Kathy M Bell

From: Galie Jean-Louis <galiejeanlouis@gmail.com>
Sent: Sunday, January 11, 2026 12:00 PM
To: Kathy M Bell; Steven C Sundin; Blake G Lyon
Cc: MY - mayorsoffice@cob.org
Subject: Mud Bay Cliffs House Development Stormwater Impact- Public Comment

Kathy Bell, Senior Planner, kbell@cob.org

Steve Sundin, Senior Planner, ssundin@cob.org

Blake Lyon, Planning & Community Development Department Director, bglyon@cob.org

Planning & Community Development Department

210 Lottie Street

Bellingham, WA 98225

Dear Ms. Bell, Mr. Sundin, and Mr. Lyon,

We are concerned about the proposed stormwater management with the new housing development on Mud Bay Cliffs and want the City of Bellingham to conduct more impact studies to drive appropriate mitigation requirements. We are opposed to the development of the proposed project and support the efforts of PMBC. We ask you to become more engaged in this matter as our mayor and represent the citizens of those who first funded your campaign; particularly your stated commitment to Bellingham's environmental concerns and ask that you listen and respond to our safety concerns about this potential development.

We moved to Clarkwood Drive in 2015. After a heavy rainfall, especially in the fall, the street drains would overflow resulting in excess water flowing on the south side of our home. The volume of water was significant enough to push large rocks through a small opening beside our gate onto our lawn. In addition, the excess water would remove the mulch covering around our trees exposing the ground cover cloth.

We thank the City of Bellingham (COB) for updating the street drains and building berms around 2018 which has helped improve the situation, but the drains still get clogged resulting in excessive water flow on our property.

Around 2021, we discovered during winter with the level of ground saturation, that water would accumulate under our vapor barrier in the crawlspace. We had to add another sump pump in order to handle the increased water accumulation.

We added roof gutters to our home in 2018 which connected to the stormwater pipe. At that time the City of Bellingham discovered that there was a large opening in the stormwater pipe on our property. This would explain why that part of our lawn is muddy through most of the year and raised our concern about hillside shifting and damage to landscape, water infrastructure and structures. After numerous requests, COB is reportedly scheduled to repair the defect in the stormwater pipe this year.

In addition, we recently purchased the home "downstream" of our current property on Clarkwood. We attached a photo showing a steady water flow on our driveway from the easement area after it has not been raining for 3 days. We do not know if this flow of water is from the broken stormwater pipe above it or from another source.

Based upon the facts that stormwater street mitigation measures are still not effective to control the flow of water, the need to add a sump pump due to excessive groundwater saturation, the unexplained water flow in the easement area and that it has taken 8 years - yet to schedule a repair of a problem that COB discovered, we are concerned that COB does not have the resources to mitigate any added stormwater from a Mud Bay Cliffs housing development. We request that COB evaluate the impacts of stormwater before the housing project begins. We are concerned about the current and ongoing negligence and safety issues of storm water management in Edgemoor and surrounding Bellingham Bay areas.

Respectfully,

Galie Jean-Louis and Vincent Matteucci

Cc: Mayor Kim Lund

Public Comment

Name

Susan Hutton

Full name or organization

Your name is required for identification as a part of the public record.

Choose Topic

The Woods at Viewcrest

Topics available for online public comment are listed above. If no topics are listed, there may be opportunities for public comment on various topics through email, letters, and public comment periods during meetings.

More information on this topic can be found at https://cob.org/project/the-woods-at-viewcrest

Comment or Testimony

To: Steve Sundin, Senior Planner
Kathy Bell, Senior Planner
Planning and Community Development Dept.
City Hall, 210 Lottie St.
Bellingham, WA 98225
Transmitted Online Via: https://cob.org/gov/public/public-hearing-testimony
January 12, 2026
RE: SEPA MDNS decision for The Woods at Viewcrest Development

Dear Mr. Sundin and Ms. Bell,
Thank you for the opportunity to comment on the proposal to develop the 38 acres on the Mud Bay Cliffs overlooking Chuckanut Bay. I have read the documents related to the SEPA review, and I have concerns about the proposed development.
I am the executive director of Whatcom Million Trees Project, a non-profit organization in Whatcom County whose mission is to plant native tree seedlings and protect mature in urban neighborhoods and key watersheds that will enhance the County's community's health, equity, biodiversity, and resilience. Proposed developments like The Woods at Viewcrest fall within our purview because they threaten to disrupt a mature coastal forest that is considered one of the best in the county and contains stands that haven't been logged for more than 100 years. I am speaking on behalf of our organization.
The proposed development would cause significant harm to the mature coastal forest where it is proposed to take place, and it would fracture the rare, interconnected forest habitats around it. It would likewise compromise the connection between the estuarine wetland ecosystem and that of the upland forest, and it would do so in ways that have been detailed extensively and accurately elsewhere in the comment materials you've already received. On a day when the National Weather Service has issued another flood watch, intentionally damaging a rare and sensitive mature forest that helps to prevent pollutants from reaching the wetlands and mudflats habitats that lie beneath it seems astonishingly short sighted. It would cause a net loss of shoreline ecological function on a watershed scale.
Perhaps this project has managed to check all of the boxes to meet the SEPA definition of "no net loss," but there is no question that the losses it will create will be lasting and damaging. That our laws didn't immediately stop this proposal in such a pristine and sensitive area in its tracks is a failure and something that should shame all of us. We must do better.
Thank you for taking the time to read our letter and for listening to the many community concerns about this planned development project.

