communities described above. Given constraints in scope, this review of provisions and good practices was not based on a thorough evaluation of costs, benefits, and effectiveness of alternative good practices or a comparison of them to business as usual.

2.0 Context for SDS Bylaw

2.1 Climate Impacts

What are the expected impacts of future climate on Columbia Basin communities?

An underlying motivation for updating SDS bylaws is to ensure communities are resilient to past and future changes in climate and the related environment. Though the future cannot be predicted with 100% certainty, historic observations provide insights which illustrate that the climate has been changing in significant ways that will affect Basin communities. Analyses of records from weather stations show that annual average temperatures have increased between 0.7 °C and 1.7 °C from 1901-2004. Western communities have warmed more than eastern ones, nighttime lows more than daytime highs, and winter temperatures more than other seasons. Precipitation has also increased in all seasons, though the pattern of change is more varied and degree of change less clear. The greatest increase in precipitation has been in the spring, ranging between 3% and 7% per decade. Summer precipitation has increased 1% to 4% per decade. Communities have also reported less consistency in climate from season to season and year to year, noting more extreme weather including more intense wind, rain, and drought.[29]

The basic sequence of links between climate and community adaptation is illustrated in Figure 1. Changes in climate variables will lead to climate impacts (see Box 4) which will affect the vulnerability of communities. Good practices or adaptation measures can then be implemented to minimize the adverse effects or take advantage of opportunities associated with future climatic and environmental changes. For instance, increases in the intensity, duration, and frequency of rainfall events can lead to a greater amount of surface water runoff over short periods of time. Such increases can increase the vulnerability of storm drainage systems and property, potentially leading to damage to both. To avoid potential losses, communities can adjust the configuration and design of storm drainage and sanitary systems (e.g., collection and transmission structures, overflow systems, and treatment facilities) to better accommodate expected impacts on stormwater runoff.

> **Box 4. Defining climate impacts**
>
> Throughout this document the term "climate impact" is used to refer to the environmental changes expected to occur as a result of a changing climate. Climate impacts can include changes in climate conditions (air temperature and precipitation), but also the related environmental changes (glaciers, snowpack, water supplies, forest cover, wildfire, biodiversity) that have the ability to affect communities.

Appendix B summarizes the scientific evidence and projected exposure of Basin communities to sixteen climate impacts which have the potential to affect infrastructure of local governments. Relevant climate impacts include:[30]

Intense rain (IR): Changes in the intensity, duration, and frequency of storm events that have the potential to increase surface water runoff along impervious surfaces or within streams and rivers.

Total annual rainfall (TR): Changes in the total amount of rainfall over the year that has the potential to affect the amount and form (rain vs. snow) of water contributing to the annual water balance.

Seasonal rainfall (SR): Changes in the seasonal distribution of rainfall which has the potential to affect seasonal amount, form, and timing of water availability.

Overland flooding (OF): Changes in the magnitude and timing of spring time peak flows or flooding that spills into the floodplain at other times of year.

Drought (DR): Changes in severity, timing, and duration of low flows that occur during the summer or other times of year.

Extreme heat (EX): Increases in the intensity, duration and frequency of hot spells.

Temperature variations (TV): Changes in the occurrence of rapid fluctuations in temperature over short periods of time (e.g., freeze-thaw cycles, daytime and nighttime temperatures).

Rain vs. snow (RS): Changes in the amount of precipitation that falls as snow which can lead to rain on snow events and increases in surface water runoff.

Blizzards (BL): Changes in the intensity and frequency of snow storms.

Ice storms (IS): Changes in the intensity and frequency of ice storms.

Wildfire (WF): Changes in location, intensity, frequency and duration of wildfires in vegetated areas.

Biodiversity (BD): Changes in climate preferences and habitat suitability for vegetation, wildlife, and fish species that can affect their growth, distribution and abundance.

Intense wind (WI): Changes in the intensity and frequency of intense wind storms.

Pests / invasives (PE): Changes in climate preferences that lead to increases in growth, distribution and abundance of non-native pests or invasives.

Terrain stability (TE): Increases in the frequency and intensity of slope failures due to a decrease in the stability of terrain associated with intense rain storms.

Water quality (WQ): Alterations in water quality conditions, such as water temperature, turbidity, nutrient concentrations.

Table 3 provides a general characterization of the vulnerability of community infrastructure based on assumed exposure to these climate impacts and expected sensitivity of components in the SDS model bylaw (from Table 1). This alignment is useful for understanding which climate impacts pose the greatest threat (by looking at the number of interactions down each column) and for ensuring that good practices are able to respond to the suite of climate impacts affecting each component (by looking at the range of interactions across each row).

How might these climate impacts vary across Columbia Basin communities?

Given the current variation in climate and environmental features across the Basin, it is reasonable to expect that future changes in climate impacts will also vary across the region. For instance, high elevation communities may see smaller decreases in precipitation as snow or fewer changes in freeze-thaw cycles when compared to lower elevation communities. Communities that currently have higher annual and summer temperatures may be more adversely affected by extreme heat events while communities that currently have more annual rainfall may be less affected by drought.

A consideration of current variation is important because it can help clarify the degree of exposure of a community to a climate impact, the expected sensitivity of a community's infrastructure, and the effectiveness of a particular good practice. In an SDS bylaw, variation within and across communities could be explicitly represented using Schedule A – Level of Works and Services – to specify which good practices would be most appropriate under which set of environmental conditions across the Basin. Where common conditions exist, there may be opportunities for communities to tailor works and services in a similar way or implement similar good practices across different SDS bylaws. Alternatively, it will be important to recognize differences in conditions across communities and tailor good practices accordingly.

Figure 2 illustrate variation in current conditions across Basin communities from three perspectives. Figure 2A shows climate sub-regions for the Basin. These areas represent major topographic differences that are expected to remain constant over a long time (thousands of years) with climate conditions expected to remain more similar within sub-regions than between them.[31] Figure 2B shows the distribution of biogeoclimatic (BEC) zones across the Basin. These zones represent ecologically distinct units that integrate climate, topography, and vegetation cover over a more recent though shorter time (decades) and for which projections of future changes are available.[32] Figure 2C (mean annual temperature) and Figure 2D (total annual precipitation) show variation in annual measures of climate for a historic baseline period (1961-1990). These images also show that Basin communities tend to be concentrated within lower elevation valley bottoms. The difference between the highest and lowest elevation community is approximately 1,000 m. Given the strong link among elevation, air temperature, precipitation as snow and vegetation cover, this difference in elevation can be expected to lead to differences in climate impacts across communities.

Clearly there are meaningful differences in environmental conditions across Basin communities that should be considered when updating SDS bylaws and tailoring good practices to enhance resilience to future climate. This variation is reflected by the distinct climate sub-regions as well as through differences in BEC zones and climatic variables with the east tending to be drier than the west and the north tending to be cooler than the south. These representations could be useful for grouping communities having similar current climate conditions and who may be exposed to similar future climate impacts. Depending on a community's location, differences in good practices could then be represented in a Schedule A. For instance, communities in drier and hotter zones could be more focused on responding to drought and wildfire, while communities in wetter zones could prioritize responding to intense rain events. These groupings could be used with more standard ways of specifying level of works and services through a Schedule A (e.g., lot size, zoning requirements, and/or location relative to an environmental hazard – steep slope or floodplain).

How confident are future predictions of climate impacts?

Figure 1 also shows there are several sources of uncertainty which can cloud the level of understanding about future climate, related environmental changes to which communities need to adapt, and good practices that will most successfully enhance resilience. There are a large number of projections from equally plausible Global Climate Models and emissions scenarios, as well as the different approaches for converting global climate projections to local scale information (cloud A). There are large gaps in our ability to link future changes in climate to future changes in the environment – e.g., water, forest cover, and wildfire (cloud B). These gaps are represented by the varying levels of completeness in scientific understanding and ranges of projections in climate impacts (see Appendices A and B).[33] There are contrasting, and equally valid, views among the public, decision makers, and politicians on how to balance social, environmental, and economic priorities which will affect the perceived vulnerability of communities. Moreover, there is uncertainty in understanding the benefits, reliability, and effectiveness of good practices that could be implemented to enhance climate resilience (cloud C).

Given the range and sources of unknowns, it will never be possible to have a high degree of confidence in understanding precisely the severity, location, and timing of future climate impacts. To address this challenge, it is best to recognize these uncertainties explicitly when making decisions about responding to climate impacts and implementing good practices for enhancing climate resilience (see Table 4 and Section 5.1). For instance, a community's motivation to update its SDS bylaw may be strongest when responding to climate impacts that are the most severe and certain or when implementing good practices for which effectiveness is the most well-known or for which there are multiple co-benefits (i.e., representing 'no regrets' measures).

2.2 Other Legal Requirements

Beyond the SDS bylaw itself communities should consider the package of laws and policies flowing from the *Local Government Act* (LGA) and *Community Charter* (CC) within which the SDS bylaw sits because they will direct the site selection, density of uses, design, and construction of a subdivision or development. It is this entire regulatory approach that will lead to the best climate resiliency; therefore, each local government is encouraged to evaluate its land development bylaws and policies to ensure that each addresses climate adaptation, resilience and mitigation within its specific jurisdiction. This jurisdictional suite includes:

- Official community plans (LGA s. 875);
- Zoning (LGA s. 903);
- Development permit areas (DPAs) for hazards (LGA ss. 919.1-920);
- Development permit areas for water conservation (LGA ss. 919.1-920);
- Drainage bylaws (CC s. 69 and LGA ss. 540-542);

- Runoff control and impermeable surfaces (LGA s. 907);
- Landscaping bylaws (CC s. 15, LGA s. 909);
- Watercourse protection bylaws (CC ss. 8-9 and Spheres of Concurrent Jurisdiction – Environment and Wildlife Regulation B.C. Reg. 144/2004);
- Water conservation bylaws (CC s. 8 and LGA s. 796);
- Floodplain bylaws (LGA s. 910); and
- Development cost charges (DCC) (LGA s.933).

While section 877(3) of the *Local Government Act* requires official community plans (OCPs) to include targets for the reduction of greenhouse gas emissions, and proposed policies and actions of the local government for achieving those targets, most of the jurisdictional elements listed above do not fit into SDS bylaw processes as defined in section 938 of the *Local Government Act*. Typically, SDS bylaws include only drainage, runoff control and impermeable surfaces, and landscaping, as well as specifications for hard infrastructure such as roads, sanitary sewer, water and other services.

It is also important to note that an approving officer can refuse to approve a subdivision that does not conform to all local government bylaws regulating subdivision and zoning.[34] Courts have interpreted this to mean that an approving officer has no jurisdiction to approve a subdivision that does not meet the requirements of a local government's bylaws. In addition, the approving officer may refuse to approve the subdivision plan if the approving officer considers the plan to be against the public interest. This gives the approving officer extensive discretion to require an applicant to address climate adaptation approaches when supported by bylaw provisions and policies that are located outside of the SDS bylaw.

Finally, the climate resilience of any development or community will depend to a large degree on location or siting and design, and the ability of the green infrastructure or existing natural systems to deal with changing climatic conditions. Where and how much of any use is located is primarily dictated by OCPs and zoning as in the *Local Government Act* (LGA), with the *Community Charter* enabling municipalities to protect watercourses. Including these regulatory methods into a climate resilient approach to community development will yield a more comprehensive package for land development.

The rest of this section briefly describes some of the climate resilient policies and bylaw provisions outside of the SDS bylaw that support infrastructure adaptation.

Official Community and Area Plans

Official community plans their sub-plans such as neighbourhood plans, local area plans, and/or watershed plans set out a local government's objectives and policies for planning and land use management. Although not directly binding on local government decisions, all bylaws must be consistent with the OCP,[35] and OCPs give important direction to approving officers and other decision-makers as to the appropriateness of development applications.

In addition to containing policies for the "*preservation, protection, restoration and enhancement of the natural environment, its ecosystems and biological diversity*",[36] an OCP must include statements and map designations for the approximate location, and phasing of any major road, sewer and water systems, as well as restrictions on land that is subject to hazardous conditions or that is environmentally sensitive to development. Therefore, from a climate resilience and adaptation perspective the OCP is a key document in directing development to appropriate locations and in the appropriate density.

In general, the OCP will provide direction that subdivisions should be avoided on floodplains, landslide areas and other high risk areas that are susceptible to extreme weather events, unless adaptations such as levies and slope stabilization are practical and can be implemented sustainably. The OCP will also direct climate resilient development to cluster in appropriate locations, leaving open space for stormwater infiltration and flood detention.

Areas plans and OCPs also often describe the kinds of good practices that applicants should consider and work towards. See, for example, the District of Maple Ridge's Silver Valley Area Plan (District Bylaw 6067-2002) that details desired infrastructure servicing requirements such as:[37]

- retaining native top soil;
- minimizing interception of ground water flow;
- maximizing storm water infiltration;
- minimizing impervious surfaces;
- maintaining watercourse base flow;
- utilizing storm water treatment ponds;
- developing storm water release rates through simulation modeling of pre-development flows; and
- limiting the effective imperviousness to 15 percent of the total area of the Valley.

See also City of Fort St John's Winter City Design Principles, contained in Appendix A to the OCP.[38]

Zoning

Zoning allows local governments to regulate the use of a piece of land and how much of that use (density) is allowed on a specific part of the land. Zoning is the primary way that local governments control where and what kind of development occurs. It can prevent development in inappropriate locations and direct more intensive development to cluster on land that is not at risk for climate impacts such as flooding.

Zoning can also protect water supplies and other infrastructure. For example, the Comox Valley Regional District's Water Supply and Resource Area zoning (Bylaw No. 2781) is designed to protect ground water. The minimum lot size for subdivision is 400 hectares, and density is limited to one single family dwelling per lot. The allowable lot coverage is 35 percent to a maximum of 1000 square metres. Though this example illustrates how zoning can protect water supplies, such measures also need to be considered in the context of how they affect other community objectives (e.g., reducing energy consumption and greenhouse gas emissions).

Development Permit Areas (DPAs) for Hazards and Water Conservation

Local governments can designate DPAs for a variety of purposes, including protection of the environment, protection of development from hazardous conditions, and establishment of objectives to promote water conservation and the reduction of greenhouse gas emissions. Land within a DPA must not be subdivided or construction of a building started unless the owner obtains a development permit. As an overlay that supplements zoning, guidelines in the OCP direct staff to issue development permits that contain site-specific conditions with which the construction must comply.

From a climate resilience perspective, DPAs allow local governments to tailor the development layout and design to the site. Conditions in the DPA can prohibit development on portions of the site, require that natural features be protected, such as vegetation for drainage purposes, and specify construction approaches. In particular, for DPAs designated for protection from hazardous conditions, a development permit may:

- specify areas of land that may be subject to flooding, mud flows, torrents of debris, erosion, land slip, rock falls, subsidence, tsunami, avalanche or wildfire, or other hazard, as areas that must remain free of development, except in accordance with conditions in the permit;
- require, in an area that the permit designates as containing unstable soil or water that is subject to degradation, that no septic tank, drainage and deposit fields or irrigation or water systems be constructed;
- in relation to wildfire hazard, include requirements for the character of the development, including landscaping, and the siting, form, exterior design and finish of buildings and other structures; and
- in relation to wildfire hazard, establish restrictions on the type and placement of trees and other vegetation in proximity to development.[39]

See, for example, the Village of Elkford's Wildfire DPA within which a wildfire hazard assessment is required before the District will issue a development permit, and its Floodplain DPA where total impervious area of new development is taken into account and on-site infiltration encouraged.[40] See also the City of Kelowna's 2009 Hillside Development Guidelines that address building on steep slopes as well as wildfire hazards.[41] The District of Campbell River's Watershed DPA also limits impervious surfaces to ten percent of the lot and requires an environmental impact assessment to assess the cumulative impacts of development on surface and ground water.

In addition, for DPA guidelines that establish objectives to promote water conservation and the reduction of greenhouse gas emissions, a development permit may include requirements for:

- landscaping;
- siting of buildings and other structures;
- the form and exterior design of buildings and other structures;
- specific features in the development; and
- machinery, equipment and systems external to buildings and other structures;

and restrictions on the type and placement of trees and other vegetation in proximity to the buildings and other structures in order to provide for energy and water conservation and the reduction of greenhouse gases.

A current example is the City of Castlegar's Energy, Water and GHG Reduction DPA which includes guidelines for layout and design features of new development, building features, stormwater management, energy conservation and water conservation, such as requiring a landscape plan and supervision of installation by a qualified professional that maximized unirrigated areas minimizes mowed turf areas.[42]

Finally, the Village of Elkford's Energy Efficiency and Water Conservation DPA includes guidelines for:

- the use of sustainable or 'green' building material;
- building design that includes passive heating, lighting and cooling;
- building orientation for passive solar gain and to maximize the use of solar thermal and solar-voltaic modules;
- the use of landscaping and windows to allow heating and cooling of buildings;
- green roofs; and
- water efficiency in landscaping and appliances.

Water Conservation Bylaws

As part of providing a service a local government has significant discretion to structure the provision of that service and regulate how that service can be used. In providing potable water a local government can establish a fee structure to pay for that water that takes into account amount of use and time of use. It can also regulate how much water and for what uses the water can be put at certain times of the day or year.

For example, the Capital Regional District Water Conservation Bylaw No. 3061 prohibits wasting water and imposes outdoor water use restrictions from May 1 to September 30. During Stage 1 of restricted water use lawn watering is limited to two days per week in the early morning or evening. Stage 3 prohibits lawn watering, as well as filling hot tubs and pools, operating a decorative fountain, and washing cars except at dealerships or commercial car washes.

Floodplain Bylaws

Local governments have the authority to designate areas as floodplain by bylaw, and once designated, the underside of any building used as a “dwelling purpose”, “business”, or “the storage of goods which are susceptible to damage by floodwater” must be above the flood level specified by the bylaw. In response to more extreme storm events, floodplain bylaws and policies in OCPs relating to floodplains can clearly direct new development away from floodplains or to be built only at certain heights above the flood level.

Development Cost Charges

A local government may levy development cost charges on most people who obtain a subdivision approval or building permit to pay for the capital costs of providing sewage, water, drainage, and highway (road) facilities, as well as providing and improving parkland that services the new development.

