The City of Bainbridge Island is in the process of updating its Critical Areas Ordinance (CAO) in accordance with the Growth Management Act (GMA). The GMA requires local jurisdictions to review and consider best available science (BAS) in the development of critical areas policies and regulations. Staff reviewed the City's current CAO for consistency with current scientific literature and applicable regulatory agency guidance.

I. Aquifer Recharge Areas

Introduction and local importance of aquifer recharge areas

Critical areas provide a variety of valuable and beneficial biological and physical functions that benefit the City and its residents. Groundwater recharge is of particular concern for the City because of the Island's sole source aquifer designation, meaning drinking water is supplied solely by groundwater (EPA 2013). Additionally, groundwater is inextricably linked with other designated critical areas as a source of water to streams and wetlands, serving a critical function for fish and wildlife habitat, and as a key factor in flooding and geologic hazards (Ecology 2005).

Critical aquifer recharge areas are defined as "areas with a critical recharging effect on aquifers used for potable water, including areas where an aquifer that is a source of drinking water is vulnerable to contamination that would affect the potability of the water, or is susceptible to reduced recharge" (Washington Administrative Code 365-190-030(3)). The functions and values of critical aquifer recharge areas are to provide the public with clean, safe, and available drinking water and to maintain sufficient groundwater to support instream flows, especially in streams used by anadromous fish.

The City's recently adopted Comprehensive Plan specifically addresses the importance of groundwater resources by adopting the following Guiding Principal (Guiding Principal #2):

> Manage the water resources of the Island to protect, restore and maintain their ecological and hydrological functions and to ensure clean and sufficient groundwater for future generations.

The Water Resources Element of the Comprehensive Plan includes goals and several policy directives aimed at instituting an added level of development and redevelopment permit review to prevent or mitigate potential pollutant-generating activities or activities that could affect stormwater runoff and aquifer recharge associated with a proposed land use (COBI 2017).

The City's Comprehensive Plan also acknowledges the finite nature of the Island's natural resources and the unpredictable cumulative impacts of climate change in our region by including integration of the precautionary principle and mitigation sequencing to protect and preserve natural resources as a high priority implementing action. WAC 365-195-920 supports the use of the precautionary principal:

> Where there is an absence of valid scientific information or incomplete scientific information relating to a county's or city's critical areas, leading to uncertainty about which development and land uses could lead to harm of critical areas or uncertainty about the risk to critical area function of permitting development, counties and cities should use the following approach:

> (1) A "precautionary or a no risk approach," in which development and land use activities are strictly limited until the uncertainty is sufficiently resolved; …

<u>Designation of critical aquifer recharge areas</u>

Growth Management Act (chapter 36.70A RCW)

The Growth Management Act (GMA) requires local jurisdictions to designate critical areas (RCW 36.70A.170(1)(d)). The GMA also requires cities to adopt development regulations to protect designated critical areas. The goal of designating critical aquifer recharge areas is to protect the functions and values of a community's drinking water by preventing pollution and maintaining supply (CTED 2007). The GMA allows for differences in regional or local conditions and does not require a "one size fits all approach."

The state produced a handbook, *Critical Areas Assistance Handbook: Protecting Critical Areas Within the Framework of the Washington Growth Management Act (*CTED 2007*),* to help local jurisdictions design locally appropriate programs for designating and protecting critical areas. While every local jurisdiction is required by the GMA to designate and protect critical areas, the Handbook provides the following broad direction:

> Each critical area performs different functions and each community assesses the values of the critical areas in their environment differently. Therefore, the purpose of protecting critical areas is unique for each community.

and

> Each city or county must decide which approaches to critical areas protection are appropriate to apply locally, consistent with the requirements of the GMA and the community's future vision.

Washington Administrative Code (WAC)

WAC 365-190-100(2) states that the "quality and quantity of groundwater in an aquifer is inextricably linked to its recharge area." The WAC provides definitions and classification criteria for critical areas, including aquifer recharge areas. Several substantive amendments to the WAC applicable to critical aquifer recharge areas were made in 2010. These amendments (shown in <u>underline text</u>, below) focus largely on classification requirements and strategies and are relevant to classification of critical aquifer recharge areas on Bainbridge Island. As stated in WAC 365-190-100:

> (3) Counties and cities must classify recharge areas for aquifers according to the aquifer vulnerability. Vulnerability is the combined effect of hydrogeological susceptibility to contamination and the contamination loading potential. High vulnerability is indicated by land uses that contribute directly or indirectly to contamination that may degrade ground water, and hydrogeologic conditions that facilitate degradation. Low vulnerability is indicated by land uses that do not contribute contaminants that will degrade ground water, and by hydrogeologic conditions that do not facilitate degradation. <u>Hydrological conditions may include those induced by limited recharge of</u>

an aquifer. Reduced aquifer recharge from effective impervious surfaces may result in higher concentrations of contaminants than would otherwise occur.

… (b) The following may be considered to evaluate vulnerability based on the contaminant loading potential:
(i) General land use;
(ii) Waste disposal sites;
(iii) Agriculture activities;
(iv) Well logs and water quality test results;
(v) Proximity to marine shorelines; and
(vi) Other information about the potential for contamination.

(4) A classification strategy for aquifer recharge areas should be to maintain the quality, and if needed, the quantity of the ground water, with particular attention to recharge areas of high susceptibility.

(a) In recharge areas that are highly vulnerable, studies should be initiated to determine if ground water contamination has occurred. Classification of these areas should include consideration of the degree to which the aquifer is used as a potable water source, feasibility of protective measures to preclude further degradation, availability of treatment measures to maintain potability, and availability of alternative potable water sources.

(b) Examples of areas with a critical recharging effect on aquifers used for potable water may include:
(i) Recharge areas for sole source aquifers designated pursuant to the Federal Safe Drinking Water Act;
(ii) Areas established for special protection pursuant to a ground water management program, chapters 90.44, 90.48, and 90.54 RCW, and chapters 173-100 and 173-200 WAC;
(iii) Areas designated for wellhead protection pursuant to the Federal Safe Drinking Water Act;
(iv) Areas near marine waters where aquifers may be subject to saltwater intrusion; and
(v) Other areas meeting the definition of "areas with a critical recharging effect on aquifers used for potable water" in these guidelines.