Sincerely,

Susan Hutton
Executive Director
Whatcom Million Trees Project

Files
Documents or images related to your comments.

Email

susan@whatcommilliontrees.org

Your email address will only be used to send you a copy of this comment and any official notifications related to this topic.

Date

1/12/2026

Public Comment

Name

Dave Clark

Full name or organization

Your name is required for identification as a part of the public record.

Choose Topic

The Woods at Viewcrest

Topics available for online public comment are listed above. If no topics are listed, there may be opportunities for public comment on various topics through email, letters, and public comment periods during meetings.

More information on this topic can be found at https://cob.org/project/the-woods-at-viewcrest

Comment or Testimony

A SEPA Determination of Non-Significance (DNS) for this project is blatantly inaccurate, and it doesn't take a biology degree to understand why.

Do not approve this development. Preserve the land as it stands today.

Files

Documents or images related to your comments.

Email

deblobly@gmail.com

Your email address will only be used to send you a copy of this comment and any official notifications related to this topic.

Date

1/13/2026

Kathy M Bell

From:	Christopher Grannis <chrgra@ymail.com>
Sent:	Tuesday, January 13, 2026 9:09 AM
To:	G.Proj.Wood at Viewcrest
Subject:	Fw: Comment for HE hearing 1/14/26 Woods at Viewcrest

The Chukanut Creek estuary is not a salt water body as the Planning Department maintains. At low tide pollutants from the proposed "Woods at Viewcrest" development at the north edge of the estuary would flow several hundred feet over the mud flats before it got to the Chuckanut Bay salt water body. If it were a salt water body the pollutants would dissipate quickly and be much less damaging. The City must acknowledge this is an estuary, not a salt water body, and require an Environmental Impact Study to determine how much damage polluted storm water would do.

It is well documented that the Chuckanut Creek estuary, also known as mud bay, is one of the highest functioning estuaries in the US part of the Salish Sea. Today rain is filtered through the mature second growth forest providing clean runoff. We know that development causes pollution in storm water including runoff from blacktop with dangerous petrochemicals brake and tire wear particles from vehicles, pet waste, landscaping fertilizers and herbicides. These pollutants are deadly to the microbiome at the base of the food chain that supports all living things in and on the Salish Sea. Storm water treatment is notoriously unreliable. We need an EIS to tell us how damaging a rain/storm water runoff event from the development would be at low tide when pollutants would flow over hundreds of feet of mud flats and during the incoming tide which would push the pollutants further into the estuary and the adjacent salt water marsh.

Huge boulders litter the shore at the north side of the mud flats. The boulders have fallen from the site of the proposed development and are evidence that the site is geologically unstable. Clearing the trees, vegetation and topsoil then cutting in the necessary roads and utility corridors would further destabilize the site. It would be foolish to build homes without an EIS.

Please require the city to do an Environmental Impact Study before developers are allowed to degrade the estuary and build on unstable ground.


Chucka
Mud Bay

Not a salt water body.

Kathy M Bell

From: Janet Higbee-Robinson <jhhigbeerobinson@gmail.com>
Sent: Tuesday, January 13, 2026 8:11 PM
To: Kathy M Bell
Subject: Mud Bay Cliffs

Hello Ms. Bell,
Thanks for your work on behalf of Bellingham.
Please do all you can to protect Mud Bay Cliff area from further development. At least require a proper EIS for the Woods at Viewcrest. The Sandstone Cliffs are too steep and yielding and will erode; they cannot support another neighborhood above them. The beach here is unique and will be further degraded by more human habitat and activity uphill. Nearby wetlands provide water fowl with a place to fish and mate and must not be further disturbed. For future generations and other species, we need to leave some areas relatively wild, especially beautiful ones that serve as corridors for wildlife.

Have you ever visited Lummi Island South Shore and witnessed the effect of homes built above the steep shore there? Homeowners rmust deal with losing their stairs and access to the beach. Their land is literally being washed away.

Yours,
Janet Higbee-Robinson
2078 Wildflower Way
Puget Neighborhood, Bellingham, 98229

Kathy M Bell

From:	Protect Mud Bay Cliffs (PMBC) <info@mudbaycliffs.org>
Sent:	Wednesday, January 14, 2026 7:16 AM
To:	Kathy M Bell
Cc:	Kristina J Bowker
Subject:	MDNS is Clearly Erroneous
Attachments:	MDNS is Clearly Erroneous 1-14-26.pdf

To: Kathy Bell
Cc: Kristi Bowker
From: Protect Mud Bay Cliffs
Re: PMBC Public Comment for the Woods at Viewcrest Public Hearing
Date: January 14, 2026

Please find attached the above referenced public comment letter for the Woods at Viewcrest public hearing.

Thank you for including this comment in the administrative record and posting on the city's Woods at Viewcrest webpage.

The Woods at Viewcrest
MDNS is Clearly Erroneous

PART I — EXECUTIVE SUMMARY

The City of Bellingham's issuance of a Mitigated Determination of Nonsignificance (MDNS) for the proposed Woods at Viewcrest subdivision under the State Environmental Policy Act (SEPA), chapter 43.21C RCW is clearly erroneous because the record demonstrates both (1) a reasonable likelihood of significant – and ***severe*** – adverse environmental impacts and (2) pervasive deficiencies in the application materials that prevent informed environmental review, in violation of WAC 197-11-080 and related SEPA requirements.

SEPA requires preparation of an Environmental Impact Statement (EIS) whenever a proposal may have significant adverse environmental impacts, or where uncertainty and incomplete information preclude a reasoned threshold determination. An MDNS is appropriate only where the lead agency has taken a "hard look" at the environmental consequences of the proposal and reasonably concluded that impacts are not significant. The city did not meet that standard here.