Local governments can impose variable DCCs that are tailored to different types of development and in different areas to reflect the actual cost of providing services to development and to create incentives to build using favourable climate-adaptable techniques and approaches. Development cost charges can be tailored both to the location of the development and to the type of development. While development cost charge bylaws of Columbia Basin communities tend to levy similar charges on a per unit or per square foot or metre basis, and sometimes based on where the development takes place,[43] the City of Kelowna charges significantly more (upwards of $10,000) in DCCs at the periphery of its serviced area compared with a unit in downtown, recognizing that it costs more to provide services at the edge of the serviced area compared with infill in an existing serviced area.

From a climate resilience perspective, DCCs can pay for green infrastructure that serves multiple purposes as parkland. Passive parkland and/or greenways corridors can be strategic parts of the stormwater management system for a local government. They can host detention ponds and more significantly hold flood water in severe storm events. Development cost charges for parkland and stormwater can pay for such infrastructure, as the City of Surrey has done along the Highway 99 corridor and as part of the Grandview Heights Neighbourhood Concept Plan.

2.3 Financing

In transitioning to a climate resilient approach to subdivision and development servicing local governments and applicants may question the cost. Though the fiscal benefits of climate resilience are unclear at this time, a recent study on smart growth development found that costs are on average one-third less for upfront infrastructure, ongoing delivery of services is on average 10 percent less, and tax revenues per acre can be 10 times higher than conventional suburban development.[44] While costs of climate resilience will, ultimately, be site-dependent, there is no general conclusion that a climate resilient approach is more costly to service than conventional hard infrastructure. In fact, this study suggests that the costs of a climate resilient approach may in fact provide greater benefits than costs.

To assist with the transition, local governments are taking advantage of grants, such as the Green Municipal Fund of the Federation of Canadian Municipalities,[45] to assist with funding new green infrastructure. They are also retooling DCCs to better reflect the actual cost of development. In particular, local governments want to ensure that new development that has a smaller impact on infrastructure, for example by infiltrating 95 percent of rainwater, is not charged the same DCC amount as a development that does not take a climate resilient approach.

2.4 Works and Services Outside Subdivision

When it comes to establishing a subdivision for single lots, or splitting a relatively small lot into three or more lots, requirements for developers are usually less onerous. In larger subdivisions, however, local governments require a number of engineering design, environmental, and other evaluations before it issues a Preliminary Layout Approval (see process as set out in the SDS model bylaw). The focus of these detailed evaluations, led by consulting professionals, usually remains within the immediate vicinity of the boundaries of land being developed.

When the developer is the only one benefiting from a required upgrade to a larger public infrastructure component (e.g., a water storage reservoir, pumpstation, flood detention works), the developer is asked to design and construct the component at their cost. Where oversizing is required to take care of future developments, the local government usually contributes a portion of the cost, or allows a Latecomer Agreement to be developed whereby the developer can claim a portion of the costs from other developers when they tie into the system. Where off-site works benefit multiple developers or the broader community, a local government usually takes care of upgrades to this infrastructure by drawing on Development Cost Charge funds.

Various offsite works and services that local governments develop and maintain are listed below with a brief description of the potential sensitivity to climate impacts and links to good practices for enhancing climate resilience. These offsite works have the potential to be additionally affected by future climate and can be linked to an SDS bylaw. For instance, potable water supplies to a subdivision are usually provided by a local government or their designated utility company, though an SDS bylaw requires that the developer's consulting professional confirm that this supply is adequate, reliable and of suitable quality.

Offsite stormwater management

- Flooding and increased sediment transport in waterways through cities is becoming an increasing concern, especially from a public safety, damage and liability perspective.
- An increase in the frequency and intensity of wildfires can lead to hydrophobic soils which can cause major flooding. Changes to offsite road culverts can be used to help avoid future problems with flooding (e.g., Kelowna, BC).
- Local governments have been moving towards the implementation of source controls such as encouraging the construction of bioswales, infiltration trenches/french drains, detention ponds, and other means of slowing down surface stormwater flows.
- Local governments have also been requiring stormwater detention and water quality treatment above or below new subdivisions. During subdivision planning and design process, local government staff and developers usually liaise closely on how achieve broader public benefits, and who will carry the cost of these off site works.

Water resources, treatment, and storage

- Earlier and larger peak stream flows during the freshet period have been observed and are expected to continue into the future. These changes can lead to lower stream flows later in the year and may cause concerns in the reliability of drinking water sources in future. Some creeks can become dewatered in winter due to freezing. Changes in local planning and development of water resources can help address these concerns including building dams to create more water storage and reduce the variability of stream flows or harnessing groundwater from well fields.
- A reduction in surface flows due to human water use and over-abstraction from wells for irrigation and other uses can have adverse effects on groundwater well fields used in some communities. Hydrogeologists have been studying this phenomenon and others are developing technical (groundwater recharge) and policy (water licensing) solutions.
- Higher peak flows can lead to higher sediment concentrations in streams. Pre-settling and other techniques have been employed to bring treatment costs down.
- In some places water treatment facilities can be affected by power outages caused by severe wind and other storms. Backup treatment and pumping redundancy can be used to mitigate impacts.

Distribution systems (potable water and wastewater)

- Higher water temperatures can encourage the growth of bacteria which could impact water treatment and the growth of biofilms in a subdivision's water distribution system.

- Extreme weather events can lead to power outages that cause downtime in sanitary pump stations. Public health problems can occur if there is no redundancy to deal with excess sanitary flows.
- Fire protection flows are usually drawn from the same distribution pipelines as potable water. An increase in the frequency and intensity of wildfires in the future will strain existing water distribution systems. Upgrading pipeline systems or moving to dual water supply pipelines (i.e., potable and fire flows/irrigation separately) is an option being implemented to address such concerns.
- In addition to the installation of water metres in homes to reduce demand, some local authorities are considering the installation of district and zone wide water meters to help curb leakage across the water distribution system and over use of scarce treated water supplies.

Other existing infrastructure

- Infrastructure upstream and downstream of a subdivision may not be adequately sized to accommodate the new development in the face of changing environmental conditions.
- New subdivisions will increase the flow of traffic on existing public roads. Increased wear and tear on road surfaces could become more pronounced as freeze-thaw cycles become more frequent. Any upgrades to the road systems and traffic controls need to be planned and coordinated by local and provincial authorities.
- Power, telephone, cable and natural gas infrastructure upgrades are usually conducted by the responsible Utility Companies, though costs are sometimes passed on to the local government or developer. This infrastructure could be increasingly affected by climate impacts in the future (e.g., terrain stability).

Though beyond the scope of an SDS bylaw, a consideration of the above offsite works and services is important because they are consistent with the good practices that would be promoted through an SDS bylaw and undertaken within a subdivision.

3.0 Process Requirements (pages 1-15)

This section describes the model bylaw and its relationship to both climate impacts and good practices, primarily from a procedural perspective (see Box 5). The goal of the bylaw is to require owners who are subdividing their property or require a building permit to make an application under the SDS bylaw. The model bylaw sets out the procedural requirements for applying and obtaining approval from the local government.

The model bylaw directs attention to designing subdivisions and developments using good practices and with a view to considering potential climate impacts. In addition to directing applicants and their consultants to Schedule B, which contains the engineering design specifications for works and services, the bylaw includes landscaping as a work and allows the local government to retain security deposits for up to two years post-substantial completion to ensure that the works, including climate adapted works, are functioning. Finally, a two year post-substantial completion monitoring or testing requirement allows the local government to obtain information about the performance of works.

> **Box 5. Linking the guidance document to the model bylaw**
>
> Sections 3 and 4 of this guidance document relate directly to the process requirements and Schedule B of the SDS model bylaw. Section and page numbers are included in the section and sub-section headings here to refer to the specific locations to which a section applies in the SDS model bylaw.

3.1 Interpretation (pages 1-4)

These sections set out general interpretation approaches to the bylaw. Two climate-specific provisions are of note. The first is the Whereas recital before the substantive portion of the bylaw that makes reference to Council's desire to address the impact of climate change. While of no legal effect, this recital can assist in the interpretation of the bylaw and alerts the reader that there may be climate specific requirements in the bylaw. The second is the definition of "Works" in section 7, which includes landscaping as a work to reflect the importance of landscaping in adaptable and infiltration-based approaches to drainage and stormwater management.

3.2 Works and Services Required (pages 4-9)

This part prohibits subdivision or development unless that activity complies with Schedule B of the bylaw and receives approval from either the Approving Officer, in the case of subdivision, or the Chief Building Official, in the case of building permits. This part contains the majority of the climate-related bylaw provisions.

Section 12 makes provision for the consideration of alternative development standards that address climate resiliency, environmental or technical solutions that provide more sustainable approaches for works and services on specific sites. In support of alternative approaches, section 13 requires the applicant to take into account good practices when designing the subdivision or development. In particular, the bylaw refers the applicant to a variety of toolkits and guidance documents that elaborate on good practices for local governments.

Much of the remainder of the part requires owners to comply with Schedule B in the provision of specific types of works and services for subdivision and development. These include a water distribution system, a storm drainage system, sanitary sewage collection and disposal, and connectivity, highways (roads), and active transportation that include sidewalks and other non-motorized transportation infrastructure. Of note for climate resilience, the storm drainage system must include green infrastructure such as natural watercourses, landscaping and trees (section 15.1), and the drainage system may terminate in the ground or, stated another way, may be based on infiltrating rainwater (section 15.2). Also of note is that a local government may require additional land adjacent to a highway if the Approving Officer believes that additional land is needed to support and protect a new highway due to terrain and soil conditions (section 21.3).

Finally, sections 27-28 direct the owner to all applicable laws and bylaws, focusing on natural amenities that assist with drainage. It also mentions climate resilient policies and bylaws, which will give staff the ability to point to other documents that give direction to subdivision layout and design. Finally, section 29 prohibits the alteration of natural watercourses without the approval of the local government in recognition that enhancing existing hydrology is a key approach to climate resilience.

3.3 Security and Servicing Agreement (pages 9-11)

In keeping with most SDS bylaws, this part requires the owner to provide a security deposit and enter into a subdivision servicing agreement with the local government. The security deposit acts as a monetary guarantee of completion for the works to the satisfaction of the Municipal Engineer. If the owner does not complete the works and services as agreed to in the servicing agreement, the local government may complete the works and use the security deposit to pay for the cost of its employees or contractors completing the works.

3.4 Application and Approval (pages 11-12)

Section 46 establishes the requirements for application and the process for approval of built works and services. In particular, section 48 acknowledges the kinds of additional information that the Approving Officer and Chief Building Official may require from applicants in support of enhancing climate resilience. Related information includes calculations of site imperviousness and rainwater infiltration rates, as well as various plans such as climate adaptation, passive solar, integrated stormwater management, wildfire interface and landscaping. While the power to ask for additional information exists irrespective of this subsection i.e., the Approving Officer or Chief Building Official may ask for information as part of the application process, by setting this out explicitly it alerts staff and applicants to the kinds of information that may be required as part of climate resilience considerations. While applicants may be wary of the amount of information that a local government may request, local governments can daylight the process further by providing information on their web site and as part of their information package to applicants as to what the usual process is for requesting information. It is important to note that an approving officer's jurisdiction is not limited by section 46. An approving officer has independent jurisdiction under the *Land Title Act* and can ask for any information they deem necessary.

Section 49 requires applicants to meet with planning staff, the Approving Officer and/or the chief Building Official to discuss subdivision and development proposals during what is called an "integrated design meeting". While this requirement may be too onerous for staff in small local governments, it is an attempt to give them some face-to-face time with the applicant and consultant so staff can underscore the importance of an integrated design approach and draw attention to the climate resilient policies and bylaws. The purpose of the meeting is to provide a forum for addressing potential issues before significant time has been invested in a particular approach or design.

3.5 Completion of Works and Services (pages 12-14)

This part focuses on how the local government will acknowledge and accept completion of works and services. Of note is the attention paid to securing compliance and enabling monitoring and testing for a two year period. Subsection 58 allows the local government to reduce the security deposit supplied by the applicant as works are completed to the satisfaction of the Municipal Engineer. However, sections 59-64 and 68 require the local government to holdback ten percent of the security deposit for regular works for a period of two years and twenty percent of the security deposit for landscaping for a period of two complete growing seasons to ensure the owner maintains the works, remedies any defects or pays for damages resulting from the defects. If the owner fails to do so, the local government may maintain or fix the works and use the security deposit to pay for their efforts. These provisions are found in many SDS bylaws and are important aspects of ensuring that new infrastructure approaches to climate adaptation are properly functioning.

This requirement for security in the amount of 125 percent of the cost of the works and holdback of security is standard practice for local government that have a commitment to ensuring that green infrastructure becomes operational. For example, the City of Kelowna requires security in the amount of 140 percent in its subdivision bylaw.[46] Holdback of a percentage of the security for two years or two growing seasons is particularly important to ensure that installation of landscaping and green works and services is successful.

Finally, section 70 enables the Approving Officer or Chief Building Official to require monitoring or testing of works for up to two years post-completion. This can assist local government staff to better understand how different infrastructure designs work under different siting circumstances and conditions, and in different locations.

4.0 Design Criteria, Specifications and Standard Drawings (Schedule B, pages 16-110)

This section provides information for each of the infrastructure components noted in Table 1 and for which provisions are described in Schedule B of the SDS model bylaw. This information includes:

- A brief background to the issues relating to climate impacts and infrastructure resilience.
- The rationale used to develop appropriate bylaw wording and good practices.
- Examples of good practices with links to where further information can be found.
- Notes on how these bylaw and policy provisions will promote climate resiliency, sustainable infrastructure development, greenhouse gas emission reduction, energy and water conservation, protection of natural water courses, business investment competitiveness, and emergency preparedness and response.

In analysing the various infrastructure components related to establishing a subdivision, this review focused on identifying good practices to respond to extremes in weather conditions. Changes in averages, such as an increase in average temperature between 0.7°C and 1.7°C, will probably not have a major impact on public infrastructure in subdivisions. Rather, it will be the more frequent temperature extremes and freeze-thaw cycles accompanying these average changes that will most likely cause a rapid deterioration of infrastructure components (e.g., increase number of potholes).

While reviewing bylaws, codes, ordinances, and development rules from around the world, it was difficult to find specific mention of climate change or climate resilience. Instead, bylaws often refer to design and other guidelines that have been prepared by cities and other organizations to make new public infrastructure more durable in a changing world. For example, Toronto's development bylaws make reference to guidelines and manuals that provide consulting professionals with appropriate direction.[47] Thus, from a developer's and engineer's perspective updated bylaws should ideally be kept short, using performance based rules, and referring to design manuals, stormwater guidelines, and methodologies for evaluating resiliency to future climate, among other objectives.

With this reflection in mind, Schedule B in the SDS model bylaw has been kept comprehensive with the view of allowing individual Columbia Basin communities to select the provisions that may be most appropriate in their bylaws. To facilitate an understanding and selection among the range of good practices that are available, Table 5 provides an overview of a subset of measures that could be used to further specify details in the provisions of Schedule B.

4.1 General Information (Section 1.0, pages 19-21)

Introduction (Section 1.1)

This section of Schedule B is intended to orientate the reader given the importance of placing the SDS bylaw in its appropriate context (as articulated in Section 2 of this guidance document). An SDS bylaw is a regulatory tool utilized by a local government to convey the "rules of the game" to land developers when they apply for the subdivision of land within that local government's area of jurisdiction. Schedule B sets the deliverables, criteria, specifications and engineering performance standards when developers and their consulting professionals prepare engineering design reports and drawings in the construction works associated with the subdivision of land and development of neighbourhoods.

Integrated Design and Sustainability (Section 1.2)

This section was drawn from the District of North Vancouver's Development Servicing Bylaw 7388.[48] The intention is to set the right tone with regards to an integrated planning and design approach that yields a sustainable long-term development.

From the perspective of future climate, the intent with this section is to promote new bylaw provisions at this point in the Schedule to ensure that subdivision layouts be given much more thought than they are currently afforded. All too often, consulting professionals are placed under unrealistic planning deadlines by developers. The result is a hastily planned subdivision layout that subdivides the development area into small parcels with very little open space. Such an approach is not conducive to creating livable neighbourhoods and does not allow enough space to implement above ground and more resilient stormwater systems, among other improved infrastructure solutions. Apart from ensuring a subdivision is properly laid for the thousands of residents that will inhabit it for the next 100 years, there needs to be an opportunity to create a neighbourhood layout that also allows climate resiliency and other innovations to be implemented easily. Examples of these innovations include:

- Thoughtful layouts provide room for wider walkways, bike paths and green spaces that also act as evacuation routes and buffers against wildfires;
- Less impervious road and other pavement areas help land drainage after extreme rainfall events. Less length of roadways in subdivisions saves developers money and saves local governments in long-term maintenance costs;
- Development that respects natural landscape features (as opposed to bulldozing an area flat) has a higher aesthetic, environmental and financial value. It also provides homes with views and walking/play areas that build a more attractive neighbourhood. Developers can charge more for these units;
- Routing stormwater overland through green spaces and detention ponds saves underground pipe requirements and future maintenance. It also allows for infiltration and water quality treatment;
- Use of greywater for irrigation purposes; and
- Water, sanitary and other lines can be run through green spaces, reducing the lengths required and future maintenance, which can lead to cost savings for developers and local governments.

Examples of integrated planning approaches may be found in:

- Puget Sound LID;[49]
- Prefurbia principles;[50]
- SmartGrowthBC principles;[51] and
- New Urbanism principles.[52]

Application (Section 1.3)

This section in Schedule B notes that the land owners, developers and their consulting professionals remain fully responsible for the design and construction of public infrastructure that is directly related to a new subdivision.

There is a still a debate as to whether or not to make an SDS bylaw prescriptive or performance-based. The argument for a prescriptive bylaw is based on the fact that the consulting professionals remain responsible for what goes into and onto the ground. They are only legally bound by what is specified in a bylaw. Outside of this requirement they can specify what they believe is in the public and developer's best interest.

If a performance-based approach is taken, then reference should be made to specific guidelines and design criteria manuals that articulate the standards that the local government expects in subdivisions within its jurisdictional boundaries. This approach seems to have worked well in other centres, such as Toronto[53] and Calgary.[54]

Schedule B has provided wording surrounding criteria, specifications and standard drawings that have been collated from a number of municipalities around the world. Even if not specifically related to future climate, an attempt was made to provide wording that reflects current approaches to providing infrastructure that is durable, easy to maintain, and protects the integrity of the environment in which it is placed.