(c) Some aquifers may also have critical recharging effects on streams, lakes, and wetlands that provide critical fish and wildlife habitat. Protecting adequate recharge of these aquifers may provide additional benefits in maintaining fish and wildlife habitat conservation areas.

The WAC provisions above direct the City to classify aquifer recharge areas according to vulnerability to contamination; proximity to marine shorelines; and related to hydrogeologic conditions that facilitate degradation, including reduced aquifer recharge from effective impervious surface, in order to maintain the quality, and, if needed, the quantity of groundwater. Examples of areas with a critical recharging effect on aquifers used for potable water relevant to Bainbridge Island include: recharge areas for sole source aquifers, areas near marine waters, and aquifers with the potential to maintain instream flows for streams and wetlands that provide critical fish and wildlife habitat.

Critical Aquifer Recharge Area Guidance Document

The Washington State Department of Ecology's *Critical Aquifer Recharge Areas Guidance Document* is considered current best available science for designating critical aquifer recharge areas and recommends strategies for their protection. This guidance document helps local jurisdictions and the public understand what is required for the protection of local groundwater resources under the GMA. It includes guidance for planning, ordinances, and for including BAS as it relates to critical aquifer recharge areas.

The 2005 guidance document recommends eight steps to characterize where groundwater resources are important to the community (Steps 1-5) and how to protect them (Steps 6-8):

- Step One: Identify where groundwater resources are located.
- Step Two: Analyze the susceptibility of the natural setting where groundwater occurs.
- Step Three: Inventory existing potential sources of groundwater contamination.
- Step Four: Classify the relative vulnerability of groundwater to contamination events.
- Step Five: Designate areas that are most at risk to contamination events.
- Step Six: Protect by minimizing activities and conditions that pose contamination risks.
- Step Seven: Ensure that contamination prevention plans and best management practices are followed.
- Step Eight: Manage groundwater withdrawals and recharge.

Each of these steps was used to identify where "areas with critical recharging effect on potable aquifers" are located, analyze their physical characteristics, and to assess the risk for contamination using the following BAS documents (Apfelbeck 2017, Attachment A):

- Conceptual Model and Numerical Simulation of the Groundwater-Flow System of Bainbridge Island, Washington
- Hydrogeological Assessment of Groundwater Quantity, Quality, and Production
- Bainbridge Island Groundwater Model: Review Findings and Recommendations and Critical Aquifer Recharge Area Assessment
- Well Information Database (Kitsap Public Utility District)
- Washington's Source Water Protection Program (SWAP)
- Hydrogeologic Framework, Groundwater Movement, and Water Budget of the Kitsap Peninsula, West-Central Washington
- Department of Ecology Toxics Cleanup Program's List of Confirmed and Suspected Contaminated Sites (website-based data)
- Critical Aquifer Recharge Areas Guidance Document – Appendix A: U.S. EPA Potential Sources of Drinking Water Contamination Index
- Ground Water Numerical Model Initial Scenario Selection Report
- Support Document for Sole Source Aquifer Designation of the Bainbridge Island Aquifer System

- Bainbridge Island Groundwater Model: Aquifer System Carrying Capacity Assessment

The *Bainbridge Island Groundwater Model: Review Findings and Recommendations and Critical Aquifer Recharge Area Assessment* document noted above specifically concludes that "areas across much of the Bainbridge Island area may have a critical recharging effect on aquifers that are sources of drinking water" (Aspect 2015a). Other specific criteria to consider when designating critical aquifer recharge areas include the public water supply system wellhead protections areas, Environmental Protection Agency sole source aquifer designation, and Island-wide extent of water table aquifer (perched or semi-perched aquifer) without an overlying protective, impermeable layer resulting in a high susceptibility rating according to the Washington Department of Health.

The 2005 guidance document notes that BAS can be used upfront, during the planning process (e.g., adopting development standards) or at the time of application (e.g., during permit review through a hydrogeologic report).

Regional groundwater and aquifer recharge

The hydrologic system of our region evolved from, and is dependent on, the characteristics of undisturbed Pacific Northwest watersheds – including mature forest canopy and uncompacted soils – that intercept, store, and slowly release and infiltrate precipitation through complex pathways (PSP and WSU, 2005 and 2012). Recharge is water that is added to groundwater through one or more phases of the hydrologic cycle. In a natural, undeveloped setting, deep percolation of precipitation is the major source of recharge to the region's aquifers. Annual precipitation percolates vertically through the ground beneath the root zones of plants and recharges the groundwater system at the water table. The amount of recharge varies as a function of precipitation rate, vegetation type, land use, land slope, soil type, and near-surface geology (Bidlake and Payne 2001, Frans, et al. 2011 and Welch, et al. 2014). Groundwater levels fluctuate over time, both seasonally and over longer time periods, due to changing rates of groundwater recharge and discharge (e.g., well withdrawals, stream flows).

The processes of groundwater movement are influenced by the hydrogeologic characteristics of the aquifer system in which they occur and other factors, such as the spatial distribution of precipitation and land cover (Frans et al. 2011). The controls on recharge include physical characteristics (topography, soil characteristics, land use and cover, surficial geology) and water budget components at or near the land surface (actual evapotranspiration (AET), surface and subsurface runoff, and precipitation) (Vaccaro, et al. 1998). Factors such as the permeability of surficial soils, the hydrogeologic units they formed on, and the hydrogeologic units and landcover characteristics affect recharge. Therefore, the relation between precipitation and recharge depends on soils and landcover characteristics (Welch et al. 2014, Bidlake and Payne 2001).