The Woods at Viewcrest proposal involves intensive residential development on steep, geologically constrained terrain draining directly to Mud Bay — a low-energy pocket estuary characterized by extensive mudflats, estuarine wetlands, and shoreline areas designated as Critical Saltwater Habitat. The receiving environment is inherently sensitive, has limited assimilative capacity, and functions as a long-term sink for sediments and pollutants. These characteristics heighten the environmental significance of stormwater discharges, sediment transport, and pollutant loading associated with the proposal.

The application materials submitted by the applicant are fundamentally flawed. They contain errors, omissions, internal inconsistencies, and unsupported assertions regarding stormwater management, geologic stability, hydrologic conditions, pollutant treatment, and downstream impacts. Critical analyses — including quantitative stormwater modeling, post-development slope stability evaluation, and receiving-water sensitivity analysis — are absent. Where information is missing or unreliable, SEPA does not permit the city to assume compliance or defer analysis to later permitting stages. Uncertainty of this magnitude weighs in favor of a Determination of Significance, not an MDNS.

Notwithstanding these deficiencies, the information that *is* present in the record establishes a reasonable likelihood of significant adverse environmental impacts. Independent expert review and agency guidance demonstrate that the proposal may increase erosion and sediment delivery, alter hydrologic flow regimes, discharge untreated or inadequately treated pollutants to Mud Bay, degrade estuarine and wetland functions, and exacerbate existing public safety risks related to slope instability, traffic, and pedestrian exposure.

The city's MDNS rests on assumptions, categorical framings, and reliance on mitigation measures that have not been shown to be effective in the specific environmental context of this site. SEPA prohibits reliance on mitigation or regulatory compliance alone to avoid preparation of an EIS, particularly where the effectiveness of such measures is uncertain or dependent on future analysis.

For clarity and analytical rigor, this appeal organizes the city's SEPA errors into a series of interrelated but independently sufficient "Pillars," each of which warrants reversal of the MDNS or remand for preparation of an EIS:

1. **Failure to Accurately Characterize Mud Bay as a Highly Sensitive Receiving Environment.**
   The city mis-framed Mud Bay as a generic receiving water rather than a mudflat-dominated estuarine system and wetland complex with critical ecological functions and limited assimilative capacity.
2. **Stormwater Treatment Failures and Toxic Pollutant Discharges.**
   The proposal relies on Modular Wetland System (MWS) devices that do not sufficiently remove many pollutants of concern, including nutrients, metals, hydrocarbons, and 6PPD-quinone, which would be discharged directly to Mud Bay's mudflats and estuarine wetlands, with adverse ecological and human health implications.
3. **Improper Reliance on Flow-Control Exemptions and Non-Compliance with Stormwater Minimum Requirements.**
   The city improperly treated the project as eligible for flow-control exemptions inconsistent with Ecology guidance for estuarine wetlands and failed to ensure compliance with applicable stormwater management minimum requirements.
4. **Geologic and Landslide Hazard Risks.**
   The project site is subject to significant geologic hazards documented in prior investigations, including the 2009 Geologic Feasibility Investigation. The application fails to evaluate post-development slope stability or the interaction between altered hydrology and landslide risk.
5. **Application Deficiencies and False or Unsupported Claims.**
   The applicant failed to provide information reasonably sufficient to identify and evaluate probable environmental impacts, contrary to WAC 197-11-080 (Exh. N).
6. **Traffic, Pedestrian, and Public Safety Impacts.**
   Existing conditions in the Edgemoor area present documented safety risks that would be exacerbated by increased traffic and development intensity, without adequate analysis.

7. **Recreation and Shoreline Use Impacts.**
   Long-term accumulation of pollutants and sediments along the Mud Bay shoreline threatens recreational use and public access, implicating shoreline policy objectives and public trust values.

Each Pillar independently demonstrates that the city's MDNS is clearly erroneous. Considered cumulatively, the record compels preparation of an Environmental Impact Statement to evaluate the proposal's environmental consequences in a comprehensive, integrated manner, as SEPA requires.

PART II — DETAILED NARRATIVE BY PILLAR

PILLAR 1 — FAILURE TO ACCURATELY CHARACTERIZE MUD BAY AS A HIGHLY SENSITIVE RECEIVING ENVIRONMENT

A. Overview

A foundational error in the city's SEPA review is its failure to accurately characterize Mud Bay as a highly sensitive receiving environment. This mischaracterization permeates the MDNS and undercuts the city's conclusions regarding stormwater impacts, pollutant loading, flow control, mitigation effectiveness, and overall environmental significance.

Mud Bay is not a generic shoreline or open-water receiving body. It is a low-energy pocket estuary dominated by extensive mudflats, estuarine wetlands, and shoreline areas designated as Critical Saltwater Habitat. These characteristics impose heightened obligations under SEPA to carefully evaluate how changes in hydrology, sediment delivery, and pollutant loading will affect ecological functions and human use.

Because the city failed to recognize and analyze Mud Bay's actual environmental sensitivity, its threshold determination is clearly erroneous.

B. Mud Bay's Physical and Ecological Characteristics

Mud Bay is a shallow, low-gradient embayment characterized by fine-grained sediments, limited tidal flushing, and extensive intertidal mudflats. These physical conditions cause Mud Bay to function as a **sink** rather than a conduit for sediments and pollutants. Materials delivered to the bay are retained and accumulate over time rather than being rapidly dispersed.