This approach has also been taken in producing standardized design criteria and construction practice within the BC Master Municipal Construction Documents (MMCD).[55] The MMCD also has a specific Green Design Guideline[56] that is of relevance.

Alternative Solutions and Designs (Section 1.4)

Schedule B and associated design manuals and guidelines are aimed at providing the minimum standards required by an individual local government. This section has been inserted to allow a certain amount of flexibility for consulting professionals in their detailed design. It basically states that the local government will consider alternative solutions and designs that may be more favourable to the local community.

This addition provides the flexibility to allow innovative subdivision layouts and technical solutions that produce livable and sustainable neighbourhoods that are resilient to the impacts of future climatic conditions. Such flexibility is necessary given that developers tend to have small profit margin, yet bear large legal and financial risks. The flexibility set out in these initial sections allows room to also seek affordable solutions.

In regards to vulnerabilities to future climate and related good practices to adapt, this section may be a good place to make consulting professionals aware of state-of-the-art design guidelines. Examples include:

- "Stormwater Planning: A Guidebook for British Columbia" (Ministry of Water Land and Air Protection 2002)[57]
- "Best Management Practices Guide for Stormwater" (Greater Vancouver Sewage and Drainage 1999)[58]
- "FireSmart Manual" (BC Ministry of Forests, Lands and Natural Resource Operations 2003)[59]
- "Water Conservation Planning Guide for British Columbia Communities" (The POLIS Project on Ecological Governance 2009) [60]
- "Land Development Guidelines for the Protection of Aquatic Habitat" (Department of Fisheries and Oceans 1993)[61]
- "Climate Change, Impacts and Adaptation in the Canadian Columbia Basin: From Dialogue to Action" (Columbia Basin Trust 2012)[62]

Wording could be added to this section of Schedule B that outlines the overall approach of requesting developers, and their consulting professionals, to assess their infrastructure proposals in terms of vulnerability to future climate extremes.

Independent Utilities (Section 1.5)

Consulting professionals are tasked with coordinating designs with various utility companies (e.g., hydro, telephone, cable, natural gas), while the utility companies usually conduct their own design and construction.

Local government staff usually meet with the developer and consulting professionals before the final submission of the subdivision application. At this stage, staff should encourage the consulting professionals to prompt utility companies to consider climate adaptation and infrastructure resilience in their design processes. Examples include:

- placing power cables underground to get away from overhead lines that are susceptible to catching windfall trees and increasing threats from wildfire;

- making additional capacity in their electrical distribution systems to allow for future technologies, such as household plug-ins for electric cars; and
- providing for prearranged reinstatement for gas companies to ensure this end of project work does not cause carefully planned stormwater technologies (e.g., drainage, bioswales) to fail.

Revisions to this Schedule (Section 1.6)

This section invites a healthy debate among the community, consulting professionals and developers regarding necessary updates of the Schedule in future.

Interpretation of Criteria (Section 1.7)

This section gives the local government's Approving Officer the final say in which the design criteria and standards are interpreted. The normal routes of legal appeal are available to developers in the case of serious disagreements.

Statutory Requirements By Other Authorities (Section 1.8)

This section covers off the requirements that cannot legally be called for in an SDS bylaw. The consulting professional is responsible to meet the requirements of other regulatory agencies, as well as other local government policies and bylaws.

Other General Requirements (Section 1.9)

Most local governments have their own preferred list of infrastructure materials and products. They keep the list updated on their municipal website. Typical lists could be adapted to make sure materials are climate resilient and manufacturers are socially responsible.

4.2 Design and As-built Deliverables (Section 2.0, pages 23-31)

This section of Schedule B has been collated to provide an opportunity for a non-prescriptive approach to an SDS bylaw. In other words, the local government provides some general rules and policies, and then refers the developer to design manuals, guidelines and good practices. In reviewing SDS bylaws from elsewhere, it was found that most local authorities outside Canada take this approach, as well as some Canadian municipalities. Examples of this approach include:

- City of Toronto;[63]
- City of Calgary;[64]
- Isthmus District of the City of Auckland, New Zealand;[65] and
- City of Canterbury, England.[66]

Introduction (Section 2.1)

This section highlights the need for a pre-application meeting which will help orientate the local government staff and help the developer in streamlining the planning and subdivision process.

List of Application Requirements (Section 2.2)

Local governments are encouraged to provide a checklist after the pre-application meeting to guide the developer and consulting professionals in the preparation of a complete application. A comprehensive checklist is provided in this section of Schedule B. Depending on the size of the subdivision, the local government may require all or only a portion of the items listed. Good communication at this stage of the project will help streamline the whole approval and implementation process, potentially saving the developer a lot of time and money. One of the added benefits is that there is a greater chance that appropriate subdivision layouts and climate resiliency strategies will be included.

Survey Information (Section 2.3)

Where subdivision work is proposed near creeks or waterways, the local government may wish to have cross-sections of the water courses surveyed, as part of flood level determination and other climate investigations. Upstream and downstream survey work may also be worthwhile. Conveying surface stormwater through a subdivision is far preferable than underground piping, which can be both expensive and require maintenance in future. If the developer is willing to conduct these offsite surveys, a small rebate in Development Cost Charges (DCCs) may be considered as a reward. The City of Penticton has passed a DCC Reduction Bylaw that allows a 50% reduction in DCC's if a proposed development scores well on a sustainability checklist.[67]

Drawing Submission (Section 2.4)

The section of the Schedule B includes a few examples of drawing and plan specifications relevant to future climate from the District of North Vancouver's Development Servicing Bylaw 7388.[68]

Construction Inspection Reports and Other Requirements (Section 2.7)

Although this section sounds like a requirement for complying with official paperwork, the construction supervision and testing tasks behind this paperwork are extremely important to ensure that infrastructure and climate resilient strategies are implemented properly. If this quality control is not carefully exercised, it defeats the objective of finding ways to extend the lifespan of public infrastructure in subdivisions.

As-Built Submissions (Section 2.8)

This section is included to ensure that good drawing records are kept of what was installed in a new subdivision to help in the cost effective operation and maintenance of public infrastructure in future.

4.3 Storm Drainage Systems (Section 3.0, pages 33-68)

It has been noted that storm drainage solutions feature prominently when discussing the potential impacts of climate extremes on municipal infrastructure. It is also believed that storm water management should be one of the first considerations when planning a neighbourhood. It is important to:

- move towards the creation of onsite surface stormwater handling facilities;
- shift away from expensive and maintenance intensive underground piping;
- reduce impervious surfaces; and
- minimize high peak flows discharging into the downstream environment.

Recommendations include that provisions be adopted and the good practice below be accommodated within innovative neighbourhood layouts as noted in Section 4.1 of this guidance document. These up-to-date layout planning strategies make open space allowances, which slow stormwater down, and at the same time create public amenities and viewscapes that improve the livability of a new neighbourhood. Tree retention and the utilization of specially adapted vegetation will also go a long way to achieving these goals.

The "Best Management Practices Guide for Stormwater"[69] supports the view of creative subdivision layouts, namely through BMP #NS1: Buffer Zones/Preservation of Key Drainage and Habitat Features and BMP #NS2: Reduction/Disconnection of Impervious Area.

Given the importance of stormwater management in relation to climate resilience, it may be worthwhile to refer the design parameters and criteria to a separate stormwater management guide or design criteria manual prepared by the local government. Alternatively, Schedule B could refer consulting professionals to an existing guide. Examples include:

- "Stormwater Management and Design Manual" (City of Calgary);[70]
- "Stormwater Source Control Practices Handbook" (City of Calgary);[71]
- "Low Impact Development Stormwater Management Planning and Design Guide" (City of Toronto);[72] and
- "Stormwater Planning: A Guidebook for British Columbia" (Ministry of Water Land and Air Protection).[73]

In preparing their own SDS Bylaws, some local governments of the Columbia Basin may want to refer to separate bylaws for some stormwater requirements in subdivisions. Some examples include:

- District of Elkford's Draft Sanitary Sewer and Storm Drainage Bylaw;[74]
- City of North Vancouver Watercourse Bylaw;[75]
- City of Abbotsford Storm Water Control Bylaw;[76]
- District of Sechelt's environmental development permit process;[77]
- City of Toronto Sewer Bylaw;[78]

- City of Troy, Ohio Floodplain Regulation;[79]
- City of Auckland, New Zealand Stormwater Bylaw;[80] and
- Floodplain mapping and flood management plans.

General (Section 3.1)
The point is made at the beginning of this section that the consulting professional should make contact with the local government staff to coordinate the planning and design of stormwater management solutions in the proposed subdivision. This liaison is crucial to ensure that local climate resilient policies are implemented.

Objectives (Section 3.2)
This section (drawn from the District of North Vancouver[81]), provides some overall goals that should be considered in developing stormwater management strategies.

Definitions (Section 3.3)
A preliminary list of definitions is provided that can be expanded upon in future by an individual local government in drafting its SDS bylaw.

Determining Stormwater Runoff Up and Downstream of Proposed Subdivision (Section 3.4)
The intent of this section is twofold. First, to provide some form of standardization in the determination of stormwater hydrology results, and secondly to guide the consulting professional towards consideration of stormwater management upstream and downstream of the proposed subdivision.

It should be noted that this is one example of wording that can be used in these sections. The local government can change requirements and methodologies that are more appropriate to their area.

Updates to Intensity Duration Frequency (IDF) curves used in hydrological equations is important as historical rainfall data is expected to change in the future. These updates will help ensure stormwater infrastructure is designed for the future. If required, new IDF curves could be developed for various areas in the Basin. Appendix C of this guidance document provides a brief scope of work for doing so. Having said this, it is well known in the engineering community that the rational method used for small stormwater catchments overestimates peak flows by up to 50%. Also, engineers tend to build factors of safety into piping and detention ponds. In the case of uncertainties regarding the accuracy of IDF curves, it may be worth adding a paragraph into this section of Schedule B that requests that the consulting professional present a design sensitivity analysis.

Although the requirement of slowing down overland flows is dealt in later in sections, it may be worthwhile adding some paragraphs at this point to guide consulting professionals towards the need to work on offsite stormwater detention options with the view of lengthening the time of concentration.

With regards to flood routing it may be expedient to incorporate text referring to the fact that consulting professionals will have to describe and quantify the flood routing above, through and downstream of the proposed subdivision.

Stormwater Management Plan (Section 3.5)

This section begins to specify what a local government may want to see in a Stormwater Management Plan that is submitted on behalf of a developer.

Stormwater Management Systems: Performance Standards (Section 3.6)

In developing an SDS bylaw, some communities may wish to see a Schedule B that is less prescriptive. This section of Schedule B provides a good example of performance standards that has been drawn from Elkford's Draft SDS bylaw.[82] An approach may be to utilize these performance standards with reference to the "Stormwater Planning: A Guidebook for British Columbia"[83] to simplify the local regulatory process and allow consulting professionals the freedom to produce a product that exceeds the minimums usually stated in SDS bylaws.

Stormwater Volume Analysis (Section 3.7)

An example of wording has been provided to standardize a method for determining runoff volumes.

Stormwater Management Facilities (Section 3.8)

The wording provided in this section of Schedule B is intended to help guide consulting professionals towards the climate resilient solutions that are commonly recommended around the world (e.g., maintaining natural watercourse features, on-site stormwater capture, control and infiltration).

Even though routing of natural low and flood flows through the proposed subdivision is discussed earlier in subdivision layout, this section goes further by referring to lot grading within the subdivision, infiltration swales, french drains, rain gardens, impermeable driveways and walkways (pavers), stormwater quality control, erosion and sedimentation control detention facilities, flood routing, storm sewers, etc.

Each municipal area may have differing climate and hydrology factors that determine the design of stormwater facilities. The drafting of local guidelines is probably best way to ensure climate resilience is built into a local government's stormwater management planning and design in future.

Apart from examples of wording included in Schedule B, the discussion below presents some solutions that have been recommended and described in various guidelines. Examples include:

- The City of Calgary's "Stormwater Source Control Practices Handbook" provides cold weather adapted details that could be adopted by local governments in the Columbia Basin. [84]
- A series of stormwater drainage good practices, which includes concept drawings, has been prepared by the Greater Vancouver Sewage and Drainage and are described in the "Best Management Practices Guide for Stormwater".[85]
- One of the best compilations on Low Impact Development is found in "Low Impact Development: Technical Guidance Manual for Puget Sound" from Washington State Governor's Puget Sound Action Committee.[86]
- The City of Seattle is a leader in implementing innovative stormwater management and related infrastructure solutions. A collation of the City's Director of Planning and Development's interpretation of their Stormwater Code (bylaw) and some related Client Assistance Memo's are available as a guide to others.[87]
- Prefurbia principles represent one of the more progressive planning techniques that are being implemented widely in the United States. Additional subdivision layout and climate resilient examples of sustainable neighbourhoods are presented in "Introducing the Prefurbia Solution To Urban Renewal".[88]
- The State of Massachusetts "Metropolitan Area Planning Council Low Impact Development Toolkit" provides another relevant example of guidelines.[89]

An example of the level of detail provided for bioretention areas in the City of Calgary's "Stormwater Source Control Practices Handbook" includes:

4. Bioretention Areas
    - 4.1 Description
    - 4.2 Application
    - 4.3 Hydrologic benefits
    - 4.4 Design
        - 4.4.1 Design approach
        - 4.4.2 Design examples
            - 4.4.2.1 Groundwater separation
            - 4.4.2.2 Run-off flow
            - 4.4.2.3 Grading
            - 4.4.2.4 Mulch layer
            - 4.4.2.5 Side sloping
            - 4.4.2.6 Depth of ponding
            - 4.4.2.7 Drawdown/emptying time
            - 4.4.2.8 Filter media
            - 4.4.2.9 Subdrain and drain rock layer
            - 4.4.2.10 Utility crossings
            - 4.4.2.11 Geotextiles
        - 4.4.3 Limitations
        - 4.4.4 Vegetation
        - 4.4.5 Space requirements
    - 4.5 Construction
        - 4.5.1.1 Inspection
    - 4.6 Performance and impact on surrounding community/environment
        - 4.6.1 Impact on adjacent infrastructure
        - 4.6.2 Community and environmental factors
        - 4.6.3 Performance with regard to pollutants of concern
        - 4.6.4 Performance under cold climate conditions
    - 4.7 Long-term issues
        - 4.7.1 Long-term sustainability
        - 4.7.2 Life-cycle costs
        - 4.7.3 Safety and liability
        - 4.7.4 Failure scenarios

At the end of the day the consulting professional is required to take ultimate responsibility for installation of the infrastructure. A non-prescriptive approach to an SDS bylaw that has been promoted in the Columbia Basin would best be served by providing guidelines and other forms of direction. The local government's mandate would then be to ensure that good practices have been implemented and that any variations to these practices be in the best interest of the public at large.

4.4 Water Distribution System (Section 4.0, pages 70-84)

Within subdivisions, future climate is not expected to have serious impacts, since standard engineering design practices and construction testing have evolved to a point where long term resilience of this infrastructure has become a key factor. Climate impacts outside of the particular subdivision in the larger watershed will, however, play a significant role. Initiatives to counter these impacts usually lie within the realm of local government. Even though the local government has to shoulder the responsibility for addressing water resource and water quality impacts at a watershed level, there are some solutions that can be implemented by developers within new subdivisions to assist in climate resilience. Examples are presented in the sections below.

General (Section 4.1)

Information and guidelines are provided by the Interior Health Authority.

Definitions (Section 4.2)

No definitions were included in the model bylaw, but can be sourced from similar bylaws (e.g., District of North Vancouver's Development Servicing Bylaw 7388).[90]

Water Resource Availability and Quality (Section 4.3)

Future climate is expected to have impacts on water resources leading to above average peak flows and rates of decline that ramp down earlier in spring, lower flows during the late summer, potential losses of streamflow during the winter due to freezing, and potential impacts on water quality (e.g., temperature, sedimentation, nutrients).

Responsibility for creating water storage or some other form of developing water resources usually resides with the local government and not the developer (i.e., an SDS bylaw).

Even so, the consulting professional that plans and assesses a proposed subdivision is responsible to prove that there is a reliable supply of water before the subdivision can be approved. A water balance approach is usually employed (quantity of water available in the water cycle balanced against quantity of water proposed to be taken out of the water cycle). The cumulative impact of future developments in the area also needs to be assessed by local government staff.

Sourcing water from groundwater reserves for a new subdivision requires consideration by a hydrogeologist. The Okanagan Water Board's "Groundwater Bylaw Toolkit" is a very useful resource to assist in this regard.[91]

Reference may be made to groundwater mapping in future versions of the model or individual community SDS bylaws (i.e., the developer may need to be made aware of the particular status of groundwater in the area that they are considering for development).

The Cities of Vernon and Cranbrook are known to have taken the lead to implement a dual water system in certain areas. Treated effluent or greywater is utilized for irrigation uses, thus saving on potable water supplies. A section dedicated to greywater reuse is included as a placeholder in Section 5.14 of Schedule B.

It is recommended that if a lower minimum water demand is adopted by a local government for a new subdivision, then this limit should be recorded on property title for future house owners. For example, if a new home owner wants to rip out existing xeriscaping to plant grass lawns, they should be aware that there are restrictions on water use that will be monitored. Such an approach would have to be endorsed in a bylaw by Council before it could be enforced.

Since this issue is mainly the responsibility of a local government (and not a developer), no further work was conducted on water resource availability in the SDS model bylaw. In future, however, references may be needed in an SDS bylaw to a local government's policies and bylaws with regards to water restrictions and water conservation.

Water Demands (Section 4.4)

Water conservation[92] and water demand management[93] are one of the most important issues related to future climate.

It has been difficult to find examples of where a local government had incorporated such initiatives into their SDS bylaws. Typically, such initiatives are found at a policy level or in an Official Community Plan. Policy, guidelines and possibly new Schedule B wording would have to be prepared by a local government if they wish to incorporate this into their SDS bylaw. Some content and examples are presented below.

As is the case with stormwater management, an individual local government may rather want to specify a design guideline or set of policies in the SDS bylaw to ensure that developers implement water conservation and water demand measures.