Deep percolation and recharge are difficult, if not impossible, to measure directly, resulting in an accepted degree of uncertainty in any recharge estimate (Frans, et al. 2011). That said, regional recharge rates and water budgets have been modeled and described over the last two decades, as summarized below, and used as the basis for these same efforts completed for the Island.

Vaccaro et al. (1998) estimated average annual recharge for the entire Puget Sound Lowland. Their approach involved summarizing several previous recharge investigations. They developed separate equations to predict recharge rates for natural conditions for areas underlain by glacial till or fine-grained sediments and for areas underlain by coarse-grained alluvial deposits. To account for land use and landcover, recharge for urban-type areas (more than 90 percent of the surface covered by impermeable materials) were set to zero, recharge for built-up areas (about 95 percent of area covered) was reduced by 75 percent, and recharge for residential areas with large population densities (about 50 percent of area covered) was reduced by 50 percent (Vaccaro et al. 1998).

Bidlake and Payne (2001) developed a technique for estimating recharge to groundwater from precipitation in Kitsap County. The recharge estimates were used to develop predictive equations for annual recharge based on annual precipitation for five groups of soil and landcover types: (1) nonforest vegetation on soils formed in glacial outwash and other alluvium, (2) forest vegetation on soils formed in glacial outwash and other alluvium, (3) forest and nonforest vegetation on soils formed on glacial till or fine-grained sediments, (4) developed or urban lands, and (5) water and wetlands. Group (1) was found to have the highest recharge rate, with Group (5) estimated at zero. An important component of this investigation was a study of interception loss from an approximately 80-year-old stand of Douglas fir to develop a better understanding of evaporative losses from conifer foliage. The investigation revealed that interception losses from the stand accounted for approximately 20 percent of the precipitation that was measured near the stand. However, the study also includes a critical review of sources of uncertainties in the recharge estimates, including a lack of published information with which to verify that evapotranspiration estimates were accurate, and uncertainties caused by lumping many soil and land-cover types into five groups. The findings of this study are relevant to Bainbridge Island because the recharge estimates are used in future predictive modeling studies for Bainbridge Island and Kitsap County (Frans, et al. 2011 and Welch, et al. 2014).

<u>Local groundwater and aquifer recharge</u>

Groundwater is the sole source of drinking water on Bainbridge Island. In 2013, the Bainbridge Island Aquifer System was designated as a sole source aquifer (SSA) by the EPA. EPA defines a SSA as an aquifer or aquifer system which supplies at least 50 percent of the drinking water consumed in the area overlying the aquifer, and for which there is no reasonably economical or feasible alternative source. Primary groundwater-related concerns for the Island are pumping rates above the aquifer system’s safe yield (amount of water that can be removed from the aquifer without causing adverse effects) and the risk of seawater intrusion (migration of saltwater into the freshwater drinking supply) (COBI 2017a). Outside of the City’s drinking water utility, the City’s control over water use is quite limited since the right to use water and permitting and certifying wells are the purvey of other agencies (Washington State Department of Ecology and Kitsap Public Health District).

The quality and quantity of the Island’s groundwater and aquifer system is rooted in the hydrologic cycle typical of the Puget Sound lowland forests described above. Our understanding of the Island’s groundwater and aquifer recharge system is informed through historical studies (Kato and Warren, Inc., and Robinson and Noble, Inc. 2000; Vaccaro et al. 1998), United States Geological Society (USGS) modeling efforts (Bidlake and Payne 2001, Frans, et al. 2011 and Welch, et al. 2014), local modeling efforts and assessments (Aspect, 2015, 2015a and 2016), the Environmental Protection Agency (EPA) sole source aquifer support document (EPA 2013), and monitoring and assessments completed over the last decade by the City’s Groundwater Management Program. This work includes the development, calibration and utilization of groundwater models, the development of a well monitoring network and the implementation of long-term monitoring.

Precipitation is the primary source of almost all groundwater on the Island. Secondary recharge also occurs from septic-system returns (approximately 3 inches per year or less), and lateral inflow to the Island from the Kitsap Peninsula in the deep Fletcher Bay Aquifer contributes about another 5% (Frans, et.al. 2011).). Approximately 34-38 inches of rain falls annually, with the majority occurring in the winter months (EPA 2013).

Groundwater quantity

Given that the Island's population depends solely on groundwater for drinking water, as the population grows, the demand for groundwater increases. The quantity of usable groundwater is limited, largely because the Island is bounded by seawater and the potential for the water level declining and seawater intrusion increases as groundwater usage increases (Frans, et al. 2011).

The Island's groundwater levels, recharge rates, and carrying capacity have been modeled through a variety of efforts. These include United States Geological Survey reports for Bainbridge Island (Frans et al. 2011) and Kitsap County (Welch et al. 2014) and City-commissioned work completed by Aspect Consulting, LLC (Aspect 2015, 2015a and 2016). These documents describe the hydrogeology of the Bainbridge Island aquifer system, recharge rates, groundwater elevation, water budget and groundwater flow direction, and provide predictive models to estimate projected aquifer system responses to potential growth and land use modifications. In general, the model results show water level decreases across most of the aquifer system. While not necessarily indicative of aquifer-wide trends, the results warrant consideration of approaches to maintain the overall sustainability of the system given the uncertainties inherent in modeling, future consumption, and/or conservation and climate change impacts.

In addition to these modeling projects, the City monitors public and domestic wells in all six aquifers and assesses water level data against an early warning level, or EWL, for safe yield. Over the last 10 years, most water level trends were relatively steady or increasing. However, one well in the deep Fletcher Bay Aquifer appeared to exceed the safe yield EWL. This well was identified in previous assessments (Aspect, 2009 and 2015). KPUD, the current well owner, increased monitoring in this well and is in the process of building water level and production data sets to better discern local cause and effect and to design appropriate actions. Though no other wells exceeded the EWL, some individual wells showed slight to moderate water level declines over the last ten years. To determine if these are representative of a developing problem rather than natural variations in water levels over time, the City will conduct continued monitoring and assessment (COBI, 2017a).