The mudflats and associated estuarine wetlands support a range of ecological functions, including benthic invertebrate production, forage fish habitat, avian foraging areas, nutrient cycling, and transitional habitat between freshwater and marine systems. These functions depend on stable sediment chemistry and hydrology and are particularly vulnerable to incremental changes in pollutant concentrations and sediment composition.

Shoreline areas of Mud Bay are designated as **Critical Saltwater Habitat**, reflecting their ecological importance and sensitivity. Estuarine wetlands within the bay are afforded heightened protection under both shoreline and stormwater regulatory frameworks due to their limited capacity to absorb disturbance without long-term degradation.

C. Limited Assimilative Capacity and Cumulative Vulnerability

A defining characteristic of Mud Bay is its **limited assimilative capacity**. Unlike high-energy marine shorelines or well-flushed water bodies, Mud Bay cannot readily dilute, transport, or break down pollutants delivered through stormwater discharge.

Fine sediments bind contaminants such as metals, hydrocarbons, and organic compounds, leading to accumulation in benthic substrates. Over time, even low-level discharges can result in elevated concentrations that impair benthic organisms, disrupt food webs, and reduce habitat suitability.

SEPA requires that environmental review consider not only the magnitude of individual discharges, but also the **context** of the receiving environment. In the context of Mud Bay, incremental pollutant inputs are environmentally significant precisely because they accumulate and persist.

The city's SEPA review does not meaningfully address this context. Instead, it treats Mud Bay as if it were a generic receiving water capable of assimilating stormwater discharges without adverse effect.

D. Relationship Between Site Hydrology and Mud Bay Impacts

The Woods at Viewcrest project site drains directly toward Mud Bay. Stormwater discharges from steep slopes increase the likelihood of sediment transport, erosion, and pollutant delivery during storm events.

The interaction between altered upland hydrology and a low-energy estuarine receiving environment is critical to understanding environmental impact. Increased runoff volumes, higher peak flows, and concentrated discharge points amplify the delivery of fine sediments and attached pollutants to Mud Bay's mudflats and estuarine wetlands.

The city's MDNS does not evaluate how these upland changes interact with Mud Bay's physical characteristics. Without this analysis, the city could not reasonably conclude that impacts are insignificant.

E. Human Use, Recreation, and Public Trust Considerations

Mud Bay is not only an ecological resource; it is also a site of ongoing human use and recreation. Members of the public access the shoreline for walking, wildlife observation, and informal recreation. Accumulation of pollutants, oily residues, and contaminated sediments along the shoreline degrades these uses and raises concerns regarding long-term human exposure.

SEPA requires consideration of impacts to “the environment,” broadly defined to include human health, safety, and welfare. Repeated exposure to contaminated muds and sediments along the shoreline implicates these concerns, particularly where pollutants persist and concentrate over time.

The city’s SEPA review does not address how long-term pollutant accumulation may affect public use of the Mud Bay shoreline or public trust values associated with shoreline access.

F. SEPA Significance of the city’s Mischaracterization

By failing to accurately characterize Mud Bay as a highly sensitive estuarine and wetland receiving environment, the city understated the environmental significance of stormwater discharges and pollutant loading associated with the project.

This error is not a matter of scientific nuance. It goes to the heart of SEPA’s threshold determination. Where a proposal discharges to a receiving environment with limited assimilative capacity and high ecological sensitivity, uncertainty regarding pollutant fate and ecological response triggers the need for an Environmental Impact Statement.

The city’s reliance on generalized assumptions, categorical descriptions, and future mitigation measures does not satisfy SEPA’s requirement for informed decision-making at the threshold stage.

G. Pillar 1 Conclusion

The record demonstrates that Mud Bay is a highly sensitive receiving environment characterized by mudflats, estuarine wetlands, and critical saltwater habitat with limited assimilative capacity. The city’s failure to accurately characterize and analyze this environment led directly to an underestimation of environmental impacts and an improper issuance of an MDNS.

Because the proposal may result in significant adverse impacts to Mud Bay’s ecological functions, sediment quality, and human use — and because the magnitude of those impacts cannot be evaluated without comprehensive analysis — SEPA requires issuance of a Determination of Significance and preparation of an Environmental Impact Statement.

PILLAR 2 — STORMWATER TREATMENT FAILURES, TOXIC POLLUTANTS, AND 6PPD-QUINONE DISCHARGES TO MUD BAY

A. Overview

A second, independent basis for overturning the MDNS is the city's failure to evaluate whether proposed stormwater treatment will prevent significant adverse impacts from toxic pollutants discharged to Mud Bay. The city accepted, without adequate scrutiny, the applicant's reliance on Modular Wetland System (MWS) devices and "enhanced treatment" classifications, despite substantial evidence that these systems do not remove many pollutants of concern and are ill-suited to a low-energy estuarine receiving environment.

This failure is particularly consequential because the project proposes **direct discharge of treated stormwater to Mud Bay's mudflats, estuarine wetlands, and critical saltwater habitat**. In such an environment, residual pollutants accumulate rather than disperse, magnifying ecological and human health risks.

SEPA requires evaluation of the **effectiveness and limitations of proposed mitigation** in the specific environmental context of the site. That evaluation did not occur here.

B. Nature of Stormwater Pollutants Generated by the Project

Stormwater runoff from residential development contains a complex mixture of pollutants, including but not limited to metals (e.g., copper and zinc), petroleum hydrocarbons, nutrients, pesticides, tire wear particles, microplastics, and chemical transformation products such as 6PPD-quinone.