Some of the water conservation and water demand management measures listed below are likely best suited at a higher policy level for a local government. The list is not exhaustive but contains many key measures:[94]

Water conservation measures in resource management functions

- Watershed management (i.e., removal of invading alien plants, wet-land rehabilitation)
- Dam storage optimisation (i.e., suppression of evaporation)
- Protection of water resources from over utilisation
- Social awareness and education, social marketing campaigns
- Managing land use
- Water quality management
- Drought contingencies

Demand management measures in the distribution and water supply functions

- Regulations
- Guidelines
- Infrastructure optimisation
- Town planning policies
- Different levels of service
- Loss minimisation (i.e., reducing unaccounted for water, canal lining)
- Reuse and reclamation options
- Metering
- Pressure management
- Dual distribution systems
- Education, awareness, and training

Demand management measures on customers / end users

- Regulations / Guidelines
- Metering
- Different level of service
- Irrigation scheduling
- Auditing
- Incentives
- Minimising and metering institutional water use (own use)
- Loss minimisation (domestic plumbing or irrigation systems leak reduction)
- Retro-fitting existing systems (replace plumbing or irrigation systems with efficient systems)
- Effective pricing
- Effective billing
- Customer education and awareness, social marketing campaign

Water conservation measures for return flow management

- Infrastructure optimisation
- Minimising losses
- Minimising infiltration
- Minimisation pollution
- Reclamation

One of the related initiatives is reducing water losses in the distribution systems. For this infrastructure water pressure, water infrastructure material types, and the way the infrastructure is installed cumulatively add to reducing water demands.

The installation of mainline water flow meters and in-building water use meters may be a significant addition to servicing a subdivision. These measurements combined with places to monitor water system pressures could provide an effective way to cut system water losses and reduce individual building water use.

Similarly, water usage inside buildings can be minimized by using low flow water fixtures. Reference to WaterSmart guidelines may be a possible addition,[95] with numerous other guidelines available from Canada and around the world.[96] Furthermore, the BC Ministry of Environment provides a water conservation strategy along with other publications.[97]

General Residential Potable Water Demand Requirements (Section 4.4.1)

This guidance document has been focussed on climate adaptation and mitigation. As such, values for water demand in this section have purposely been left out. Each community will need to select their own values as they will vary from community to community. It has been noted that the high water demands in the Columbia Basin (between 500 and 1,000 L/c/d) are probably due to water distribution losses. The Canadian and first world average is in the order of 350 L/c/d. Choosing a lower average annual daily demand for new subdivisions, tied in with water conservation incentives, may be the most appropriate when setting up a new SDS bylaw.

Fire Protection Flows (Section 4.4.4)

Future climate is projected to increase the risk of devastating wildfires on cities and towns in B. Thus, "fireproofing" a new subdivision is an important consideration. Through cleverly designed layouts it may be possible to use stormwater ponds, parks, roads and walkways as firebreaks and evacuation routes. BC's FireSmart program's guidelines[98] are a useful resource that can be referenced in Schedule B.

Dual distribution systems usually involve the use of water supplies from two different sources in two separate distribution networks. The two systems work independently of each other within the same service area (e.g., one for potable water and another untreated supply for fireflows, street cleaning and/or irrigation). The City of Melbourne's "Dual Water Supply Systems" publication provides an example of dual system wording that could be used in a bylaw or guideline.[99]

The above-mentioned examples are intended to help reduce the demand for scarce water resources, while also minimizing the volume of potable water that needs to be treated.

Water Network Analysis (Section 4.5)

Changing drought/flood cycles are expected to affect reservoir storage capacities for dams and concrete water distribution systems in the future. The size of these structures may need to increase to improve resilience to water shortages. Such changes usually remain the responsibility of local governments and hence have been left out of this discussion / consideration.

In preparing a subdivision application, information regarding the current status of the specific water storage system will need to be conveyed to consulting professionals by local government staff. Subdivision engineers, however, need to calculate and confirm the delivery capacities in the concrete reservoirs that provide balancing storage for water distribution systems in new subdivisions. On the water distribution modelling side, municipal engineers usually call for the consulting professional to update the city water model (e.g. WaterCAD or EPANET models). This is used by the city to evaluate the performance of the proposed potable and other water systems in the subdivision being tabled.

Water Pressure (Section 4.6)

This issue has been mentioned in the water conservation and water demand management section above. Since the observed high water demands within Columbia Basin communities may be mainly due to water system losses, the maximum pressures specified in existing SDS bylaws should likely be reviewed. The City of Kimberley is known to have implemented such pressure reduction strategies.

An insightful example of how water pressure management has been implemented in municipal system is available from South Africa.[100] This example provides information on the key issues that need to be considered when contemplating the implementation of pressure management. It explains the basic concepts where pressures are controlled using electronic or hydraulically operated modulating devices in water distribution systems. These devices reduce extremely high night time and other pressures that occur in these systems, thus reducing pipe and other hidden background leakage. These actions can result in significant water and cost savings.

This example addresses specific problems that were experienced in two installations, both of which supply water to over 500 000 residents through a single installation. Another installation is also discussed, which supplies water to a similar sized community and was only commissioned towards the end of 2008. Between these three installations, savings of over 20 million kilolitres of water are being achieved each year representing more than $6 million per annum.

Reservoir, Pumping Stations, and Pressure Reducing Valve Stations (Section 4.7)

If developers have to install this infrastructure, they must consult with the municipal engineer to ensure that designs are in accordance with the local government’s requirements (e.g., may require system flow metering and flow modulation capacity).

From the perspective of future climate, extreme weather events can cause power failures, which can cause downtimes in sewage or other pumping infrastructure that could further lead to health hazards, water shortage problems, and/or concerns with firefighting capacity. Operational redundancy is usually required (e.g., standby pumps or emergency generators) to improve resilience.

One suggestion for reducing impacts from weather-related outages in new subdivisions is to ensure that the landscaping plan does not allow large trees to be planted near above ground electrical lines. New underground electrical lines may be specified in an SDS bylaw or a standalone Design Criteria Manual.

Consulting professionals should contact the local hydro utility to discuss implementation of electrical services to and within the new subdivision.

Given the occurrence of devastating storms in recent history, jurisdictions in the United States continue to investigate options to improve resilience (e.g., SmartGrid). Some background on this topic may be found in the publication "Weather-Related Power Outages and Electric System Resiliency".[101]

Water Mains (Section 4.8)

Some communities of the Columbia Basin have indicated a preference to see some form of standard drafted to include zone or district water meters in water mainlines. The financial responsibility for the installation of these meters will need to be clarified (i.e., developer or the local government).

Minimum Size (Section 4.8.2)

Most local governments' are open to considering innovative sizing options and designs by consulting professionals. In the case of innovative subdivision layout and creating space for surface stormwater management, cost savings have been observed (e.g., due to not having to install large stormwater pipes, less roadway, and less impervious surfaces). In other cases, intuitively making subdivision servicing systems more climate resilient will cost developer's more money (e.g., providing porous pavements, storing more stormwater on site, burying pipes deeper down). It will be important to ensure that if initial construction may be a little higher, that operation and maintenance costs are lower in the longer run. For instance, it will not be reasonable to install new innovative solutions that are costly and difficult to operate and maintain for the next 50 to 100 years.

Freezing Considerations (Section 4.8.10)

Local experience of Columbia Basin communities has indicated that consideration should be given to placing pipes away from the travelling surface of the roadway. Indications are that snow piled on the ground above pipes can act as an insulator. Another motivation for doing so is that vehicle traffic tends to drive frost downwards. Since more right of way space would be required to accommodate this measure, it may be worth combining these strip areas with bioswales and other stormwater detention/treatment good practices. Another suggestion has been made to provide an allowance for "winter pipe bleeding" to help with pipe freezing problems.

Depth of bury (Section 4.8.10)

The perception that water pipelines are buried too deep has often been raised by civil contractors. Their main motivation for this concern is that cost rises exponentially when pipes have to buried deeper than 6 feet. However, future climate projections suggest reductions in snow cover and lower temperature extremes could seriously affect the lifespan and integrity of piping materials if pipes are buried shallower than what a local government recommends. Ultimately, depth of bury needs to be tailored to local conditions.

Pipe joints (Section 4.8.11)

When pipes are laid, the MMCD requires fairly stringent pressure testing to ascertain potential leaks (i.e., where rubber seals have been rolled out of alignment). Even so, especially in the case of sanitary and stormwater pipelines, the local government may want to consider some language regarding acceptable rates of groundwater infiltration or pipe leakage.

Infrastructure resiliency-corrosion protection (Section 4.8.13)

Protection against corrosion of water, valves, hydrants and other subdivision services is sometimes overlooked. This concern can drastically reduce life expectancy and create leakage. The soil corrosivity testing called for in this section of Schedule B is relatively inexpensive in comparison to the loss of water from conveyances, when it comes to the increased risk of droughts, less water available, and expected increases in water treatment costs in the future.

Valves (Section 4.9)

With regard to weather extremes and its effect on valves, it is recommend that the local government specify a series of resilient water and air valves in their standard materials list.

Hydrants (Section 4.10)

Local government and MMCD specifications for fire and blow off hydrants already cater for weather extremes. The hydrants self draining valves should be checked regularly to ensure that they are working properly. Ice build up would cause damage to the hydrants.

Air Valves (Section 4.11)

With regard to weather extremes and its effect on valves, it is recommend that the local government specify a series of resilient air valves in their standard materials list.

Thrust and Joint Restraints (Section 4.12)

Proper restraints (concrete or mechanical) will help reduce water leakage in future.

Service Connections (Section 4.14)

These connections tend to be in places where a significant amount of water leakage takes place. Modern corrosion resistant materials should be specified by local governments in their standardized materials and manufacturer lists.

Since Columbia Basin communities report that their system leakage is mostly found with galvanized steel pipe services or conveyance infrastructure, it is necessary to reemphasize the need for a soil corrosion study. The cost of such a study is very small in comparison to future water leakage and unnecessary repair and replacement costs.

Water Meters (Section 4.15)

The installation of household and other building meters will assist in conserving expensive treated water. If installed, district or zonal water meters will allow leakage on mainlines to be detected at an early stage, thus saving many years of water losses from the water distribution systems. Coupled with the clever placement of pressure reducing valves, meters will provide a very effective way of managing water leakage and excessive water use. Wording that could be added to Schedule B:

"*As part of its Water Loss Management Strategy, the [Name of Local Government] is formulating a plan for [Name of Local Government]-wide water flow metering, both on the larger mainlines and from house-to-house. The Consulting Professional shall, consult with the [Name of Local Government] Engineer to determine the exact requirements for the on- and off site meters that will need to be installed and who will shoulder the financial burden of installing these system meters.*"

Private Wells (Section 4.16)

The effect of a changing climate may have an impact on groundwater resources. More frequent droughts may negatively affect water table levels. Increased precipitation may have the opposite effect on groundwater supplies and could cause problems such as waterlogging.

Slowing down stormwater and allowing infiltration in subdivisions could have a beneficial effect on the groundwater table. Having said this, it is important to ensure that runoff from roads and other sources is pretreated before being allowed to seep into the soil. If not, irreversible and long-term problems with groundwater quality could result.

In addition to referring to the groundwater resource issue in Section 4.4 of this guidance document (Water Resource Availability and Quality), the District of Elkford has included a section on private wells in its draft SDS bylaw[102], which has been included in this section of Schedule B.

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Cross Connection and Backflow Controls (Section 4.17)

The effects of incorrect connections between non-potable and potable water systems could pose major health risks. local governments' may want to specify water backflow controls to ensure that flood waters and other surcharges do not get back into house basements and other areas where it may be undesirable. Wording to this effect has been included in this section of the Schedule B.

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4.5 Sanitary Sewage Collection and Disposal (Section 5.0, pages 86-92)

General (Section 5.1)

Apart from the effect of extreme storms on sanitary pumping and the reuse of greywater, it is expected that sanitary systems will not necessarily be affected by future changes in climate.

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Design flows (Section 5.3)

In addition to specific design flow criteria, local governments may want to impose limits on groundwater infiltration into the wastewater collection systems.

Service Connections (Section 5.10)

Geo-exchange innovations are becoming more popular in BC, especially at Ski Resorts. One example may be found at Big White Ski Resort where a combination of solar thermal and geothermal is used to heat an inn.[103] Another alternative energy solution is the collection of surplus heat by wrapping sanitary sewers in glycol pipes. Heat is drawn from the sanitary flows in the pipes and converted, via a heat exchanging system, to heat boiling water and hot tubs. If these technologies will be considered in a local government's jurisdiction, then some form of specification in this Schedule may be needed in future.[104]

Sanitary Lift Stations (Section 5.11)

Extreme weather such as wind and lightning storms can result in power outages that affect sanitary lift stations. If such pumping capacity is needed to establish a subdivision, then some form of redundancy needs to be designed and installed by the consulting professional and contractor. If pumping cannot be restored reasonably quickly, then some form of temporary storage and controlled surface outflow will be required. If not, then pollution of the environment and subsequent health concerns may result.

Since portions of some Columbia Basin communities lie within floodplains, flooding can have serious impacts on sanitary systems in local subdivisions and wastewater treatment works. If there is a possibility of such flooding, the consulting professional should indicate what development solutions can be implemented to avoid infrastructure damage and health emergencies.

Force Mains (Section 5.12)

The same considerations are relevant here as for sanitary lift stations. Local governments may want to specify the use of fused HDPE pipelines (i.e., no joints) to avoid wastewater leakage into the groundwater table.

On-site Sewage Disposal (Section 5.13)

Groundwater contamination is the biggest concern with on-site sewage disposal. This concern stems from the possibility of contaminating current or future groundwater water supply sources that may be in the vicinity of the septic tanks and drain fields. Health legislation requires that accredited wastewater specialists design and oversee construction of septic fields and other on-site disposal infrastructure. This requirement should be noted in Schedule B.

Greywater Reuse (Section 5.14)

The reuse of cleaner household wastewater discharges (e.g., shower, bath, hand basins), as well as rainwater and other similar sources, can be lightly treated and used for irrigation of lawns and landscaping. This measure is intended to save on urban potable water usage during the summer months. It should be reminded that this SDS model bylaw and Schedule B refer to the establishment and servicing of subdivisions. Although greywater can take on the traditional septic field solution (as mentioned above), newer greywater innovations take this practice one step further. These new approaches treat water lightly and reuse it in toilet cisterns and for above-ground irrigation.

At this stage, the BC Building Code and Health Authorities tend to be skeptical about the reuse of greywater for these purposes. If greywater innovations are to be installed by developers within new subdivisions, then local governments may want to include additional specifications in Schedule B. In the meantime, it is suggested that a greywater guideline be developed for Columbia Basin communities or that reference be made to another City's guidelines that have been adopted elsewhere. More background and examples can be found at:

- "BC Green Building Code Background Research: Greywater Recycling" (Lighthouse Sustainable Building Centre);[105]
- "Water Reclamation and Spray Irrigation" (City of Vernon);[106]
- "Rainwater Harvesting and Grey Water Reuse" (Canada Mortgage and Housing Corporation);[107]
- "Code of Practice for the Reuse of Greywater in Western Australia 2010" (Government of Western Australia);[108]
- "WHY NOT…Reuse Greywater: Step by step guide to assist you" (Government of New South Wales);[109]
- "GreySmart" (Australian Savewater Alliance);[110] and
- "Greywater systems: Code of practice" (British Standards).[111]

4.6 Connectivity, Highways and Active Transportation (Section 6.0, pages 94-104)

General (Section 6.1)

Utilizing innovative guidelines such as FireSmart and SmartGrowth will encourage road and walkway layouts and landscaping to act as firebreaks as well as evacuation routes, wherever possible. In terms of standards or guidelines for the design of interface subdivisions, there are some basics considerations with respect to subdivision shape, density, phasing, accessibility, water supply, and perimeter protection buffers that a municipality should establish for its subdivision authority to implement. See FireSmartBC for some detailed recommendations.[112]

Road Classifications (Section 6.3)

Consulting professionals and local government staff will need to assess the merits of maintaining minimum road right of way widths in terms of their ability to handle stormwater. An alternative approach would be to allow narrower paved roadway sections in places and the use of pervious paver stones in low traffic areas such as cul-de-sacs and lanes.

Design Parameters (Section 6.4)

Design Speed (Section 6.4.1)

A deterioration in road conditions may occur if projected increases in extreme weather events occur. If so, vehicle on vehicle and vehicle on pedestrian/cyclist collisions may potentially increase. Cleverly laid out subdivisions can reduce vehicular travel speeds. This measure tied together with walkways and bicycle paths separated away from roads can help make neighbourhoods safer.

Cross Section Elements (Section 6.4.2)

As mentioned above, when it comes to reducing impervious surfaces and reducing road maintenance, it is worth considering narrower paved widths. The remaining road right of way could then be used for bioswales, infiltration trenches, tree planting, etc. These technical solutions are discussed above in Section 4.3 of this guidance document. One of the best examples of possible cross-section may be found in the “Low Impact Development: Technical Guidance Manual for Puget Sound”.[113]

Curbs and Gutters (Section 6.4.3)

Traditionally, curbs and gutters have been used to channel water to points where water can be safely discharged into the natural watercourses (i.e., limited soil erosion and detention of peak flows in ponds). On the other hand, a low impact development approach suggests alternative ways of slowing this water down by removing curbs and gutters and allowing water to trickle overland into swales and other structures. These alternatives need to be debated in policy development by individual local governments to decide whether these communities wish to adopt these proposed good practices.

Good practices discussed in Section 4.3 of this guidance document call for eliminating the installation of curbs and gutters in new subdivisions. This measure would allow water to run off and be treated in bioswales, etc. A potential concern with this approach, however, is that if not properly treated road salt can contaminate the surrounding earth and groundwater sources, which may not be acceptable to local government operation and maintenance staff.