Water quality

The Island's groundwater is vulnerable to contamination from a variety of sources, including seawater intrusion, hazardous wastes, and failing septic systems. The City's Groundwater Monitoring Program monitors chloride concentrations in aquifers and wells vulnerable to seawater intrusion. These data are assessed for exceedance of an EWL (either exceeds 100 mg/L or exhibits an increasing trend). Over the last ten-year assessment period, chloride concentrations in all wells were very low (usually less than 21 mg/L). One well in the Semi-Perched Aquifer demonstrated an increasing trend that exceeded the EWL, but the chloride concentrations were extremely low (<7 mg/L). Further, the trend was only observed in the wet season, so it is likely that onsite processes such as septic system influence, or runoff from materials stockpiles (such as de-icing salt) may be responsible rather than seawater intrusion. The City is conducting further investigation into this well and onsite processes.

In 2006, elevated chloride concentrations in exceedance of the EWL were measured in a small public supply well in the Sea Level Aquifer. A localized, focused study in this aquifer is currently underway to determine if there is a regional issue developing.

Though not in exceedance of the EWL, chloride concentration increases above background levels were reported for three Fletcher Bay Aquifer wells in 2013 and 2014 (Aspect, 2015). However, as part of data validation for the 2016 assessment, the City determined that these samples were erroneously collected after chlorine treatment, and the chlorine generators increased the chloride concentrations. This was confirmed by 2015 and 2016 sampling results which show chloride concentrations within historic, background levels for all three wells (COBI, 2017a).

The City's groundwater model (Frans et al. 2011 and Aspect 2016) was also run to examine the potential for seawater intrusion under different production scenarios and the results indicated no seawater intrusion. In general, groundwater quality on the Island is very good (EPA 2013, Aspect 2015).

<u>Impacts of land use development on critical aquifer recharge areas</u>

Before development, most of the Puget Sound lowland was covered by forests with highly permeable soils and a well-developed forest litter with a large water-retention capacity. The hydrologic system of our region evolved from, and is dependent on, the characteristics of undisturbed Pacific Northwest watersheds – including mature forest canopy and uncompacted soils -- and cannot be expected to have the same hydrologic regime when significant portions of a site are disturbed (PSP and WSU, 2002 and 2012).

Development has a profound effect on the hydrology of an area. People can cause the water table to lower both by removing groundwater from wells and by reducing the quantity of recharge, as happens where there is too much paved or impervious surface and groundwater cannot infiltrate where it formerly did (CTED 2007). Drainage patterns are irrevocably altered by land use development that result in changes in the natural hydrology, including:

- Increased volumetric flow rates of runoff;
- Increased volume of runoff;
- Decreased time for runoff to reach a natural receiving water;
- Reduced groundwater recharge;
- Increased frequency and duration of high stream flows and wetlands inundation during and after wet weather;
- Reduced stream flows and wetlands water levels during the dry season;
- Greater stream velocities (Ecology 2014).

In 2015, the City contracted with King County to conduct a stream flow and benthic macroinvertebrate (stream bug) health evaluation of several island streams (King County, 2015). Flow data analysis showed that these stream flows increase more quickly following rain events and generally have higher peaks than would be expected under forested conditions. Further, stream bug populations showed diminished diversity normally associated with increased flow “flashiness” and higher peaks, and organic pollution and fine sediment. These results were generally consistent with increasing levels of development upstream of each gauge and consistent with data collected in other Puget Sound watersheds.

The altered hydrologic regimes in urbanizing watersheds result in changes in the structure and function of watershed ecosystems. The transition from a native landscape to a built environment increases impervious surface area, with correspondent and significant effects on the hydrologic cycle by disrupting or eliminating native vegetation, upper soil layers, shallow depressions, and native drainage patterns (WSU and PSP, 2005 and 2012, Bonneau, et al. 2017, Booth, D.B., 1991, Booth, et al., 2002, Brabec, 2009, Stone, 2004, Matteo, 2006 Berland, 2017). In residential areas, groundwater recharge may be altered by grading and subsequent importing of fine grained soil. A part of the permeable soils is removed, the remaining soils are graded and compacted, reducing the effective infiltration rate, and fine-grained top soil is applied. Together, these act to limit the potential recharge rates (Vaccaro 1998).

Impervious surfaces convert precipitation to stormwater runoff, which causes water quality and quantity problems. Urban impacts to water quality and quantity have been a major focus of resource and ecosystem protection efforts for several decades, with research focusing on the impact of impervious surface thresholds (Brabec, 2002, May, et al., 1997, Booth and Reinelt, 1993, Booth and Jackson, 1997, Booth, et al., 2002). In the Pacific Northwest, “the fundamental hydrologic effect of urban development is the loss of water storage in the soil column. This may occur because the soil is compacted or stripped during the course of development, or because impervious surfaces convert what was once subsurface runoff to surface flow” (Booth et al., 2002). The displacement of forested areas by the impervious surfaces of land use development greatly intensifies stormwater runoff, with accompanying nonpoint source pollution, and diminishes groundwater recharge and summer baseflows in streams (PSP and WSU 2005 and 2012, Ecology, 2014, Stone, 2004, Matteo, 2006, Booth et al., 2002).

The Washington State Department of Ecology’s 2012 Stormwater Management Manual for Western Washington, as amended in 2014 (2014 stormwater manual), is intended to provide guidance for design of stormwater systems that reduce the impacts of development to water quality and hydrology. However, the manual itself explicitly states that its recommended approach is insufficient:

> The engineered stormwater conveyance, treatment, and detention systems advocated by this and other stormwater manuals can reduce the impacts of development to water quality and hydrology. But they cannot replicate the natural hydrologic functions of the natural watershed that existed before development, nor can they remove sufficient pollutants to replicate the water quality of pre-development conditions. Ecology understands that despite the application of appropriate practices and technologies identified in this manual, some degradation of urban and suburban receiving waters will continue, and some beneficial uses will continue to be impaired or lost due to new development. This is because land development, as practiced today, is incompatible with the achievement of sustainable ecosystems. Unless development methods are

adopted that cause significantly less disruption of the hydrologic cycle, the cycle of new development followed by beneficial use impairments will continue.