These pollutants originate from routine sources associated with residential land use and transportation, including vehicles, roofs, pavement, landscaping, and household activities. Many bind readily to fine sediments and organic matter, increasing persistence in estuarine environments.

The application materials and the city's SEPA review do not provide a comprehensive accounting of these pollutant sources or their anticipated loads, nor do they evaluate how pollutant fate differs in a mudflat-dominated estuary compared to a higher-energy receiving water.

C. Limitations of MWS and "Enhanced Treatment"

The applicant proposes to use Modular Wetland System (MWS) devices and relies on their classification as providing "enhanced treatment" under stormwater manuals. However, "enhanced treatment" is a regulatory category, not a guarantee of pollutant removal across all contaminant classes.

MWS devices are designed primarily to remove **particulate-bound pollutants** through sedimentation and filtration. They are not designed to reliably remove many dissolved pollutants, fine colloids, or emerging contaminants such as tire-derived chemicals. Even for particulate pollutants, performance varies based on influent concentrations, hydraulic loading, maintenance, and site-specific conditions.

The city's SEPA review does not evaluate:

- Which pollutants are expected to be removed,
- Which pollutants will pass through untreated,
- How remaining pollutants will behave once discharged to Mud Bay, or
- Whether the level of residual pollution is environmentally significant given the receiving environment.

Reliance on a general treatment classification without site-specific effectiveness analysis does not satisfy SEPA.

D. 6PPD-Quinone and Other Non-Removed Pollutants

6PPD-quinone, a toxic transformation product of a tire anti-degradant, is now well documented as acutely lethal to certain salmonids at extremely low concentrations. Tire wear particles are ubiquitous in roadway runoff and residential stormwater.

There is no evidence in the record that MWS devices remove 6PPD-quinone or prevent its discharge to receiving waters. Nor does the city's SEPA review evaluate the presence, concentration, or fate of this compound or similar emerging contaminants.

Even apart from 6PPD-quinone, numerous pollutants commonly found in stormwater are not effectively removed by wetland-based treatment systems, particularly under variable flow conditions. These pollutants will be discharged directly to Mud Bay's mudflats and estuarine wetlands.

SEPA requires that such risks be disclosed and evaluated where credible evidence indicates potential for significant harm. The city did not do so.

E. Interaction with Mud Bay's Physical Characteristics

As described in Pillar 1, Mud Bay's fine-grained sediments, low energy, and limited flushing cause pollutants to accumulate over time. Residual contaminants discharged through stormwater treatment systems are therefore not transient; they persist in sediments and biota.

Repeated discharges, even at concentrations deemed acceptable for other receiving waters, can result in long-term degradation in a mudflat estuary. This includes bioaccumulation, chronic toxicity, and impairment of benthic organisms that form the base of the estuarine food web.

The city's SEPA review does not evaluate these cumulative and long-term effects, nor does it assess whether "enhanced treatment" is environmentally adequate in this specific context.

F. Human Health, Safety, and Shoreline Use Implications

Mud Bay is used by the public for shoreline access, walking, and wildlife observation. Accumulation of pollutants in sediments and surface muck raises concerns about repeated human contact with contaminated materials, as well as the safe recreational use of the shoreline.

SEPA's definition of "environment" includes human health and safety. Where a proposal may result in long-term accumulation of toxic substances in areas of public access, SEPA requires evaluation of those risks.

The city's MDNS does not address potential human exposure pathways, does not consider cumulative exposure over time, and does not analyze how pollutant accumulation may affect the suitability of Mud Bay for recreational and shoreline use.

G. Improper Reliance on Treatment as a Substitute for Analysis

The city effectively treated the presence of stormwater treatment devices as dispositive, without evaluating whether those devices prevent significant adverse impacts in the context of Mud Bay. SEPA does not allow mitigation measures to substitute for environmental analysis unless their effectiveness is demonstrated and their limitations disclosed.

Here, treatment effectiveness is assumed, not analyzed. Pollutant non-removal is not addressed. Receiving-water sensitivity is not incorporated. This approach fails the "hard look" requirement and renders the MDNS clearly erroneous.

H. Pillar 2 Conclusion

The record demonstrates that the Woods at Viewcrest proposal will discharge stormwater containing pollutants that are not reliably removed by the proposed treatment systems, including 6PPD-quinone and other toxic constituents, directly into Mud Bay's mudflats, estuarine wetlands, and critical saltwater habitat.

Given Mud Bay's limited assimilative capacity, these discharges may result in significant adverse ecological and human health impacts. Because the city failed to evaluate pollutant non-removal, treatment limitations, cumulative accumulation, and exposure pathways, it could not reasonably conclude that impacts are insignificant.

This failure independently requires issuance of a Determination of Significance and preparation of an Environmental Impact Statement.

PILLAR 3 — IMPROPER RELIANCE ON FLOW-CONTROL EXEMPTIONS AND FAILURE TO COMPLY WITH STORMWATER MINIMUM REQUIREMENTS

A. Overview

A third independent basis for overturning the MDNS is the city's improper reliance on stormwater flow-control exemptions and its failure to ensure compliance with applicable stormwater management minimum requirements. The city treated the proposal as exempt from flow-control obligations without conducting the receiving-water analysis required by Ecology guidance and the Stormwater Management Manual for Western Washington (SWMMWW). In doing so, the city understated hydrologic impacts and avoided evaluating changes in flow regime that are environmentally significant in the context of Mud Bay's estuarine wetlands and mudflats.

SEPA requires disclosure and evaluation of how a proposal alters hydrology and flow characteristics, particularly where the receiving environment is highly sensitive. That analysis did not occur here.