It was not possible to find examples of this approach being integrated into an SDS bylaw. Typically, this approach is usually built into various stormwater guidelines. To aid local governments in making decisions in this regard, related discussion documents are available from the City of Duluth[114] and the US Environmental Protection Agency.[115]

Road Works Structure (Section 6.5)

Freeze-Thaw Cycles (Section 6.5.1)

Future climate projections imply that more winter day temperatures will hover around 0°C. This change will lead to more frequent freeze-thaw cycles that can have an influence on the durability of road pavement structures. A significant level of research on good practices has been done in Prince George, BC[116] and Montreal, QC.[117]

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Cul-de-sacs (Section 6.9)

The stormwater management initiatives proposed in the "Low Impact Development: Technical Guidance Manual for Puget Sound" are relevant.[118]

Intersections (Section 6.10)

The stormwater management initiatives proposed in the "Low Impact Development: Technical Guidance Manual for Puget Sound" are relevant.[119]

Driveways/Crossovers (Section 6.12)

Driveways should preferably be pervious to minimize stormwater runoff and limit reflection of the sun's radiation back into the atmosphere. Examples of such good practices are given in "Introducing the Prefurbia Solution To Urban Renewal".[120]

Walkways/Sidewalks/Bikepaths (Section 6.13)

Some local governments are planning to implement, or have already started constructing bicycle path networks. The City of Rossland has adopted an Active Transportation Plan that is relevant to vehicular movements, GHG emissions and multi-modal pathways.[121]

Rather than impervious and expensive concrete or asphalt, communities of the Columbia Basin have considered the use of alternative materials for surfaces of sidewalks and bikepaths (e.g., polymer-based, oilshale, limestone, and pea gravel). These materials can save on costs and reduce the impervious pavement area.

Weather conditions may deteriorate in future (e.g., increasingly wet, slippery, poor visibility). Such a change could result in more vehicular accidents or vehicle collisions with pedestrians and bicycles. In various communities, strategies have been implemented to move sidewalks and bicycle paths away from the side of roads. Relevant examples are described in "Low Impact Development: Technical Guideline Manual for Puget Sound"[122] and "Introducing the Prefurbia Solution To Urban Renewal".[123]

Boulevards/Streetscapes (Section 6.16)

See Section 4.7 (Landscaping) of this guidance document for further discussion.

Hillside Standards (Section 6.18)

The wording in this section of Schedule B was drawn from Elkford's Draft SDS bylaw.[124] It addresses potential climate impacts on changes in slope stability. It should be recognized that legislation calls for an approved geotechnical engineer to provide opinions and conduct designs where these conditions exist. Note that by being too specific in providing hillside specifications, a local government may set itself up for legal recourse in future.

4.7 Landscaping (Section 7.0, page 106)

Landscape architects are finding more ways to use vegetation in subdivisions that improve the environment around it. Water conservation is also being achieved as part of these landscaping strategies. The City of Kelowna has a draft bylaw referring to requirements for water conservation as related to landscaping and irrigation.[125] Some communities have specific landscaping guidelines that have to be adhered to during the design and construction of subdivisions. An example of a landscaping guideline is available for Kamloops, BC.[126]

Further development and clarification of this section should be referred to local landscape architects, horticulturists and arborists from the Columbia Basin to ensure the right mix of tree and plant species for the area which can withstand the changes in climate.

4.8 Utilities (Section 8.0, page 108)

Discussions with the various utility companies should take place from the early planning stages of a subdivision. Often, these companies have their own approaches to sustainability (e.g., PowerSmart[127]).

In some parts of British Columbia, BC Hydro, municipalities and other electricity utilities are tending to move towards laying underground lines that obviate power outages due to wind storms and trees that fall on power lines.

Innovative opportunities exist where system electrical capacity can be allowed in new subdivisions to support electric cars in future. Although electric car manufacturers and other companies are currently installing recharging stations throughout North America,[128] no clear example was found where additional recharging power capacity has been allowed for in a whole subdivision.

5.0 Final Considerations

5.1 Enhancing Adaptive Capacity

What is the best opportunity for enhancing adaptive capacity across Columbia Basin communities?

Sections 3 and 4 of this guidance document are focused on reducing sensitivity of communities to the potential impacts of future climate by recommending good practices to enhance resilience. These good practices tend to be focused on a community's "hard" or engineered infrastructure. It is acknowledged, however, that enhancing adaptive capacity (see Box 6) can also be important for increasing resilience to future climate. Related actions tend to be focused on enhancing a community's "soft" infrastructure –e.g., institutions, networks, knowledge.[129]

The Columbia Basin has been shown to have a strong foundation of adaptive capacity. The Columbia Basin Trust contributes to this foundation by supporting the financial, institutional, and technical capacity of individual communities. The involvement of Pacific Climate Impacts Consortium (PCIC) and leading scientists in further show there is a strong foundation for understanding and responding to future climate.

> **Box 6. Understanding adaptive capacity**
>
> Adaptive capacity has been described as the ability of a community to prepare, adjust, and respond to future climate.[130] It is distinct from adaptation because it reflects the ability of a community to implement adaptation measures or good practices.[131] In particular, a community's adaptive capacity can be described according to its (1) economic resources, (2) technology, (3) infrastructure, (4) information, skills, and management, (5) institutions and networks, and (6) equity.[132]

However, as noted in Section 2.1 there remains gaps in knowledge and varied levels of confidence in predicting future climate impacts and implementing effective good practices. Community planning and development need to proceed despite these unknowns. Deciding on how to proceed can be a challenge for local governments given the potential for and implications of making wrong decisions. Errors in decision making can lead to <u>overinvestments</u> – designing infrastructure for a certain intensity of storm event that will not occur, responding to a climate impact to which a community will not be exposed, or investing in a technology that does not reduce impacts on infrastructure. Errors in decision making can also lead to <u>under investments</u> – failing to respond to a climate impact, such as wildfires, that will have a significant impact or designing infrastructure below the standard needed to withstand a certain intensity of storm event. Concerns about such errors have led some local decision makers to inaction because they have a hard time justifying investments that have uncertain future benefits at the expense of investments in more pressing and immediate priorities.[133] Thus, a recommended focus for enhancing adaptive capacity is on <u>innovation and learning</u> to help reduce the potential for errors in decision making.

What is the best approach for supporting this opportunity?

Adaptive Management (see Box 7) is ideally suited for enhancing adaptive capacity given its ability to help Basin communities implement innovative practices, and learn about which will provide the greatest benefits in the face of the large unknowns. The Columbia Basin also seems like an ideal place given lessons learned about the factors that support successful Adaptive Management.[134]

> **Box 7. Adaptive Management: A tool for making decisions in light of uncertainties**
>
> Adaptive Management (AM) was first developed in the 1970s and 1980s[135] and has seen application in a wide range of natural resource sectors including fisheries management,[136] forestry,[137] environmental assessment,[138] and more recently as an approach to help communities adapt.[139] Put simply, AM is a structured, rigorous and deliberate approach to "*learn by doing*". In the context of developing subdivisions, AM should encourage implementation of deliberately varied good / innovative practices as "experiments" to better understand their cost, benefit, and effectiveness so the emerging insights could then be used to make better decisions at other times and in other locations.[140]

<u>Historical and current context</u> is a core requirement because there needs to be a clear and relevant purpose for Adaptive Management. When developing subdivisions, there is a strong motivation to resolve unknowns because they can lead to liabilities and/or costs for local governments and developers. Liabilities could result if unproven technologies / designs fail over their lifespan yet were required by communities in their bylaws or implemented by developers as a way of being innovative to achieve specified performance standards. Alternatively, if an unproven technology is required by a local government yet comes with a higher cost, there may be resistance to implement it or it may reduce a community's economic competitiveness.

<u>Clear leadership, direction and organization</u> are also seen as important because they are needed to get Adaptive Management successfully started. The Columbia Basin Trust is an organization that has a proven track record of providing leadership, direction, and structure for coordinating and communicating on a range of environmental and community issues. It could feasibly and realistically lead an Adaptive Management program.

Finally, <u>community involvement, planning, funding, staff training and the conduct of science</u> are needed to ensure Adaptive Management is successfully deployed. The level of engagement of Basin communities, potential for financial support, technical capabilities of staff, and strong foundation of science suggest that these factors could be sufficiently addressed if an Adaptive Management program were initiated to support communities in the Basin.

What can Columbia Basin communities do to support Adaptive Management?

Adaptive Management is an iterative approach to decision making involving six sequential stages:

- Assess;
- Design;
- Implement;
- Monitor;
- Evaluate; and
- Adjust.

There are varying levels of effort and consideration that can be invested at each stage. A large investment in developing and implementing Adaptive Management may cost more in the near term, but lead to faster learning about the effectiveness of good practices, improved decision making, and reduced costs in the long term, while smaller investments are likely to lead to slower learning and greater costs in the long term if a community continues to use practices that are unable to withstand future climate impacts. Thus, there will be an inevitable trade-off between the cost invested (measured in terms of people, equipment, time, and money) and the benefits from faster learning and reduced uncertainties (measured in terms of long term savings).

Given the shared interest in innovation and learning, the best strategy would be for communities to work together to develop an Adaptive Management program for the Basin. Such a program could be developed under coordination of the Columbia Basin Trust and focused on the stages of the AM cycle for which there are commonalities – assess, design, evaluate, and adjust. This broader framework could then be used as the basis for undertaking other stages of the AM cycle – implement and monitor – to test innovative practices at the community level. Innovations could be piloted across multiple communities so the value of information from an individual community would be greater when combined with information from others. In the absence of broader coordination, individual communities can do their best at designing an Adaptive Management program then focus on implementing and monitoring contrasting innovative practices at multiple locations to facilitate learning. Regardless of the level of coordination and investment, progress is possible as demonstrated by the relevant examples where AM has been applied elsewhere:

- Describing how Adaptive Management can help address future uncertainties and support the Official Community Plan for the City of Victoria, BC;[141]
- Implementing an Adaptive Management plan for testing alternative stormwater management practices, monitoring performance, and improving future urban development in the City of Portland, Oregon;[142]
- Testing innovative stormwater management strategies and monitoring their effectiveness in the high density mixed-use development, UniverCity, in the City of Burnaby, BC;[143]
- Monitoring and managing critical areas that support wetlands, fish and wildlife as part of a broader set of requirements for growth management in Snohomish County, Washington;[144]
- Examining how Adaptive Management could be used in water utility planning and decision making to better manage water system infrastructure and supplies in the face of the large uncertainties associated with future climate;[145] and
- Supporting use of Adaptive Management in the development of integrated stormwater and wastewater management plans by local and state governments in the United States.[146]

These examples show that Adaptive Management is not a theoretical or idealized approach to decision making. Tangible actions have been taken by various local governments and community focused organizations which demonstrate its value and potential for success in the Columbia Basin.

5.2 Updating Community SDS Bylaws

Having provided a substantial level of information in this guidance document and the companion SDS model bylaw, it is important to step back and summarize some of the key messages that emerge as guidance for communities seeking to update and enhance climate resilience of their individual SDS bylaws.

Before updating an SDS bylaw it will be important to remember the following contextual considerations that will have an equally or even more important influence on the success of building a community's climate resilience:

- There are large uncertainties in knowing how future climate will unfold and precisely how vulnerable a community will be. Given limited resources (time, people and money), it will be important for communities to recognize these uncertainties by prioritizing updates to respond to the highest risks, pursuing "no regrets" measures that provide multiple benefits, and adopting an attitude of "learning by doing" when implementing good practices. Such considerations will help avoid over- or under-investment in responding to future climate.
- It is the package of land use and infrastructure bylaws of a local government that will effectively promote climate resilience. The SDS bylaw is a small part of the larger picture. The suite of bylaws that point to land development and infrastructure designs that take into account climate resilience give direction to decision makers, such as staff, the approving officer, and council, on how development should occur.
- While the cost of taking a low impact development approach (rather than relying solely on hard infrastructure) may be perceived as more costly, this is not necessarily the case. The biggest cost is likely educating the development industry to design in this way.

The companion SDS model bylaw represents a "compendium" of provisions to provide the template language, structure and some examples of good practices from which a community can choose when updating their individual SDS bylaw. By adopting provisions in the SDS model bylaw, it will also be important for communities to remember the following:

- Local governments will be asking for more information about the impacts of a development up front and the SDS model bylaw requires applicants to invest more in studies to justify design approaches rather than business as usual.
- Local governments will increasingly be holding applicants responsible for ensuring that their infrastructure is functioning properly, for example by requiring an applicant to provide security before commencing development, and may also require monitoring of new infrastructure.

- When selecting provisions and good practices from the SDS model bylaw, local governments should be seeking to meet the following primary:
    - Becoming more resilient to existing and future climate conditions;
    - Minimizing long term costs of development and operating infrastructure;

  and secondary objectives;

    - Reducing energy consumption and greenhouse gas emissions;
    - Conserving water resources;
    - Protecting natural watercourses;
    - Creating wildfire evacuation routes; and
    - Remaining attractive and competitive for business.
- Prescriptive provisions will require a large amount of information in a Schedule, similar and potentially more than is contained in the SDS model bylaw. This approach may be less attractive to some consulting professionals and developers, who are ultimately responsible for the designs and construction of subdivisions. Such an approach may also open up legal dilemmas. For instance, prescriptive provisions could be too specific on high risk specifications, such as hillside development criteria, leading engineers to say they cannot assume responsibility if things go wrong because the development specifications were prescribed to them.
- Performance-based provisions can lead to more streamlined Schedules with references being made to manuals and guidelines that are provided elsewhere. A large portion of bylaws, ordinances, codes and development rules from around the world are moving towards such an approach.
- There are many technical good practices guides available that provide direction to consulting professionals designing new developments and for the staff that are reviewing applications for development. A determination of the most appropriate good practices for a particular community will depend on local conditions and how different practices balance the above competing objectives compared to the status quo. Table 5 of this guidance document summarizes some of these measures, the details of which could be included into existing bylaws and the specifications of which could be drawn from available manuals / guides.

6.0 Figures

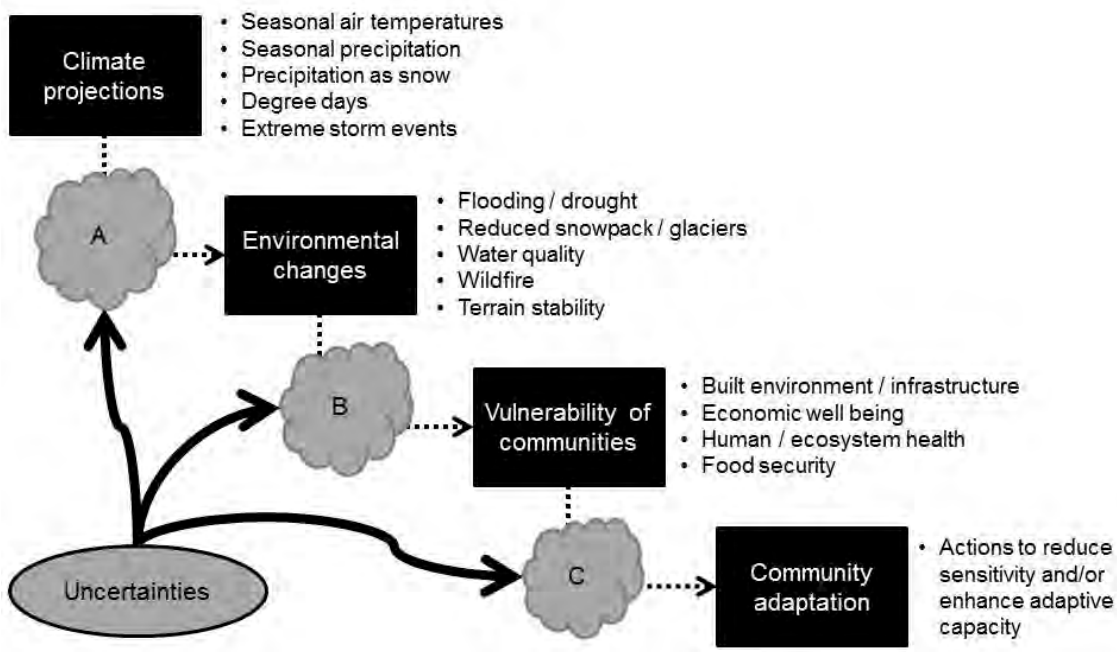

Figure 1. Illustration of the basic cause-effect links between climate projections, environmental changes, vulnerability of communities, and adaptation actions. Uncertainties cloud our understanding of the links between these steps.

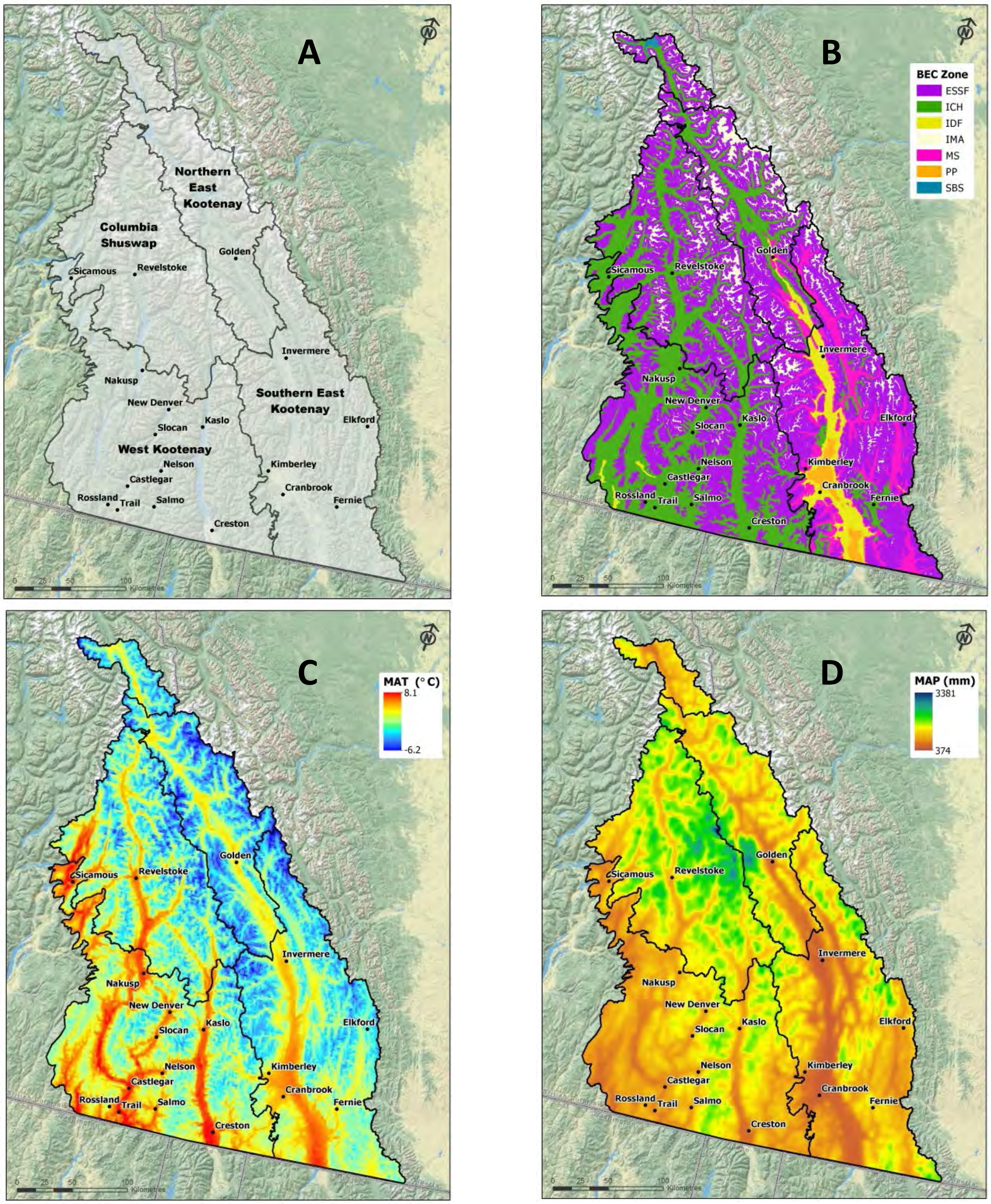

Figure 2. Overview of the Columbia Basin showing its four primary climatic sub-regions (Panel A),[147] existing Biogeoclimatic zones (Panel B),[148] and historic climate conditions (1961-1990)[149] represented as mean annual temperature (Panel C) and total annual precipitation (Panel D).