Approaches to mitigate impacts of land use development on critical aquifer recharge areas

Low impact development stormwater management

In 2015, the City adopted by reference (see BIMC 15.20.050.A & C) the 2014 stormwater manual and the 2012 Low Impact Development (LID) Technical Guidance Manual for Puget Sound (LID manual). Most site development is required to meet the City's stormwater regulations, which require the use of LID.

The primary purpose of on-site LID stormwater management techniques and practices is to reduce the disruption of the natural site hydrology. The LID manual states that a minimum 65 percent on-site native vegetation retention is the best means to maintain or more closely mimic the natural hydrologic function of the site and watershed. The 65 percent number is based on a series of studies done throughout the late 1990s to mid-2000s coupling empirical data with hydrological monitoring aimed at determining thresholds of impervious surface area (as a proxy for urban development) for maintaining watershed and stream health. Most of these studies were completed in the Puget Sound area, and this work became the foundation of both the 2002 and 2012 LID manuals. Subsequent research has shown this figure to be a "defensible target" to retain sufficient hydrologic conditions to prevent stream channel degradation, maintain base flows, and contribute to achieving properly functioning conditions for salmonids, as well as, reduce water quality problems of sediment, temperature, toxicants, and bacteria.

The highest priority LID practice is "BMP T5.30 – Full Dispersion." This BMP allows for "fully dispersing" runoff from impervious surfaces and cleared areas of development sites that protect at least 65 percent of the site in a forest or native condition. However, the BMP has a number of design criteria that are challenging to meet on many of the Island's developing parcels,and, regardless of site conditions, the City's stormwater regulations allow for use of an "LID performance standard" that can result in a structural, engineered stormwater design and little or no native vegetation and soil preservation.

There is little dispute that limited development and preservation of natural vegetation and soil maintains the natural hydrologic cycle better than development with LID practices. As such, little research has been devoted to assessing the difference. While LID practices are an improvement over past conventional tools to manage stormwater, they are still mitigation-based and flood-control focused. Questions remain as to how effective they are in maintaining or mimicking pre-development hydrology. Limited field studies have been completed to monitor the effectiveness of LID practices.

During the early 1990s in King County, Washington, empirical studies found that low-density residential development (e.g., one dwelling unit per five acres), while not creating much impervious surface area, resulted in forest clearing up to 60 percent of the landscape, with significant effects on watershed flow regime (Booth, et al., 2002). The analysis found that in rural areas, forest clearing and conversion to suburban vegetation (mainly lawns) was far more significant in determining peak discharge increases than the small increases in impervious area typical of low-density development. As a result, forest retention was adopted at the time as an alternative to structural stormwater detention.

Similar research from the late 1990s (May et al., 1997) found that typical suburban development is estimated to have 90 percent less stormwater storage than the native forested condition, with an LID approach estimated to recover only 25 percent of that storage. Monitoring in the Puget Sound region suggests that LID strategies can be effective for maintaining pre-development hydrologic conditions for light to moderate storm events typical of a maritime climate (Horner, Lim and Burgess, 2002). Effectiveness in mimicking pre-development hydrology for large storms and during extended wet periods is not well documented, although initial monitoring of projects on soils with low permeability suggests that pre-development hydrology can be approximated (Hinman, 2009).

In general, the practice of LID is still a work in progress and little is known about changes to groundwater resulting from urbanization due to a lack of data from field-based studies. Recent findings reported by Ecology in their informal draft framework for new Phase I and Phase II municipal stormwater permits suggest that LID is not adequately achieving intended outcomes of reducing impacts of development to water quality and hydrology:

> While stormwater management has made great strides since the first permits were issued in 1995, the science is clear that a site and subdivision approach to controlling stormwater runoff from developed and developing areas still falls short of protecting receiving water quality conditions. Early studies indicate that natural land cover and soils need to be preserved in a watershed to prevent channel degradation, and to maintain base flows and functional habitat conditions for salmonids … all of our conventional flow control, runoff treatment, and low impact development best management practices will not be enough to fully attain standards protective of designated beneficial uses or to counteract the challenges posed by urbanization.

More specifically, it is largely unknown how infiltrated water from LID practices travels along the subsurface pathways within a built environment (Bonneau et al., 2017). The most recent and relevant research related to the impact of LID practices on groundwater has largely occurred outside the United States (Bonneau et al., 2017, Locatelli, et al., 2016, Han, et al., 2017) with limited research on the implications of LID practices, specifically infiltration, in the United States (Endreny and Collins, 2009, Berland et al., 2017, Booth, et al. 2002, PSP 2005 and 2012). These studies provide a review of several shortcomings and uncertainties of LID related to groundwater and aquifer recharge:

- Land use development and its associated surface and subsurface infrastructure results in complex water balance changes that redistribute groundwater recharge locations, modify recharge mechanisms, and impact recharge rates (e.g., net decrease, increase or minimal changes) and quality.
- LID practices are largely focused on infiltration (e.g., rain gardens, bioswales, and permeable pavements). Infiltrated water can raise water tables and cause groundwater mounding, which may subsequently cause flooding, sewer backups, and unwanted return flow into collection systems.
- The focus on infiltration alone overlooks other pathways for stormwater in the hydrologic cycle that native vegetation provides.
- LID practices do not necessarily mimic like-for-like hydrologic processes (e.g., shallow infiltration vs. deep infiltration, interflow vs. infiltration).

- LID practices may not adequately mimic predevelopment hydrology for large storms and during extended wet periods.
- No analysis is currently available on the larger hydrologic impacts of converting spatially distributed subsurface flows to more limited or point discharges and few analytic tools to assess those consequences have been developed.
- LID techniques do not compensate for the cumulative and adverse impacts from road networks and off-site development.
- LID requirements based on new and redevelopment have little impact on runoff from existing development.
- Any analysis of flow durations will not address changes to groundwater recharge or discharge, because no constructed detention ponds, even the largest, can delay wintertime rainfall sufficiently for it to become summertime runoff; however, this level of delay does occur under predevelopment conditions since far more of the precipitation is stored as groundwater.