B. Ecology Guidance Requires Careful Receiving-Water Analysis

Under Ecology guidance and the SWMMWW, flow-control exemptions are limited and context-specific. They are not categorical carve-outs based solely on proximity to salt water. Where stormwater discharges to **estuarine wetlands, mudflats, or other sensitive shoreline environments**, Ecology guidance emphasizes protection of wetland functions, maintenance of natural hydrology, and avoidance of erosive or disruptive flows.

Mud Bay's mudflats and estuarine wetlands are expressly the type of receiving environments for which **altered flow regimes can cause significant adverse impacts**, including sediment redistribution, erosion of tidal channels, degradation of benthic habitat, and changes to wetland hydroperiods.

The city's SEPA review does not demonstrate that it evaluated whether altered flows from the project would be environmentally benign in this specific context.

C. Mud Bay Does Not Function as an Exempt Receiving Water

The city treated Mud Bay as if it were an open, high-energy saltwater body capable of assimilating increased stormwater flows without adverse effect. As established in Pillar 1, Mud Bay is instead a low-energy pocket estuary with extensive mudflats and estuarine wetlands and limited assimilative capacity.

Flow-control exemptions are premised on the assumption that receiving waters can tolerate increased or altered flows without harm. That assumption does not hold for Mud Bay. Increased runoff volumes, higher peak flows, and altered timing can disrupt sediment deposition patterns, scour fine substrates, and impair wetland functions.

SEPA required the city to evaluate whether the proposal would alter flow regimes in a manner that is environmentally significant for Mud Bay. The city did not do so.

D. Failure to Comply with Stormwater Minimum Requirements

PMBC's April 24, 2024 public comment submittal, included as Exhibit C of PMBC's Notice of Appeal (Appellant Exhibit MB-001, Bates stamp pages MB-00352 through MB-00377) documents multiple failures to comply with applicable stormwater management minimum requirements. These include deficiencies in flow-control analysis, lack of demonstrated compliance with hydrologic performance standards, and reliance on assumptions rather than modeling.

Stormwater minimum requirements exist to protect downstream resources by maintaining pre-development hydrologic conditions to the extent practicable. Where those requirements are not met, increased erosion, sediment transport, and pollutant delivery are foreseeable environmental consequences.

The city's SEPA review does not meaningfully analyze these deficiencies or explain how non-compliance would avoid significant adverse impacts. Instead, it treats compliance as presumed or defers resolution to later permitting stages.

E. Improper Deferral of Hydrologic Analysis

Flow-control determinations depend on quantitative analysis of runoff volumes, peak flows, and durations under pre- and post-development conditions. The application materials lack the modeling necessary to support such determinations.

SEPA does not permit deferral of hydrologic analysis where altered flows may cause environmental harm. Deferral is particularly improper where downstream receiving environments are wetlands or estuarine systems with known sensitivity to hydrologic change.

By accepting incomplete analysis and deferring critical evaluation, the city failed to take the "hard look" required at the threshold stage.

F. Cumulative and Contextual Effects

Even modest changes in flow regime can be environmentally significant when repeated over time and combined with other stressors, including pollutant loading and sediment delivery.

Flow-control exemptions that might be acceptable for robust receiving waters can be harmful when applied to fragile estuarine wetlands.

The city's SEPA review does not evaluate these cumulative effects or explain why altered flows would not exacerbate the impacts described in Pillars 1 and 2.

G. Pillar 3 Conclusion

The record demonstrates that the city improperly relied on flow-control exemptions and failed to ensure compliance with applicable stormwater minimum requirements. In doing so, it avoided evaluating hydrologic changes that are environmentally significant in the context of Mud Bay's mudflats and estuarine wetlands.

Because altered stormwater flows may result in erosion, sediment redistribution, wetland degradation, and cumulative ecological impacts — and because these effects were not adequately analyzed — SEPA requires issuance of a Determination of Significance and preparation of an Environmental Impact Statement.

PILLAR 4 — GEOLOGIC AND LANDSLIDE HAZARD RISKS AND IMPROPER DEFERRAL OF GEOTECHNICAL ANALYSIS

A. Overview

A fourth independent basis for overturning the MDNS is the city's failure to adequately evaluate geologic and landslide hazard risks associated with the Woods at Viewcrest proposal. The project site is characterized by steep slopes and geologic conditions that present known instability concerns. These conditions are documented in prior investigations, including the **2009 Geologic Feasibility Investigation** (City Exhibit C-184), and are exacerbated by development activities that alter drainage patterns, increase impervious surfaces, and concentrate stormwater.

SEPA requires that geologic hazards be evaluated at the threshold stage where slope failure, mass wasting, or erosion may result in significant adverse environmental impacts. **The city's reliance on assumptions and deferral of post-development geotechnical analysis renders the MDNS clearly erroneous**.

B. Existing Geologic Conditions and Documented Hazards

The 2009 Geologic Feasibility Investigation identifies site conditions that warrant careful scrutiny, including steep slopes, soil and subsurface characteristics susceptible to instability, and the presence of groundwater and seepage pathways that influence slope behavior. Such conditions are widely recognized as risk factors for landslides, slumps, and debris flows, particularly when disturbed or subjected to altered hydrologic regimes.

These hazards are not hypothetical. They are inherent to the site's geology and topography and require site-specific evaluation under anticipated development conditions to determine whether environmental impacts may be significant.