7.0 Tables

Table 1. Summary of the priorities and rationale for developing the model bylaw and guidance document.

SDS bylaw component	Engineering element	Within scope	Rationale for inclusion / exclusion
Storm Drainage System	Federal & Provincial legislation	N	Beyond scope of model bylaw.
	Drainage masterplanning	N	Not in SDS bylaw, usually a function of the Local Authority.
	Servicing objectives	N	Addressed at a local authority level.
	Stormwater control plan	Y	To address increased peak flows and volumes that need to be considered (e.g., earlier interception, infiltration).
	Lot grading plan	Y	To address green technologies that help slow the surface runoff of water.
	Sediment control plan	Y	To reduce maintenance and cleaning of storm systems and to preserve topsoil where it belongs.
	Groundwater interactions	Y	To address surface and groundwater interaction, including water quality.
	Detention control	Y	To slow down surface runoff.
	Stormwater runoff generation (hydrology)	Y	To address changes in climate data and determination of peak and low flows.
	Design criteria	Y	To address changes that may be required in some areas (although fairly robust).
	Method of analysis (minor systems)	Y	To address changes in climate data and determination of peak and low flows.
	Method of analysis (major systems)	Y	To address changes in climate data and determination of peak and low flows.
	Storm sewers	Y	To address stormwater control measures that may assist in reducing pipe sizes and cost, including depth of bury.
	Manholes	N	Deemed relatively insensitive to climate impacts.
	Catch basins	N	Design criteria in MMCD are deemed sufficient.
	Ditches	N	Though not a focus of research, some considerations in model bylaw to address overland flow, links to stormwater management and water quality.
	Culverts	Y	To address changes in sizing (smaller when less runoff versus larger when changes in watershed characteristics due to deforestation or wildfires).
	Inlet and outlet structures	Y	To address impact of floods and debris.
	Flow control structures	Y	To address extreme weather events.
	Storm service connections	Y	To address options for disconnecting them from public system and allowing for localized groundwater infiltration where appropriate.
	Sub surface drains	Y	To address possibility for use of french and infiltration drains in cold climates.
	Surface drainage on public rights of way	Y	To address infiltration and treatment swales.
	Innovations	Y	To address innovations such as retaining topsoil; maximizing groundwater infiltration; minimizing groundwater seepage into infrastructure; minimizing impervious surfaces; onsite rainwater storage; infiltration basins.

SDS bylaw component	Engineering element	Within scope	Rationale for inclusion / exclusion
Water Distribution System	Health Authority requirements	N	Beyond scope of model bylaw. However, some mention to reluctance of Health Authorities to allow the reuse of greywater in homes (which may change in the future).
	Design methodologies	N	Sizing of potable water infrastructure deemed relatively insensitive to climate impacts. If dual water systems (i.e., one system for potable water and another system for firefighting and irrigation) are adopted in future, then design methodology may change.
	Water demands (residential/landscape)	Y	To address new technologies that could help in promoting water conservation and water demand management.
	Fire protection	Y	To address expected increase in wildfire threats through subdivision layout and the use of roads, walkways, bikepaths and greenspaces can be used as buffers and escape routes in addition to other FireSmartBC solutions.
	Design flows	N	Simple engineering, deemed relatively insensitive to climate impacts.
	Reservoirs	N	Beyond scope of model bylaw. More of a Local Authority's responsibility than developers of subdivisions.
	Pumping stations	Y	To address electricity outages due to weather or other causes that could result in shortages in potable water to residents.
	PRV stations	Y	To address excessively high water pressures that cause a deterioration in pipe lifespans and cause leakage.
	Water mains	Y	To address resiliency of pressures, leakage, and pipe materials (includes transport, storage and installation). Water metering at district, zone and household level is becoming more and more important.
	Gate valves	N	Deemed relatively insensitive to climate impacts. Though corrosion protection of all metal valves, hydrants, blow offs, mechanical restraints is becoming important. If this protection is not afforded, then the lifespan of this infrastructure may be drastically reduced.
	Hydrants	N	Deemed relatively insensitive to climate impacts, though potential for blow offs and positioning are possible considerations.
	Air valves	Y	To address temperature, freeze-thaw cycles that could cause malfunctioning and service delivery problems.
	Joint restraints	N	Underground concrete pipe anchors or mechanical restraints deemed relatively insensitive to climate impacts.
	Chambers (incl. Manholes)	N	Deemed relatively insensitive to climate impacts.
	Service connections	N	Deemed relatively insensitive to climate impacts.
	Water meters	Y	To enable water conservation and curb water leakage.
Sanitary Sewage Collection and Disposal System	Health Authority requirements	N	Beyond scope of model bylaw.
	Method of Analysis	N	Deemed relatively insensitive to climate impacts.
	Peak factors and design flows	N	Deemed relatively insensitive to climate impacts.
	Groundwater and stormwater infiltration	N	Beyond scope of model bylaw.
	Gravity sewers	N	Buried pipe deemed relatively insensitive to climate impacts.
	Force mains	N	Beyond scope of model bylaw.
	Sewage pumping stations	Y	To address power outages that could cause overflows and health problems.

SDS bylaw component	Engineering element	Within scope	Rationale for inclusion / exclusion
	Aerial pipe bridges and siphons	N	Current engineering practices deemed sufficiently resilient.
	Pipe anchoring & restraints	N	Deemed relatively insensitive to climate impacts.
	Manhole structures	N	Deemed relatively insensitive to climate impacts.
	Service connections	N	Deemed relatively insensitive to climate impacts.
	Septic fields	N	Beyond scope of model bylaw, though potential for impacts on groundwater in floodplains.
	Greywater reuse	Y	To address potential benefits as water resources become scarcer.
Connectivity, Highways and Active Transportation	Road classifications	N	Beyond scope of model bylaw.
	Design standards	Y	To address alternative impervious pavement technologies and ways to address changes in freeze thaw cycles (which affects pavement structural integrity).
	Urban/rural cross-section elements	Y	To address issues with drainage and infiltration.
	Alignments	N	Beyond scope of model bylaw.
	Intersections	N	Beyond scope of model bylaw.
	Railway crossings	N	Beyond scope of model bylaw.
	Traffic control devices	N	Beyond scope of model bylaw.
	Cul-de-Sacs	N	Beyond scope of model bylaw.
	Traffic barriers	N	Beyond scope of model bylaw.
	Curbs and gutters	Y	To address retention or removal of curbs and gutters which would allow surface water to runoff into treatment swales and increase infiltration into the groundwater table.
	Sidewalks and walkways	Y	To address various innovations.
	Bikeways	Y	To address infiltration versus impervious surfaces through changes in surface materials; can reduce operation and maintenance costs.
	Transit facilities	N	Beyond scope of model bylaw.
	Driveways	Y	To reduce impervious surfaces.
	Pavement structures	Y	To address ideas related to water runoff interception and considerations related to pavement resiliency.
	Innovations	Y	To address location of roads to counteract wildfire threats.
Landscaping	Type of landscaping required	Y	To address xeriscaping; rainfall interception; shading; types of vegetation that will survive as weather changes.
	Irrigation requirements	Y	To allow for a consideration of types of sprinklers; automation, etc. which can lead to efficiencies in water use.
Utilities	Power Company requirements and design	N	Beyond scope of model bylaw, other than a consideration of redundancies or less reliance on electrical system.
	Street lighting	N	Beyond scope of model bylaw.
	Telephone Utility requirements and design	N	Beyond scope of model bylaw.
	Cablevision Utility requirements and design	N	Beyond scope of model bylaw.
	Natural Gas Utility requirements and design	N	Beyond scope of model bylaw.
	Mail delivery	N	Beyond scope of model bylaw.
	Power outages	Y	To address storms and trees taking down powerlines, an increase in lightning strikes, etc.
	Innovations	Y	To address future innovations such as electric car charging capacities in homes.

Table 2. Description of criteria for evaluating feasibility of alternative good practices or adaptation measures.[150]

Category	Abbrev-iation	Criteria	Criteria levels		
			Low	Medium	High
Costs	IC	Implementation cost	Cost of implementation is high relative to cost of inaction.	Cost of implementation is moderate relative to cost of inaction.	Cost of implementation is low relative to cost of inaction.
	OC	Operating and maintenance cost	Cost of operation and maintenance is high.	Cost of operation and maintenance is moderate.	Cost of operation and maintenance is low.
Benefits	MB	Mitigation co-benefits	Results in increased greenhouse gas emissions.	Would not affect greenhouse gas emissions.	Would reduce greenhouse gas emissions.
	AB	Ancillary benefits**	This measure will contribute little or not at all to other goals for the community.	This measure will contribute somewhat to other goals for the community.	This measure will contribute significantly to other goals for the community.
Effectiveness	IM	Degree of impact	Future impacts are minor.	Future impacts are moderate.	Future impacts are potentially catastrophic.
	UN	Uncertainty of impact	The impact is not well understood.	Some uncertainty exists.	The impact is generally understood.
	RE	Reliability of adaptation measure	This measure is untested.	Experimental but has expert support.	The effectiveness of this measure is proven.

** Other relevant goals for communities in the Columbia Basin include (1) conserving water resources, (2) ensuring adequate evacuation routes and emergency response, and (3) remaining attractive and competitive for businesses. Reducing energy consumption is considered a part of mitigation co-benefits.

Table 3. Sensitivity matrix showing the potential interactions between climate impacts and relevant engineering elements from Table 1.

SDS bylaw component	Engineering element	Climate impacts															
		IR	TR	SR	OF	DR	EX	TV	RS	BL	IS	WF	BD	WI	PE	TE	WQ
Storm Drainage System	Stormwater control plan	X		X	X			X	X		X						X
	Lot grading plan	X		X	X				X								
	Sediment control plan	X		X	X												X
	Groundwater interaction	X	X	X	X				X								X
	Detention control	X		X	X				X								X
	Stormwater runoff generation	X		X	X				X								
	Design criteria	X	X	X	X												X
	Method of analysis (minor systems)	X	X	X	X				X								
	Method of analysis (major systems)	X	X	X	X				X								
	Storm sewers	X		X	X				X								
	Culverts	X		X	X				X		X						
	Inlet and outlet structures	X		X	X				X		X						
	Flow control structures	X		X	X				X		X						
	Storm service connections	X		X	X				X								
	Sub-surface drains	X		X	X												X
	Surface drainage on rights of way	X		X	X												
	Innovations	X		X	X				X								X
Water Distribution System	Water demands (resident'l /landscape)		X	X		X	X										
	Fire protection			X		X	X					X			X		
	Pumping stations									X		X		X			
	PRV stations							X									
	Water mains											X					
	Air valves							X									
	Water meters		X														
Sanitary Sewage Coll'n and Disp'l	Sewage pumping stations									X				X			
	Greywater reuse		X	X		X	X					X					X
Connectivity, Highways and Active Transportation	Design standards	X			X			X				X				X	
	Urban/rural cross-section elements	X			X			X				X				X	
	Curbs and gutters	X			X						X						
	Sidewalks and walkways											X					
	Bikeways											X					
	Pavement structures							X									
	Innovations					X											
Landscaping	Type of landscaping required		X	X		X	X					X	X	X	X		X
	Irrigation requirements		X	X		X	X						X				
Utilities	Power outages										X	X		X			
	Innovations																

Table 4. Alignment of climate impacts according to the presumed degree of impact and uncertainty of impact associated with the supporting evidence in Appendix B.[151]

		Degree of impact		
		Future impacts are minor	Future impacts are moderate	Future impacts are potentially catastrophic
Uncertainty of impact	The impact is generally understood			
Uncertainty of impact	Some uncertainty exists		• Total annual rain • Seasonal rainfall • Extreme heat • Biodiversity • Pests / invasives	• Intense rain • Drought • Temperature variations • Wildfire
Uncertainty of impact	The impact is not well understood		• Blizzards • Ice storms • Intense winds • Water quality	• Overland flooding • Rain vs. snow • Terrain stability

Table 5. Priority sections within Schedule B and related context for good practices that could be used to improve a community's climate resilience. Abbreviations describing source include: COK (City of Kamloops and Kelowna), CPG (City of Prince George), DNV (District of North Vancouver), DOE (District of Elkford), and GVSDD (Greater Vancouver Sewerage and Drainage District). Evaluation criteria are described in Table 2.

Schedule B Section		Context and examples of good practices	Source	Evaluation criteria						
No.	Heading			IC	OC	MB	AB	IM	UN	RE
1.2	Integrated Design and Sustainability	Can be used to help find an appropriate balance between development needs, environmental changes, cost, effectiveness, etc. when planning and designing a subdivision. This can lead to appropriate and cost effective subdivision infrastructure being built that is resilient to future climate and other changes.	DNV	H	M	H	H	L	H	H
1.4	Alternative Solutions and Design	Can allow for alternative subdivision layouts that provide space for implementing the good practices suggested in Low Impact Development and other subdivision planning and design approaches.	Various	H	H	H	H	L	H	M
Sect 3	Best Management Practices Guide for Stormwater	Can be used as a reference to specify a range of structural, operational and maintenance, and non-structural good practices, including: <u>Structural Good Practices (design standards and costing criteria)</u> • coalescing plate separator • water quality inlet • manhole sediment trap • trapped catch basin • dry detention basin • wet pond • dry detention vault and wet vault • constructed wetlands • grassed channel/wet swale • vegetated filter strip • off-line infiltration basin • roof downspout system • porous pavement • concrete grid and modular pavers • bioretention and dry swale with underdrains • sand filters • catch basin filter • organic filter • multi-chambered treatment train	GVSDD	M	M	M	M	L	H	M

Schedule B Section No.	Heading	Context and examples of good practices	Source	Evaluation criteria IC	OC	MB	AB	IM	UN	RE
		<u>Operational and Maintenance Good Practices</u> • maintenance of structural good practices • detection, removal and prevention of illicit connections • spill and complaint reporting and response • street cleaning • maintenance of runoff conveyance systems and hill slopes • catch basin cleaning • roadway and bridge maintenance <u>Non-Structural Good Practices</u> • buffer zones/preservation of key drainage and habitat features • reduction/disconnection of impervious areas • construction design, review, inspection, and enforcement • education and training of municipal employees, consultants, contractors, commercial enterprises • public education								
Sect 3	Various Guides and Manuals	Can be used to provide more detailed guidance on development approaches than can reasonably be contained within an SDS bylaw. For leading examples, see guidelines from Toronto, Calgary, Puget Sound, Seattle, Auckland and others.	Various	M	M	M	M	L	H	M
3.2	Objectives / Goals: Stormwater	Can provide the developer with the overarching goals for treating stormwater and lead to selection of appropriate good practices to achieve these objectives / goals.	DNV	M	M	M	M	L	H	H
3.4	Updating IDF Curves	Can help determine both current and future peak stormwater flow through subdivisions. Updating IDF curves based on future projections can affect the location and sizing of infrastructure and future maintenance costs.	Append C	H	M	M	M	M	M	M
3.5	Stormwater Management Plan	Can involve the integration of various good practices listed above to reduce infrastructure needs (e.g. overland instead of underground pipes). Such a plan can also determine the overall system in which stormwater above, in and below a subdivision is treated (e.g., lot grading, infiltration control, disposal, detention, erosion control, and flood routing).	Various	H	M	M	M	M	H	H
3.6	Stormwater Management Systems: Performance Standards	Can be used by local governments in their SDS Bylaws to describe performance based stormwater requirements, as opposed to providing prescriptive requirements for consulting professionals. The worldwide trend is to move towards performance standards.	DOE	H	M	M	M	L	M	H

Schedule B Section No.	Heading	Context and examples of good practices	Source	IC	OC	MB	AB	IM	UN	RE
3.8	Stormwater Management Facilities	Can include the following good practices, among others: • upstream watershed source controls and detention • sizing and cost of stormwater detention ponds • overland flood routing vs sizing of storm sewers • conserving forest cover and wetlands • riparian management • roads, driveways and parking • lot and subdivision layout • limitation of impervious surface coverage • permeable paving • lot grading • vegetated roofs • roof rainwater collection • landscaping, amending site soils and trees • bioretention areas • infiltration swales • rain gardens • french drains • oil/grit separators • sediment control • ground/surface water interactions	Various	M	M	M	M	L	H	M
4.3	Water Resource Availability and Quality	Can be used to specify special watershed and water resource development planning and project implementation to ensure sustainability of sufficient quantity and quality of water supplies for communities. Such measures may be increasingly important as the demand for water increases and additional pressure is placed on finite water resources.	Various	H	M	M	H	H	H	H
4.4	Water Demands	Can be used to specify domestic, industrial, irrigation, landscaping and fire water use targets tailored to a specific community. Water conservation and water demand management strategies play a major role in meeting these targets. Out of necessity, Australia and South Africa have implemented such strategies for decades.	Various	H	M	M	H	H	H	H
4.5 to 4.7	Water Networks and Pressure Management	Can be used to specify strategies to make these systems more resilient to future climate. Such strategies will be required when planning subdivisions since high water pressures in distribution systems are synonymous with water leakage and water infrastructure breakdowns. As well, power outages can result in system failures if there is no redundancy built into the design of the systems.	Various	H	M	M	M	H	H	H