Further study is needed to understand the flowpath of infiltrated water to ensure LID practices deliver optimum outcomes. Additionally, there are large areas with near-surface glacial till deposits across the island where infiltration is infeasible or less than optimal. These identified shortcomings and uncertainties of LID related to groundwater and aquifer recharge warrant consideration.

Native vegetation and soil protection

Retaining mature native vegetation and soil protection areas is a primary objective of site planning to maintain the natural hydrological function of the site and watershed and is the most efficient and cost-effective tool for managing stormwater quantity and quality (PSP and WSU, 2002 and 2012). The LID guidebook for local governments prepared for the Puget Sound Partnership for integrating LID into local codes recommends local jurisdictions add a native vegetation retention section of code that allows for the setting aside of an undeveloped portion of the site and set native vegetation retention standards for sites based on land use and density (PSP, 2012).

Since relying on use of LID BMPs in accordance with the 2014 stormwater manual may be insufficient to preserve the natural hydrologic cycle, it is reasonable to look toward an alternative. While the relationship between land use development and aquifer recharge is complex, with many ecosystem- and development-related variables, we know that alternative land use patterns generate differential ecological effects (Alberti et al. 2007). A higher proportion of built components in a watershed has a significant effect on hydrologic and ecosystem functions (Matteo, 2006, Alberti et al., 2007, Brabec, 2002 and 2009). A higher percentage of native vegetation and soil cover can mitigate nonpoint source pollution and peak flowimpacts to groundwater recharge and stream base flow (PSP, 2012, PSP and WSU 2002 and 2012). Decentralized “green infrastructure” leverages the capabilities of soil and vegetation to infiltrate, redistribute, and otherwise store stormwater volume, with the potential to realize synergistic ecological benefits (Berland et al., 2017) such as wildlife habitat, open space, recreation, and wetland and stream function.

The principal of site planning to maintain the natural hydrologic function of a site through retaining natural contours and vegetation to the maximum extent possible is not new (Arnold and Gibbons 1996, Booth and Jackson 1992, Booth et al. 2002, CWP 1998). Recent research has shown that trees and soils can be extremely effective means to maintain or mimic natural hydrology (Berland et al. 2017, Cappiella et al. 2016, CWP 2016, Herrera, 2008, Arbor Day Foundation, 2010). Through combined processes of tree leaves and roots, trees contribute to stormwater control and recharge of groundwater. While canopy interception loss and transpiration may be the primary means by which trees provide direct stormwater control, trees may improve infiltration by modulating the soil ecosystem via root growth and senescence, higher organic matter inputs, higher microbial activity, and stabilization or formation of soil structure. Tree roots, combined with organic material that typically builds on the soil at the base of trees, promote the infiltration of runoff through shallow subsurface zones, helping to reduce both the rate and volume of stormwater runoff (Herrera, 2008). Living and decaying roots create channels in the soil through which groundwater can flow, and the expansion of roots is especially important for generating channels in the soil to facilitate infiltration.

More specifically, Herrera Environmental Consultants (2008) reviewed a series of field studies showing that in natural settings trees can provide increased infiltration capacity in underlying soils. This may not hold true with the removal of leaves and organic buildup that degenerates the organic layer and compacts soils, providing support for maintaining native soils. Herrera's study found that the combined processes of infiltration, transpiration, and interception associated with trees can be expected to significantly reduce annual runoff and concluded that it is reasonable to expect at least a 30 percent reduction in annual runoff due to conifers in the Pacific Northwest. This number was subsequently used as a basis for establishing a maximum net benefit of individual coniferous trees or forested areas (based on canopy cover) to develop "tree credits" for minimizing stormwater flow requirements in Seattle, Washington.

II. Fish and Wildlife Habitat Conservation Areas (FWHCA)

Most documents related to FWHCAs have been prepared by Washington Department of Fish and Wildlife (WDFW). Other sources, largely Bainbridge-based, as well as legislative changes were also reviewed.

WDFW Documents and Programs

Priority Habitats and Species Program (PHS). WDFW updated its PHS list in 2008. The new list should be referenced where appropriate and used to clarify Class I and Class II FWHCA. In addition, designating

biodiversity areas and corridors may be considered. Note: The Bald Eagle was removed from the federal Endangered Species List in 2007; but the species remains classified as a State Sensitive species by WDFW.

Landscape Planning for Washington's Wildlife: Managing for Biodiversity in Developing Areas (Washington Department of Fish and Wildlife, Habitat Program, Olympia, WA, December 2009). This document gives examples of stressors linked to residential land uses that influence wildlife, considerations for developing Habitat Management Plans (HMP) at the site-scale and planning at the watershed-scale. This document may be a required reference for HMPs and/or development standards for PHS biodiversity areas and corridors.

Management Recommendations for Washington's Priority Habitats. This is a series of documents that provides recommendations for protection and management of habitat of priority species. HMPs are currently required to use these management recommendations. Updated management recommendations for the Great Blue Heron were published in 2012.

Fish Passage Program. WDFW maintains a centralized database of fish passage, diversion screening, fish use, and habitat information from inventory efforts conducted throughout Washington State. WDFW's Fish Passage and Diversion Screening Inventory (FPDSI) database is a main data source for planning fish passage projects. The map application shows human-made barriers where a fish passage barrier inventory has been conducted.

Aquatic Habitat Guidelines
Stream Habitat Restoration Guidelines
Water Crossing Design Guidelines

These documents provide support for the existing CAO and could be used to update development standards.