C. Interaction Between Hydrology and Geologic Stability

Geologic stability cannot be evaluated in isolation from hydrology. Changes in surface and subsurface water conditions — including increased runoff, infiltration, and concentrated discharge — directly affect pore water pressures, soil strength, and slope stability.

As discussed in Pillars 2 and 3, the proposal would alter hydrologic conditions through increased impervious surfaces and engineered drainage systems. The application materials do not analyze how these hydrologic changes interact with the site's geologic conditions to affect post-development slope stability.

SEPA requires evaluation of these interactions where failure could result in environmental harm, including sediment delivery to downstream waters, damage to habitat, and public safety risks.

D. Absence of Post-Development Slope Stability Analysis

The application materials lack a comprehensive post-development slope stability analysis that accounts for grading, vegetation removal, stormwater management features, and long-term hydrologic changes. Instead, the city accepted general assurances that engineering controls and future design refinement would adequately manage geotechnical risk.

This approach improperly substitutes assumption for analysis. SEPA does not allow a lead agency to defer evaluation of potentially significant geologic hazards to later permitting stages where those hazards are central to the threshold determination.

E. Downstream and Off-Site Consequences of Slope Failure

Slope instability and mass wasting events are not confined to the footprint of development. Failures can mobilize large volumes of sediment and debris, which are then conveyed downslope through drainage systems to downstream receiving environments.

In the context of this project, such material would be delivered toward Mud Bay, compounding the sedimentation and pollutant concerns described in Pillars 1 and 2. These downstream consequences are ***severe*** environmental impacts that SEPA requires to be evaluated.

The city's SEPA review does not analyze these pathways or their potential magnitude.

F. Public Safety Considerations

Geologic instability also implicates public safety, including risks to residents, infrastructure, and users of adjacent public areas. SEPA's definition of "environment" includes public health and safety, and geologic hazards are a recognized category of significant environmental impact.

The city's MDNS does not meaningfully evaluate whether development on geologically constrained slopes, under altered hydrologic conditions, may increase risks to people or property.

G. Improper Reliance on Deferral and Mitigation

The city relied on the expectation that future geotechnical review, construction-phase controls, or mitigation measures would address instability risks. However, mitigation effectiveness cannot be assumed where baseline risks have not been quantified and analyzed.

SEPA requires that the lead agency disclose and evaluate geologic risks before issuing an MDNS. **Deferring that evaluation deprives decision-makers and the public of the information necessary to assess environmental significance**.

H. Pillar 4 Conclusion

The record demonstrates that the Woods at Viewcrest proposal is located on geologically constrained terrain with documented instability concerns and that development will alter hydrologic conditions in ways that may exacerbate landslide and erosion risks. **The city failed to evaluate post-development slope stability, downstream consequences of potential failures, and public safety implications**.

Because these geologic hazards may result in significant — and ***severe*** — adverse environmental impacts and were not adequately analyzed at the threshold stage, SEPA requires issuance of a Determination of Significance and preparation of an Environmental Impact Statement.

PILLAR 5 — APPLICATION DEFICIENCIES, ERRORS, AND UNSUPPORTED CLAIMS PRECLUDING INFORMED SEPA REVIEW

A. Overview

A fifth independent basis for overturning the MDNS is the applicant's failure to provide application materials that contain information reasonably sufficient to identify and evaluate the proposal's probable significant adverse environmental impacts, as required by **WAC 197-11-080**. This failure is not confined to a single technical discipline. Rather, it reflects a pattern of errors, omissions, internal inconsistencies, and unsupported assertions across stormwater management, geologic hazards, receiving-water characterization, and public safety analysis.

Where application materials are incomplete or unreliable, **SEPA does not permit a lead agency to issue an MDNS based on assumptions, regulatory checklists, or future review**. Instead, uncertainty of this nature triggers preparation of an Environmental Impact Statement.

B. SEPA's Information Sufficiency Requirement

WAC 197-11-080 requires applicants to provide information "reasonably sufficient to identify and evaluate the probable environmental impacts" of a proposal. This requirement exists to ensure that the lead agency can take the requisite "hard look" at environmental consequences before making a threshold determination.

Information is not "reasonably sufficient" where:

- Critical analyses are missing;
- Conclusions are unsupported by data or modeling;
- Assumptions are substituted for evaluation; or
- Key environmental pathways are ignored or mischaracterized.

The Woods at Viewcrest application fails this standard.

C. Errors and Omissions in Stormwater and Hydrologic Analysis

The application materials lack quantitative stormwater modeling necessary to evaluate pre- and post-development runoff volumes, peak flows, and flow durations. Despite this absence, **the city's SEPA erroneously review asserts that stormwater modeling was reviewed and found acceptable**.

This disconnect between what the record contains and what the city claims to have reviewed is itself a material deficiency. Without modeling, the city could not evaluate erosion potential, pollutant transport, or flow-control compliance, particularly in the context of a sensitive estuarine receiving environment.

SEPA does not permit reliance on generalized compliance statements in lieu of analysis.

D. Deficiencies in Geologic and Landslide Hazard Evaluation

As discussed in Pillar 4, the application does not include a comprehensive post-development slope stability analysis. It fails to evaluate how grading, vegetation removal, and altered drainage patterns will affect slope stability under long-term operating conditions.

Instead, the application relies on assurances that geotechnical risks will be addressed through future engineering design and construction-phase controls. **Such deferral deprives decision-makers of information necessary to assess environmental significance at the threshold stage**.

E. Mischaracterization of the Receiving Environment

The application and SEPA review repeatedly describe Mud Bay in generic terms, failing to acknowledge its function as a mudflat-dominated estuarine wetland system with limited assimilative capacity. This mischaracterization affects conclusions regarding flow control, stormwater treatment adequacy, and pollutant fate.