Schedule B Section No.	Heading	Context and examples of good practices	Source	Evaluation criteria IC	OC	MB	AB	IM	UN	RE
4.8	Water Mains	Can be used to specify depth of bury, which will vary across municipalities according to climatic conditions. Options to reduce depth of bury, or use insulating technologies to save on construction costs, need to be weighed against potential future maintenance problems. Water metering and cross-connection controls are other good practices that will improve the operation and management of water distribution systems.	-	M	M	M	L	M	M	M
4.16	Private Wells	Can be used to guide the sustainable control and management of private groundwater wells in municipalities.	DOE	H	H	M	M	M	H	H
5.10	New Technologies	Can be used to specify new technologies may need to be developed to increase a community's resilience (e.g., geo-exchange and district heating systems that draw heat from sanitary mains).	-	H	H	H	M	L	M	M
5.14	Greywater Reuse	Can be used to specify how the reuse of cleaner household wastewater discharges (e.g. shower, bath, hand basins), as well as rainwater and other similar sources, can be lightly treated and used for irrigation of lawns and landscaping. This measure is intended to save on urban potable water usage during the warmer summer months.	Various	H	H	M	H	M	H	M
6.3	Road Classifications	Can be used to articulate a local government's policy regarding cross-sectional road widths, and other attributes of subdivision roads. For instance, reductions in impervious surfaces and the ability to include new infrastructure and innovative landscaping technologies are benefits that may be considered in planning and designing subdivisions. Municipalities have differing views on the use or non-use of curbs and gutters. Specific good practices will be specific to the individual needs of each municipality	Various	M	M	M	M	M	M	M
6.5	Road Works Structure	Can be used to specify the layers below finished asphalt, or other road surfaces, that may be required to make road infrastructure more resilient to increased freeze-thaw cycles and the potential for increased breakup of road surfaces. Various techniques are required to make road infrastructure more resilient.	CPG	M	M	M	M	H	M	M
6.18	Hillside Standards	Can be used to specify hillside development standards to address concerns related to alterations in slope stability due to a changing future climate.	DOE	M	M	M	M	H	H	H
7	Landscaping	Can be used to specify how landscaping can be used to assist in temperature control, stormwater treatment, etc. The choice of landscaping in subdivisions also has relevance to water conservation policies of municipalities.	COK	M	M	M	M	M	M	M
8	Utilities	Can be used to specify how various utilities should be developed. For instance, specifying below ground versus above ground power lines (that might be affected by wind storms), or sizing of power and other utility capacities to cater to future household technologies (e.g., electric cars, zero energy or energy plus buildings, etc).	-	M	H	H	H	L	M	M

8.0 Endnotes

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[40] Village of Elkford Official Community Plan Bylaw No.710, 2010 Schedule "A" at sections 9.2 and 9.3.

[41] http://www.kelowna.ca/CityPage/Docs/PDFs/Development%20Services/Hillside%20Development%20Guidelines.pdf

[42] City of Castlegar Official Community Plan Bylaw No. 1150, 2011 at section 25.9.

[43] City of Revelstoke Development Cost Charge Bylaw No. 1781, 2005; Village of Elkford Specified Area Cost Charges Bylaw, 1980; City of Castlegar Bylaw No. 695, 1994. The Town of Rossland does not charge DCCs.

[44] Smart Growth America. 2013. Building Better Budgets: A National Examination of the Fiscal Benefits of Smart Growth Development. Available online: http://www.smartgrowthamerica.org/documents/building-better-budgets.pdf

[45] For more information see: http://www.fcm.ca/home/programs/green-municipal-fund.htm.

[46] Subdivision, Development and Servicing Bylaw No. 7900 at section 7.1. http://www.kelowna.ca/CityPage/Docs/PDFs/%5CBylaws%5CSubdivision%2C%20Development%20and%20Servicing%20Bylaw%20No%2E%207900/Bylaw%20%2D%20Subdivision%2C%20Development%20and%20Servicing%20Bylaw%20No%2E%207900%2Epdf

[47] See process at: http://www.toronto.ca/developing-toronto/pdf/guide_sectionB.pdf#section_b

[48] http://www.dnv.org/upload/pcdocsdocuments/11bg01!.pdf

[49] http://www.psp.wa.gov/downloads/LID/LID_manual2005.pdf

[50] http://www.rhsdplanning.com/psur.pdf

[51] http://www.smartgrowth.bc.ca/Default.aspx?tabid=133

[52] http://www.newurbanism.org/newurbanism/principles.html

[53] http://www.toronto.ca/developing-toronto/pdf/guide_sectionB.pdf#section_b

[54] http://www.calgary.ca/PDA/DBA/Pages/home.aspx?redirect=/dba

[55] http://www.mmcd.net/

[56] http://www.mmcd.net/downloads/24093-GreenDesignGuidelines-Sept1-05.pdf

[57] http://www.env.gov.bc.ca/epd/mun-waste/waste-liquid/stormwater/

[58] http://www.metrovancouver.org/about/publications/Publications/BMPVol1a.pdf

[59] http://www.embc.gov.bc.ca/ofc/interface/pdf/homeowner-firesmart.pdf

[60] http://poliswaterproject.org/publication/243

[61] http://www.dfo-mpo.gc.ca/Library/165353.pdf

[62] Columbia Basin Trust (CBT). 2012. Climate change, impacts and adaptation in the Canadian Columbia Basin: From dialogue to action. Available online: http://www.cbt.org/uploads/pdf/DialoguetoAction_Final_lo-res.pdf

[63] http://www.toronto.ca/developing-toronto/pdf/guide_sectionB.pdf#section_b

[64] The City of Calgary has numerous well thought out guidelines and manuals which can be found at: http://calgarycommunities.com/content/Community%20Guide%20to%20the%20Planning%20Process.pdf

[65] See Section 11 – Subdivision at: http://www.aucklandcouncil.govt.nz/EN/planspoliciesprojects/plansstrategies/DistrictRegionalPlans/aucklandcitydistrictplanisthmus/Pages/districtplantexthome.aspx

[66] http://www.canterbury.gov.uk/authority/assets/planning/validation_of_planning_applications_guidance.pdf

[67] http://www.penticton.ca/assets/City~Hall/Bylaws/Land~Use/Development%20Cost%20Charge%20Reduction%20(Bylaw%202010-11).pdf

[68] http://www.dnv.org/upload/pcdocsdocuments/11bg01!.pdf

[69] http://www.metrovancouver.org/about/publications/Publications/BMPVol1a.pdf

[70] http://www.calgary.ca/PDA/DBA/Pages/Urban-Development/Publications.aspx

[71] https://www.calgary.ca/UEP/Water/Documents/Water-Documents/Stormwater%20Source%20Control%20Practices%20Handbook%20-%20November%202007.pdf?noredirect=1

[72] http://www.sustainabletechnologies.ca/Portals/_Rainbow/Documents/LID%20SWM%20Guide%20-%20v1.0_2010_1_no%20appendices.pdf

[73] http://www.env.gov.bc.ca/epd/mun-waste/waste-liquid/stormwater/

[74] http://www.elkford.ca/include/get.php?nodeid=527

[75] http://www.cnv.org/~/media/35387DE447C540C999FACB9C58A93B19.ashx

[76] https://abbotsford.civicweb.net/Documents/DocumentDisplay.aspx?Id=22824

[77] http://www.district.sechelt.bc.ca/Work/DevelopmentinSechelt/DevelopmentPermitAreas.aspx

[78] http://www.toronto.ca/legdocs/municode/1184_681.pdf

[79] http://www.troyohio.gov/Planning/1000.10000.html

[80] http://www.aucklandcouncil.govt.nz/EN/licencesregulations/Bylaws/existingbylaws/aucklandcitycouncilbylaws/Documents/no18stormwater.pdf

[81] http://www.dnv.org/upload/pcdocsdocuments/11bg01!.pdf

[82] District of Elkford Subdivision and Development Servicing Bylaw No. XXXXX. Available online: http://www.elkford.ca/include/get.php?nodeid=520

[83] http://www.env.gov.bc.ca/epd/mun-waste/waste-liquid/stormwater/

[84] https://www.calgary.ca/UEP/Water/Documents/Water-Documents/Stormwater%20Source%20Control%20Practices%20Handbook%20-%20November%202007.pdf?noredirect=1

[85] http://www.metrovancouver.org/about/publications/Publications/BMPVol1a.pdf

[86] http://www.psp.wa.gov/downloads/LID/LID_manual2005.pdf

[87] http://ballardstormwaterconsortium.files.wordpress.com/2013/01/2012-directors-rule-for-gsi.pdf

[88] http://www.rhsdplanning.com/psur.pdf

[89] http://www.mapc.org/low-impact-dev-toolkit

[90] http://www.dnv.org/upload/pcdocsdocuments/11bg01!.pdf

[91] http://www.obwb.ca/groundwater_bylaws_toolkit/

[92] Water Conservation means the minimization of loss or waste, care and protection of water resources and the efficient and effective use of water.

[93] Water Demand Management means the adaptation and implementation of a strategy by a water institution or consumer to influence the water demand and usage of water in order to meet any of the following objectives: economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services, and political acceptability.

[94] Drawn from South African Department of Water Affairs and Forestry, available at: http://www.info.gov.za/view/DownloadFileAction?id=70350

[95] For instance, see British Columbia's water initiative: http://livingwatersmart.ca/

[96] For instance, see Australia's water initiative: www.savewater.com.au

[97] Found at: http://www.env.gov.bc.ca/wsd/plan_protect_sustain/water_conservation/

[98] http://www.embc.gov.bc.ca/ofc/interface/index.htm

[99] http://www.yvw.com.au/yvw/groups/public/documents/document/yvw001279.pdf

[100] http://www.miya-water.com/user_files/Data_and_Research/miyas_experts_articles/3_DMAs_Pressure_management/03_Implementation%20of%20pressure%20management%20in%20municipal%20water%20supply%20systems.pdf

[101] http://www.fas.org/sgp/crs/misc/R42696.pdf

[102] District of Elkford Subdivision and Development Servicing Bylaw No. XXXXX. Available online: http://www.elkford.ca/include/get.php?nodeid=520

[103] http://www.proecoenergy.ca/inn-at-big-white/

[104] More information can be gathered from: http://www.geo-exchange.ca/ and http://www.toolkit.bc.ca/tool/district-energy-systems

[105] http://www.buttecounty.net/publichealth/environmental/Graywater%20Research.pdf

[106] http://www.vernon.ca/services/utilities/reclamation/

[107] http://www.cmhc-schl.gc.ca/publications/en/rh-pr/tech/03-100-e.htm

[108] http://www.gwig.org/downloads/files/The_Code_2010.pdf

[109] http://www.pittwater.nsw.gov.au/__data/assets/pdf_file/0004/44455/why_not_greywater.pdf

[110] http://www.savewater.com.au/how-to-save-water/in-the-home/greysmart

[111] http://shop.bsigroup.com/ProductDetail/?pid=000000000030184123

[112] See FireSmartBC Second Edition, Chapter 3 fore more information: http://embc.gov.bc.ca/ofc/interface/pdf/homeowner-firesmart.pdf

[113] http://www.psp.wa.gov/downloads/LID/LID_manual2005.pdf

[114] http://www.lakesuperiorstreams.org/stormwater/toolkit/swales.html

[115] http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=88

[116] http://princegeorge.ca/environment/climatechange/adaptation/Documents/2012_PGRAC_Transport_volume%20with%20Exec%20Sum.pdf

[117] http://www.mtq.gouv.qc.ca/portal/page/portal/entreprises_en/camionnage/charges_dimensions/periode_degel

[118] http://www.psp.wa.gov/downloads/LID/LID_manual2005.pdf

[119] http://www.psp.wa.gov/downloads/LID/LID_manual2005.pdf

[120] http://www.rhsdplanning.com/psur.pdf

[121] http://www.rossland.ca/node/970

[122] http://www.psp.wa.gov/downloads/LID/LID_manual2005.pdf

[123] http://www.rhsdplanning.com/psur.pdf

[124] District of Elkford Subdivision and Development Servicing Bylaw No. XXXXX. Available online: http://www.elkford.ca/include/get.php?nodeid=520

[125] http://www.kelowna.ca/CityPage/Docs/PDFs/Water%20Division/Water%20Smart%20Program/Landscape%20and%20Irrigation%20Design%20Standards%20Bylaw%207900.pdf

[126] http://www.kamloops.ca/development/pdfs/LandscapeGuide.pdf

[127] http://www.bchydro.com/powersmart.html

[128] http://www.veva.bc.ca/home/index.php

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Appendix A: Climate Indices and Projections

Table A1. Summary of climate indices and related projections as reported by Murdock and Werner (2011) and Murdock and Sobie (2012) with a representation of how these indices relate to the climate impacts expected to affect Columbia Basin communities (denoted by X's).

Climate indices	Projected change in climate index	Regional / seasonal variation in change	Climate impacts											
			IR	TR	SR	OF	DR	EX	TV	RS	BL	IS	WF	BD
Percentiles														
(1) Cool nights - TN10p: occurrence of min temperature < 10p	from 0.1 x less often to 1.2 x more frequent across months (median 0.4 less frequent)	uniform changes across basin										X		
(2) Warm days - TX90p: occurrence of max temperature > 90p	from 0.8 x less often to 6.1 x more frequent across months (median 2.2 more frequent)	uniform changes across basin						X						
(3) Cool days - TX10p: occurrence of max temperature < 10p	from 0.2 x less often to 1.2 x more frequent across months (median 0.4 less frequent)	uniform changes across basin										X		
(4) Warm nights - TN90p: occurrence of min temperature > 90p														
(5) Very wet day precipitation - R95pTOT: annual total precipitation when > 95p	very wet days will have from 25mm less to 232 mm more precipitation across all very wet days in year, 1% decrease to 13% increase(median 42 mm more)	some projections of heavier in north and eastern basin	X											
(6) Extremely wet day precipitation - R99pTOT: annual total precipitation when > 99p	extremely wet days will have from 33mm less to 128mm more precipitation across all extremely wet days in year, 2% decrease to 9% increase (median 19mm more)	variable projections, though weaker spatial pattern	X											
Return periods														
(7) 1 in 5, 1 in 10, and 1 in 25, daily warm event	1in5 from 1.6 to 4x more frequent, 1in10 from 1.5 to 6.6x more frequent, 1in25 from 1.4 to 12.5x more frequent							X						
(8) 1 in 5, 1 in 10, and 1 in 25, daily cold event	1in5 from 0.1 to 0.6x less frequent, 1in10 from 0.1 to 0.6x less frequent, 1in25 from 0.1 to 0.6x less frequent											X		
(9) 1 in 5, 1 in 10, and 1 in 25, daily precipitation event	1in5 from 0.7x less to 2.3x more frequent, 1in10 from 0.6x less to 2.8x more frequent, 1in25 from 0.3x less to 4.1x more frequent		X											

Climate indices	Projected change in climate index	Regional / seasonal variation in change	Climate impacts											
			IR	TR	SR	OF	DR	EX	TV	RS	BL	IS	WF	BD
(10) 1 in 5, 1 in 10, and 1 in 25, 3-hour precipitation event	1in5 from 0.9x less to 2.5x more frequent, 1in10 from 0.7x less to 3.3x more frequent, 1in25 from 0.3x less to 5.0x more frequent	largest increases in the north, smallest in south	X											
(11) 1 in 5, 1 in 10, and 1 in 25, daily snow depth event	highly variable projections from complete disapperance, decrease in frequency, to increase in frequency of events (weak evidence of changes)										X			
Simple indices														
(12) Daily temperature range - DTR: diurnal temperature range	from a 6.5C decrease to a 4.1C increase in diurnal variation across months (median decrease of 0.5C)	most significant decrease in winter, weaker in spring / fall							X					
(13) Hottest day - TXx: monthly max value of daily max temperature	from decrease of 0.4C to increase of 11.7C across months (median 1.9C increase)	largest changes in summer						X						
(14) Hottest night - TNx: monthly maximum value of daily min temperature														
(15) Coldest day - TXn: monthly minimum value of daily max temperature	from decrease of 5.4C to increase of 6.8C across months (median 2.2C increase)											X		
(16) Coldest night - TNn: monthly min value of daily min temperature	from decrease of 3.1C to increase of 10.6C across months (median 2.9C increase)	highly variable across regions										X		
(17) Heaviest precipitation day - RX1day: monthly max 1-day precipitation	from a 13mm decrease to a 19mm increase in heaviest precipitation day (median 1 mm increase)	decreases in summer, increases in fall	X											
(18) Heaviest 5-day precipitation - RX5day: monthly max consecutive 5-day precipitation	from a 20mm decrease to a 39mm increase in heaviest 5-day precipitation (median 2 mm increase)	largest decreases in Feb, largest increases in Nov, driven by more frequent wet events and larger single day events	X											
Complex indices (CLIMDEX)														
(19) WSDI: warm spell duration index	from a 4 day to a 52 day increase, increase of 63-913% (median 17 day increase)						X	X					X	
(20) CSDI: cold spell duration index	from a 6 day decrease to no change, -100% decrease to 20% increase(median 3 day decrease)								X			X		