Other Sources and Legislative Changes

Wild Fish Conservancy Water Type Assessment Project Summary – West Sound Watersheds Phase III Report (Wild Fish Conservancy, Duvall, WA, September, 2016). Wild Fish Conservancy (WFC) conducted water type surveys using state-sanctioned protocols to accurately map previously unmapped and incorrectly mapped water courses and generate species-specific distribution data to assist with restoration project identification and prioritization efforts. This stream data was added to the City's GIS for use and support of planning and permitting activities.

State of the Island's Waters (Prepared by Cami Apfelbeck, Department of Public Works, City of Bainbridge Island, July 2012). Describes the surface water resources of Bainbridge Island, summarizes observed pollutants and common sources and reviews general water quality concerns.

Stream Benthos and Hydrologic Data Evaluation for the City of Bainbridge Island (Prepared by Curtis DeGasperi and Chris Gregersen, Water and Land Resources Division, Seattle, WA, 2015). This document is an in-depth assessment of the City's continuous flow and stream benthic macroinvertebrate monitoring data using metrics researched and developed over the last 15 years by King County's Department of Natural Resources and Parks – Water and Land Resources Division.

WAC 365-190-130 was added in 2010 to address and amend prior regulations on fish and wildlife habitat conservation areas. Applicable changes will be included in the CAO update.

III. Frequently Flooded Areas

Local governments must address flood-prone areas under two separate statutes: The GMA and the Floodplain Management Statute. A Floodplain Management ordinance under chapter 86.16 RCW is necessary for a city to qualify for FEMA's National Flood Insurance Program (NFIP). If all of a local government's floodplain management issues are adequately addressed in its floodplain management regulations, then the frequently flooded areas chapter may incorporate the floodplain management regulations by reference. The City's floodplain management regulations are contained in BIMC 16.15, Flood Damage Prevention. The City updated its FEMA floodplain maps and corresponding regulations in January, 2017 (Ordinance 2017-04). This update was reviewed by FEMA and Ecology. Both agencies found the revisions bring the City into compliance with federal and state floodplain regulations.

The CAO update will adopt by reference BIMC 16.15 to meet the requirements regarding designation and mapping as well as standards for habitat protection included in the FEMA Puget Sound Biological Opinion on the NFIP.

IV. Geologically Hazardous Areas

The most noteworthy new science applicable to geologically hazardous areas in the City is the availability of 2015 LiDAR (light detection and ranging) imagery. The City's GIS technician used this imagery to update the GIS data layer for landslide hazard areas.

The United States Geologic Society (USGS) and Washington Department of Natural Resources (DNR) have updated mapping applications and web tools. These are useful resources but do not require revisions to current critical areas regulations.

In general, the City currently regulates geologically hazardous areas consistent with BAS and WAC guidance; however, the City's technical consultant has recommended several changes to landslide hazard regulations to improve clarity and ease of administration. The changes are consistent with the technical consultant's review of BAS and regulations in other Western Washington jurisdictions (see Attachment B). Additionally, WAC guidance provides that critical facilities should be restricted in hazard zones.

V. Wetlands

The most recent documents pertaining to wetlands have been prepared by state and federal agencies describing general guidance for CAO updates, new methodologies for identifying and characterizing wetlands, buffer effectiveness and new approaches to mitigation.

<u>General Guidance Documents</u>

Wetland Guidance for CAO Updates, Western Washington Version (Washington State Department of Ecology Publication #16-06-001, Olympia, WA, June 2016). This document replaces *Wetlands & CAO Updates: Guidance for Small Cities*, originally published in 2010 and revised in 2012. This new Ecology

guidance document will be used to update regulations related to the updated 2014 rating system, updated definitions, buffer tables, small wetlands and agricultural activities.

Wetlands in Washington State, Volume 1: A Synthesis of the Science (Washington State Department of Ecology Publication #05-06-006, Olympia, WA, March 2005). This volume is the result of an extensive search of over 17,000 scientific articles and synthesizes over 1,000 peer-reviewed works relevant to the management of Washington's wetlands. This document was the primary source of best available science used in the 2005 CAO update. Proposed revisions should be consistent with the science in this document unless specifically updated in other, more recent documents.

Wetlands in Washington State, Volume 2: Managing and Protecting Wetlands (Washington State Department of Ecology Publication #05-06-008, Olympia, WA, April 2005). This volume contains guidance on protecting and managing wetlands and their functions based on the synthesis of the science provided in Volume 1, including recommended buffer strategies. Appendix 8-C, providing options for buffer strategies, was revised in October 2014.

<u>Delineation and Categorization</u>

Washington State Wetland Rating System for Western Washington: 2014 Update (Washington State Department of Ecology Publication #14-06-29, Olympia, WA, October 2014). The current CAO uses the 2004 State Rating System, or as amended, to categorize wetlands for the purposes of establishing wetland buffer widths, wetland uses and replacement ratios for wetlands. The City formally adopted the 2014 updated in June 2016. The update of the rating systems incorporates “lessons learned” from using the rating system for 10 years and provides a more accurate rating of the functions and values of a wetland. While Ecology updated the rating system, it is not proposing any changes to recommended buffer widths; however, the City’s CAO will be updated to reflect the changes made to the wetland scoring system.

Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Western Mountains, Valleys, and Coasts (Corps, 2010). The regional supplement updates portions of the 1987 Corps’ Wetland Delineation Manual and provides additional technical guidance and updated procedures for identifying and delineating wetlands. State law requiring the Washington State Wetlands Identification and Delineation Manual (Ecology, 1997) was repealed in 2011. The Regional Supplement is now required by state law (WAC 173-22-035).

<u>Mitigation</u>

Wetland Mitigation in Washington State – Part 1: Agency Policies and Guidance (Version 1) (Washington State Department of Ecology Publication #06-06-011a, Olympia, WA, March 2006). Part 1 provides a brief background on wetlands, an overview of the factors that go into the agencies’ permitting decisions, and detailed guidance on the agencies’ policies of wetland mitigation, particularly compensatory mitigation. It outlines the information the agencies use to determine whether specific mitigation plans are appropriate and adequate.