Climate indices	Projected change in climate index	Regional / seasonal variation in change	Climate impacts											
			IR	TR	SR	OF	DR	EX	TV	RS	BL	IS	WF	BD
(21) CDD: max length of dry spell	from a 17 day decrease to a 12 day increase, 23% decrease to 63% increase (median no change)	more locations with increase in both dry and wet spells					X						X	
(22) CWD: max length of wet spell	from a 4 day decrease to a 5 day increase, 23% decrease to 26% increase (median no change)	more locations with increase in both dry and wet spells				X								
(23) GSL: growing season length	increase from 7 to 75 days, increase of 7-177% (median 27 day increase)	least affected in northeast												X
(24) FD: number of frost free days	decrease from 18 to 49 days, 7-49% decrease (median 33 day decrease)	largest decreases in northeast							X					X
(25) SU: number of summer days	from no change to increase of 19 days (median 4 day increase)													
(26) ID: number of icing days	decrease from 10 to 41 days, 7-49% decrease (median 27 day decrease)											X		
(27) TR: number of tropical nights														
(28) PRCPTOT: annual total precipitation in wet days	from decrease of 54mm to an increase of 353 mm (median 53 mm increase)	increases in the north, decreases in the south		X										
(29) SDII: simple precipitation intensity index (total precip in wet days / number of wet days)	from a 0.2mm decrease to a 1.4mm increase in precipitation intensity (median 0.3 mm increase)	uniform changes across basin	X											
(30) R10mm: annual count of days when precipitation >= 10mm	from a 3 day decrease to a 12 day increase (median 3 day increase)	largest increase in northwest	X	X										
(31) R20mm: annual count of days when precipitation >= 20mm	from a 1 day decrease to a 8 day increase (median 1 day increase)	largest increase in northwest	X											
Complex indices (specialized)														
(32) Freeze thaw cycles: night-time low < 0°C and day-time high > 0°C	from 5 fewer to 5 more events per year (low agreement among evidence)	highly variable evidence							X					
(33) Rain on frozen ground: precipitation > 6 mm when no snow on ground and temperature < 0°C	highly variable projections from large decrease, to no change, to large increase (low agreement among evidence)	highly variable evidence				X								

Climate indices	Projected change in climate index	Regional / seasonal variation in change	Climate impacts											
			IR	TR	SR	OF	DR	EX	TV	RS	BL	IS	WF	BD
(34) Rain on snow: snow pack > 10 mm, precipitation > 30 mm, and temperature > 0°C	highly variable projections from no change (most models) to considerable increase (low agreement among evidence)	highly variable evidence				X								
(35) Rapid snow melt: snow melt > 10 cm in 3 hours	highly variable projections from increase to decrease in rapid snow melt (low agreement among evidence)	highly variable evidence				X								
Other indices														
(36) Annual total precipitation	from 50% decrease to 102% increase in total precipitation across months (median 6% increase), from 6% decrease to 20% increase in total precipitation across year (median 6% increase)	largest increases in the north		X										
(37) Spring total precipitation	from 2% decrease to 22% increase in spring precipitation (median 8% increase)				X									
(38) Summer total precipitation	from 18% decrease to 2% increase in summer precipitation (median 6% decrease)	most seasonal decrease during summer			X									
(39) Winter total precipitation	from 8% decrease to 25% increase in winter precipitation (median 7% increase)				X									
(40) Fall total precipitation	from 2% decrease to 20% increase in fall precipitation (median 10% increase)	most seasonal increase in fall			X									
(41) PAS: Total precipitation as snow	from 40% decrease to 20% increase in total precipitation as snow	losses in south of basin / low elevation, gains in north / high elevation			X					X				

Notes:

- Data drawn from Murdock, T.Q., and A.T. Werner. 2011. Canadian Columbia Basin Climate Trends and Projections: 2007-2010 Update. Pacific Climate Impacts Consortium, University of Victoria, Victoria, BC, 43 pp. and Murdock, T.Q., and S.R. Sobie. 2012. Climate Extremes in the Canadian Columbia Basin: A Preliminary Assessment. Pacific Climate Impacts Consortium, University of Victoria, Victoria, BC, 57 pp
- For most indices min-max values are reported (exceptions are return period and other indices)
- For all indices, projections are to 2050s
- For most indices projections are relative to 1971-2000 baseline
- Majority of results from Murdock and Sobie 2012, most from RCM runs (few indices not), PAS from analysis of ClimateWNA data
- Abbreviations of climate impacts include:

IR = Intense rainfall / IDF curves / stormflow surges
TR = Total annual rainfall
SR = Seasonal rainfall
OF = Overland flooding
DR = Drought
EX = Extreme heat events
TV = Temperature variations / freeze-thaw cycles
RS = Rain vs. snow changes
BL = Blizzards
IS = Ice / hail storms, ice jamming / buildup
WF = Wildfire
BD = Biodiversity

Appendix B: Climate Impacts

Table B1. Summary of evidence and projected changes in climate impacts to which Columbia Basin communities will be exposed. An alignment of impacts with degree of impact and uncertainty of impact is based on criteria in Bizikova et al. (2008). Summaries of climate indices and projections are in Appendix A.

Climatic impacts	Projected change in climate impacts	Regional / seasonal variation	Degree of impact	Uncertainty of impact	Sources of evidence
IR - Intense rainfall / IDF curves / stormflow surges	Consistently projected increase in median intensity of extreme precipitation events across many climate indices (extremely wet days, very wet days, heaviest precipitation day, heaviest 5-day precipitation, precipitation intensity). Range of projections includes decrease in intensity for some places and/or models. For instance, extremely wet days will have from 33 mm less to 128 mm more precipitation across all extremely wet days in year, 2% decrease to 9% increase (median of 19mm more). Median frequency of storm events also consistently projected to increase across climate indices (frequency of 1 in 5, 1 in 10, and 1 in 25 daily / 3-hour precipitation events, count of days with high precipitation >10 and 20 mm). Range of projections includes a decrease in frequency for some places and/or models. For instance, projections include from a 3 day decrease to a 12 day increase (median 3 day increase) in the number of days with precipitation >10 mm. There is also a projection of between 0.3x less to 5.0x more frequent 1 in 25, 3-hour precipitation events (i.e., possibly becoming as frequent as a 1 in 5 event).	Expect largest increases in intensity in the north (and west), smallest in south as well as decreases in intensity in summer, increases in fall. Overall expect more frequent wet events and larger single day events.	Future impacts are potentially catastrophic	Some uncertainty exists	Murdock and Sobie 2012
TR - Total annual rainfall	Projected increase in different measures of annual precipitation with some places and/or models projecting a slight decline. For instance, projections include a decrease of 54mm to an increase of 353 mm in annual total precipitation in wet days (median 53 mm increase), a projected 50% decrease to 102% increase in total precipitation across months (median 6% increase), and a 6% decrease to 20% increase in total precipitation across the year (median 6% increase).	Expect increases in the north, decreases in the south, with largest increase in the north.	Future impacts are moderate	Some uncertainty exists	Murdock and Werner 2011; Murdock and Sobie 2012
SR - Seasonal rainfall	Projections include a relatively similar range of increases in precipitation in the spring, fall, and winter, with expected declines in the summer. Also expect an overall decrease in total precipitation as snow (PAS) in winter and shoulder seasons as temperatures increase. Some projections indicate potential for slight opposite changes, though these results are not represented by median projections (i.e., decrease in spring, fall, and winter, more precipitation as snow in winter, more precipitation in	Highest seasonal decrease during summer, with highest increase in fall. Greatest losses of PAS in south / low	Future impacts are moderate	Some uncertainty exists	Murdock and Werner 2011

Climatic impacts	Projected change in climate impacts	Regional / seasonal variation	Degree of impact	Uncertainty of impact	Sources of evidence
	summer).	elevations, gains in north / high elevation areas.			
OF - Overland flooding	Climate indices aren't sufficiently strong to project likelihood of overland flooding due to rain on snow events, storm events, or rivers spilling their banks. Available climate indices suggest that overland flooding may increase. Above evidence related to storm events indicates a projected increase in the intensity and frequency of storm events. However, the maximum length of wet spells is highly variable (from a 4 day decrease to a 5 day increase, 23% decrease to 26% increase, median no change). As well, the evidence related to rain on snow events is highly variable and inconsistent based on projections of the potential for rain on frozen ground, rain on snow, and rapid snow melt. Stronger evidence required to more reliably project changes in relevant watersheds for communities, though hydrologic modelling can be complex and data intensive.	Unknown	Future impacts are potentially catastrophic	The impact is not well understood	Murdock and Sobie 2012
DR - Drought	Similar to wildfire, projections of changes in climate indices support anticipated increase in frequency and intensity of drought. Climate projections include between a 4 and 52 day increase in duration of warm spells (increase of 63-913%, median 17 day increase) and between a 17 day decrease to a 12 day increase in the maximum length of dry spell (23% decrease to 63% increase (median no change). However, reliable projections of drought are based on complex interactions among climate, land cover, water use, and instream flow as opposed to simple climate indices. Hydrologic modelling can be complex and data intensive; reliable predictions of drought / low flows are difficult.	Unknown	Future impacts are potentially catastrophic	Some uncertainty exists	Murdock and Sobie 2012
EX - Extreme heat events	Consistently projected increase in intensity, duration, and frequency of extreme heat across models, locations, and climate indices. Monthly maximum value of daily maximum temperature projected has the potential to change between a 0.4C decrease and a 11.7C increase across months (median 1.9C increase). Duration of warm spells is projected to increase between 4 and 52 days (median 17 day increase, with a range of 63-913%). Warm days are expected to occur between 0.8 x less often to 6.1 x more frequent across months (median 2.2 more frequent), with significant increases in the frequency of 1 in 5, 1 in 10 and 1 in 25 heat events (e.g., from 1.4 to 12.5x more frequent 1 in 25 heat events).	Generally appears to be uniform heating across the Basin; largest increases in extreme heat expected in the summer.	Future impacts are moderate	Some uncertainty exists	Murdock and Sobie 2012
TV - Temperature	Projections of temperature variations are highly variable across models / places. Changes in diurnal variation across months range from a 6.5C	Highly variable	Future impacts are	Some uncertainty	Murdock and Sobie 2012

Climatic impacts	Projected change in climate impacts	Regional / seasonal variation	Degree of impact	Uncertainty of impact	Sources of evidence
variations / Freeze-thaw cycles	decrease to a 4.1C increase (median decrease of 0.5C), while changes in freeze-thaw cycles range from 5 fewer to 5 more events per year (with low agreement across models). Looking at the cold end of the spectrum, however, projections suggest a general decrease in the duration of cold spells (from a 6 day decrease to no change, median 3 day decrease, 100% decrease to 20% increase) and number of frost free days (decrease from 18 to 49 days, median 33 day decrease, 7-49% decrease).	across Basin.	potentially catastrophic	exists	
RS - Rain vs. snow changes	Projections include between a 40% decrease and 20% increase in total precipitation as snow (PAS).	Greatest losses of PAS in south / low elevation areas, gains in north / high elevations.	Future impacts are potentially catastrophic	The impact is not well understood	Murdock and Werner 2011
BL - Blizzards	Highly variable projections of changes in frequency of snow events. Range includes projections of complete disappearance, to decrease in frequency, to increase in frequency of 1 in 5, 1 in 10, and 1 in 25, daily snow depth.	Unknown	Future impacts are moderate	The impact is not well understood	Murdock and Sobie 2012
IS - Ice / hail storms, ice jamming / buildup, ice force	In general, cold events are projected to become warmer, less frequent, and be sustained for shorter periods. Though representing all months, the monthly minimum value of daily maximum temperature (coldest day) is projected to range from a decrease of 5.4C to increase of 6.8C across months (median 2.2C increase), while the monthly minimum value of daily minimum temperature (coldest night) is projected to range from decrease of 3.1C to increase of 10.6C across months (median 2.9C increase). The frequency of cold extremes / events is expected to decrease as represented through a variety of climate indices (number of icing days, occurrence of cool nights and cool days, as well as the 1 in 5, 1 in 10, and 1 in 25 cold events). For instance, the number of icing days is projected to decrease from 10 to 41 days (7-49% decrease, median 27 day decrease) and the 1 in 5 daily cold event is expected to become 0.1x to 0.6x less frequent (potentially becoming a 1 in 10 event or less). Duration of cold spells is projected to range from a 6 day decrease to no change (100% decrease to 20% increase with a median 3 day decrease).	Unknown	Future impacts are moderate	The impact is not well understood	Murdock and Sobie 2012
WF - Wildfire	Projected average increase in area burned of almost 300 times in the north basin, 30 times increase in the mid-basin, and 15 times higher in the south basin by the 2050s, relative to historic period. Though south	Historically highest in south	Future impacts are potentially	Some uncertainty exists	Murdock and Sobie 2012; van der Kamp

Climatic impacts	Projected change in climate impacts	Regional / seasonal variation	Degree of impact	Uncertainty of impact	Sources of evidence
	historically has highest incidence of wildfires, relative changes are most dramatic in north as increases above historic baseline are more significant. Similar to drought, projections of changes in climate indices support anticipated increases in frequency of wildfires and area burned. Projections include between a 4 and 52 day increase in duration of warm spells (increase of 63-913%, median 17 day increase) and between a 17 day decrease to a 12 day increase in the maximu length of dry spell (23% decrease to 63% increase (median no change).		catastrophic		and Bürger 2011; Utzig et al. 2011
BD - Biodiversity	Strongest evidence related to changes in BEC zones and changes in bioclimate envelopes related to tree / species suitability. Other biodiversity changes are not well understood. Projections for basin indicate significant expansions of IDF and PP (Ponderosa Pine) zones in low elevation valleys in the east, significant expansion of ICH (Interior Cedar Hemlock) zone in low elevation valleys in the west. Accompanying loss of ESSF (Englemann Spruce) and MS (Montane Spruce) throughout at higher elevations. Projections of changes in climate indices consistently indicate an increase in the growing season (increase from 7 to 75 days, median 27 day increase, increase of 7-177%) and decrease in number of frost free days (decrease from 18 to 49 days, median 33 day decrease, 7-49% decrease), both of which will affect bioclimate envelopes and climate suitability for native and urban vegetation.	Variation in BEC between east and west consistent with differences in precipitation pattern (east is drier). Growing degree days affected the least in northeast, though area associated with largest decrease in frost free days.	Future impacts are moderate	Some uncertainty exists	Flower et al. 2011;Gayton 2008; Wang et al. 2012
WI - Intense winds / tornados	Based on evidence from elsewhere, future projections are not possible due to limitations in predictive tools. Poor reconstruction of historical observations means that future projections are not credible.	Expect high variation due to local conditions.	Future impacts are moderate	The impact is not well understood	van der Kamp and Bürger 2011; Curry et al. 2011
PE - Biological attack, invasives, pests	Based on evidence from elsewhere, strongest evidence related to forest diseases. Other diseases / invasives harder to predict and less evidence. Expect changes in incidence of disease associated with Douglas Fir and Spruce in the region, though fewer changes than other parts of province due to the prevailing climatic conditions and dominant forest cover type.	Expect variation associated with host species changes as per changes in BEC.	Future impacts are moderate	Some uncertainty exists	Murdock and Flower 2009; Murdock et al. 2011
TE – Terrain stability	Drawing evidence from elsewhere, expect increase in frequency of landslides associated with increased precipitation, frequency and intensity of storm events. Areas associated with linear infrastructure more vulnerable. Detailed projections for the Columbia Basin were not identified, though recent incidents indicate potential likelihood and	Expect hazards to be terrain / climate specific.	Future impacts are potentially catastrophic	The impact is not well understood	Jakob and Lambert 2009

Climatic impacts	Projected change in climate impacts	Regional / seasonal variation	Degree of impact	Uncertainty of impact	Sources of evidence
	consequences of such events (e.g., Johnson's Landing).				
WQ - Water quality	Drawing evidence from elsewhere, climate-induced changes in nutrient concentrations (due to changes in forest cover and water supplies), increases in sediment concentrations (due to landslides and increased storm events), and increases in water temperature (associated with warming air temperature) are most likely. No evidence was identified to characterize degree of change in Basin specifically.	Uncertain	Future impacts are moderate	The impact is not well understood	CCSP 2008; Miller et al. 2006; Wilby and Miller 2009

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Appendix C: Scope of Work for Updating IDF Curves

Introduction

Local and regional governments use IDF curve data to design minor and major stormwater drainage systems – including *best applicable practical technology* (BAPT) incorporated in *low impact development* (LID) works used to mitigate stormwater impacts on the environment. The renewed focus on smaller, site-specific LID works as opposed to larger, regional stormwater systems has increased the need for applicable hydrological design data for site designs that incorporate future needs and a changing environment.

Approach

It is important to note forthright that the uncertainty associated with any projections of precipitation changes, even on a mean annual basis, is very large. This high level of uncertainty is well known and acknowledged within the climate change science community. Since projections of IDF curves for precipitation cannot currently be obtained with any degree of confidence, the preferred approach is to generate scenarios that are not explicitly tied to a given climate model or ensemble.

Over the course of the last decade there has begun to be a change in attitude to the production and use of climate change scenarios. The idea that climate model output can be used in a deterministic sense to direct adaptation decisions is increasingly hard to defend in the face of known uncertainties in global and regional climate modelling. Large uncertainties attached to climate model scenarios typically translate into even larger uncertainties in downscaled regional climate change scenarios and impacts. The planner is then left with a range of possibilities, and often defaults to “low regret” decisions.

Instead, plausible futures can be described by representative climates or generated from weather sequences using simple narratives of the future (such as “warmer”, “drier”, “more variable”). Scenarios are then used to test the sensitivity of the system, ideally to reveal non-linear or threshold behaviours to climate-forcing.

Downscaled projections from Pacific Climate Impacts Consortium (PCIC) can be used to guide expected changes in precipitation in conjunction with a sensitivity analysis to determine preferred system limits for IDF development. This ‘decision centric’ approach focuses more on adaptation decision and less on the production of future scenarios.[1]

[1] Excerpts and summary from: Wilby, R.L., and C.W. Dawson. 2013. Statistical DownScaling Model – Decision Centric (SDSM-DC). Version 5.1 Supplementary Note. 9 pp.

The Statistical DownScaling Model (SDSM) could be used to generate long term precipitation time series at a daily time step. The PCIC Global Climate Models (GCM) and emission scenarios are a sub-set of the full suite of GCMs and scenarios assessed in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report. Several emissions scenarios exist and the A2 scenarios is proposed for IDF development. This is considered to be a 'high' emissions scenario by IPCC; however, it appears to be more consistent with current trends than alternative lower emissions scenarios.

The daily precipitation time series could be disaggregated to sub-daily data, which is necessary for IDF curve development (hourly data is the finest resolution data available for the region). A lower, upper and median (or mean) IDF could then be developed based on results of the sensitivity analysis.