Wetland Mitigation in Washington State–Part 2: Developing Mitigation Plans (Version 1) (Washington State Department of Ecology Publication #06-06-011b, Olympia, WA, March 2006). Part 2 provides technical information on preparing plans for compensatory mitigation. Some of this information has been superseded by more recent guidance discussed below however, wetland mitigation ratios listed in this document were the basis for the City’s wetland mitigation ratios.

Selecting Wetland Mitigation Sites Using a Watershed Approach (Washington State Department of Ecology Publication #09-06-032, Olympia, WA, December 2009). Provides guidance on selecting off-site mitigation sites.

Interagency Regulatory Guide: Advance Permittee-Responsible Mitigation (Washington State Department of Ecology Publication #12-06-015, Olympia, WA, December 2012). Use of this document can be referenced and encouraged; however, advance mitigation is uncommon within the city.

Calculating Credits and Debits for Compensatory Mitigation in Wetlands of Western Washington (**Washington State Department of Ecology Publication #12-06-015, Olympia, WA, December 2012**). This document describes Ecology's newest methodology for estimating whether a project's compensatory mitigation plan adequately replaces lost wetland functions and values using a functions and values-based approach to score functions lost at the project site (i.e., "debits") compared to functions gained at a mitigation site (i.e., "credits"). Use of the method can be encouraged.

Buffer Effectiveness

Update on Wetland Buffers: The State of the Science (Washington State Department of Ecology Publication #13-06-011, Olympia, WA, October 2013. This document provides new information on

buffers and revisits the conclusions and key points in the 2005 synthesis (see Wetlands in Washington State, Volume 1: A Synthesis of the Science, above).

References – critical aquifer recharge areas

Guidance pertaining to the delineation of critical aquifer recharge areas has been prepared by the state. The most recent scientific studies pertaining to the hydrogeology of the Island's aquifer system to include extents, recharge areas, and system susceptibility have been prepared by licensed consultants and the U.S. Geological Survey.

Other sources of information include the Kitsap Public Health District's Group A & B water system inventories, Ecology's contaminated sites inventories, City of Bainbridge Island land use and zoning maps, and City of Bainbridge Island Groundwater Management Program aquifer system safe yield and seawater intrusion early warning level assessments.

Critical Aquifer Recharge Areas Guidance Document (Washington State Department of Ecology Publication #05-10-028, Olympia, WA, January 2005). This guidance document helps local jurisdictions and the public understand what is required for the protection of local groundwater resources under the Growth Management Act. It includes guidance for planning, ordinances, and for including the Best Available Science as these relate to Critical Aquifer Recharge Areas.

Critical Areas Assistance Handbook – Protecting Critical Areas within the Framework of the Washington Growth Management Act (Washington State Department of Community, Trade and Economic Development, Olympia, WA, January 2007). The purpose of this handbook is to help local jurisdictions design locally appropriate programs for designating and protecting critical areas.

Conceptual Model and Numerical Simulation of the Groundwater-Flow System of Bainbridge Island, Washington (U.S. Geological Survey Science Investigations Report 2011-5021, Reston, VA, 2011) (Frans et al., 2011). This document describes the hydrogeology of the Bainbridge Island aquifer system to include aquifer extents, recharge rates, groundwater elevation, and groundwater flow direction. This document also describes the development and use of the Island's numerical groundwater model and projected aquifer system responses to potential growth and land use modifications.

Hydrogeologic Framework, Groundwater Movement, and Water Budget of the Kitsap Peninsula, West-Central Washington (U.S. Geological Survey Science Investigations Report 2014-5106, Reston, VA, 2011) (Welch et al., 2014). This document presents information used to characterize the groundwater-flow system on the Kitsap Peninsula including Bainbridge Island, and includes descriptions of the geology and hydrogeologic framework, groundwater recharge and discharge, groundwater level and flow directions, seasonal groundwater-level fluctuations, and interaction between aquifer and the surface-water system and a water budget. This study provided updated aquifer recharge rates for Bainbridge Island.

Ground Water Numerical Model Initial Scenario Selection Report (Prepared by City of Bainbridge Island Department of Public Works-Water Resources and Department of Planning & Community Development, Bainbridge Island, WA, September 2009)(City of Bainbridge Island, 2009). Describes themethodology and supporting population and land use data behind the development of the initial scenarios run by the U.S. Geological Survey as part of the development and initial use of Bainbridge Island's numerical groundwater model. Specifically, this report defines land use intensity categorization (by % impervious cover).

Hydrogeological Assessment of Groundwater Quantity, Quality and Production (Task 1) (Aspect Consulting, LLC, Bainbridge Island, WA, December 2015)(Aspect, 2015). This technical memorandum describes the current quality and quantity conditions of Island's groundwater resources

Bainbridge Island Groundwater Model: Review Findings and Recommendations (Task 2) and Critical Aquifer Recharge Area Assessment (Task 3 Scenario) (Aspect Consulting, LLC, Bainbridge Island, WA, December 2015) (Aspect, 2015a). This technical memorandum describes a technical review and recalibration and validation of the Island's numerical groundwater model, provides both implemented and yet-to-be recommendations to update and improve the Island's groundwater model and describes the findings of the critical aquifer recharge area assessment. This study identified both shallow and deep aquifer recharge areas.

Bainbridge Island Groundwater Model: Aquifer System Carrying Capacity Assessment (Task 3 Scenario) (A, LLC, Bainbridge Island, WA, March 2016) (Aspect, 2016). This technical memorandum describes the findings from the aquifer system carrying capacity assessment using the updated Bainbridge Island numerical groundwater model to include projected growth and climate change impacts to recharge, groundwater levels, drainage to surface waters, and seawater intrusion.

Support Document for Sole Source Aquifer Designation of the Bainbridge Island Aquifer System (U.S. EPA - Region 10, Seattle, WA, March 2013) (EPA, 2013). This document summarizes readily available information and describes the technical and legal basis for the Bainbridge Island aquifer system Sole Source Aquifer designation.

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