Failure to accurately describe the receiving environment undermines the validity of all downstream impact analyses.

F. Unsupported Reliance on Treatment and Mitigation

The application assumes that proposed stormwater treatment will adequately mitigate environmental impacts without demonstrating treatment effectiveness for the full suite of pollutants expected to be generated by the project. Pollutant non-removal, system limitations, and site-specific performance are not evaluated.

SEPA prohibits reliance on mitigation measures unless their effectiveness is demonstrated and their limitations disclosed.

G. Public Safety and Traffic Analysis Deficiencies

The application materials do not adequately evaluate traffic and pedestrian safety impacts, despite existing documentation of unsafe conditions in the surrounding neighborhood. Increased traffic volumes and development intensity are foreseeable consequences of the proposal, yet their interaction with existing safety risks is not analyzed.

Public safety impacts fall squarely within SEPA's scope and cannot be dismissed as speculative where credible evidence exists.

H. Cumulative Effect of Application Deficiencies

Each deficiency described above independently undermines the city's ability to make a reasoned threshold determination. Taken together, they demonstrate a systemic failure to provide the information SEPA requires.

Where an agency lacks sufficient information to evaluate probable environmental impacts, the proper response is not to issue an MDNS, but to prepare an EIS to fill those informational gaps.

I. Pillar 5 Conclusion

The Woods at Viewcrest application materials do not provide information reasonably sufficient to identify and evaluate the proposal's probable significant adverse environmental impacts, as required by WAC 197-11-080. The city's reliance on incomplete and unreliable information, assumptions, and deferred analysis renders its MDNS clearly erroneous.

This failure independently requires issuance of a Determination of Significance and preparation of an Environmental Impact Statement.

PILLAR 6 — TRAFFIC, PEDESTRIAN, AND PUBLIC SAFETY IMPACTS

A. Overview

A sixth independent basis for overturning the MDNS is the city's failure to adequately evaluate traffic, pedestrian, and public safety impacts associated with the Woods at Viewcrest proposal. SEPA requires consideration of public health and safety impacts where development may increase exposure to known hazards. The record contains credible evidence of existing safety concerns in the Edgemoor area that would be exacerbated by additional residential traffic and construction activity, yet **the city's SEPA review does not meaningfully analyze these risks**.

B. Existing Safety Conditions and Community Documentation

The Edgemoor neighborhood has documented longstanding concerns regarding traffic speed, limited sight distances, constrained roadway geometry, and pedestrian safety, particularly for children and non-motorized users. Community records, including neighborhood correspondence to city leadership and a pedestrian safety questionnaire, identify specific locations and conditions where vehicle–pedestrian conflicts are already present.

These materials constitute credible evidence of baseline safety vulnerabilities. **SEPA requires that baseline conditions be accurately described before evaluating how a proposal will change risk levels**.

C. Project-Related Traffic Increases and Exposure

The proposal would introduce additional vehicle trips associated with new residential units, construction traffic, service vehicles, and visitors. Increased traffic volume on constrained local streets increases the probability and severity of vehicle–pedestrian and vehicle–bicycle conflicts, particularly where sidewalks are discontinuous, shoulders are narrow, and visibility is limited.

The city's SEPA review does not analyze how increased traffic interacts with existing neighborhood conditions or whether incremental increases materially elevate risk to pedestrians and residents.

D. Inadequate Evaluation Under SEPA

Rather than conducting a site-specific safety analysis, the city relied on generalized traffic assumptions and regulatory compliance statements. SEPA does not permit dismissal of safety impacts where credible evidence suggests increased exposure to harm.

Public safety impacts are environmental impacts under SEPA. Failure to evaluate foreseeable safety consequences renders the threshold determination unsupported.

E. Cumulative and Long-Term Effects

Traffic and pedestrian safety impacts accumulate over time. Even modest increases in traffic volume can significantly affect neighborhoods with pre-existing safety constraints. The city's SEPA review does not evaluate cumulative risk or long-term exposure.

F. Pillar 6 Conclusion

The record demonstrates that the Woods at Viewcrest proposal may exacerbate existing traffic and pedestrian safety hazards in the Edgemoor area. Because these impacts were not adequately evaluated, and because increased exposure to safety risks constitutes a significant adverse environmental impact under SEPA, the city's MDNS is clearly erroneous. Preparation of an Environmental Impact Statement is required.

PILLAR 7 — RECREATION, SHORELINE USE, AND LONG-TERM PUBLIC TRUST IMPACTS

A. Overview

A seventh independent basis for overturning the MDNS is the city's failure to evaluate impacts to recreation, shoreline use, and public trust resources associated with long-term degradation of the Mud Bay shoreline. SEPA requires consideration of impacts to human use of the environment, including recreational and aesthetic values.

B. Existing Recreational and Public Uses of Mud Bay

Mud Bay's shoreline and adjacent tidelands are used by the public for walking, wildlife observation, informal recreation, and enjoyment of natural scenery. These uses depend on physical access, safe conditions, and a shoreline environment free from excessive contamination and nuisance conditions.

C. Long-Term Accumulation of Pollutants and Sediments

As described in Pillars 1 and 2, Mud Bay's physical characteristics cause pollutants and fine sediments to accumulate over time. Repeated stormwater discharges contribute to the formation of contaminated shoreline muck, oily residues, and degraded substrates.

Such accumulation directly affects recreational suitability by:

- reducing walkability and access,
- creating unpleasant or unsafe contact conditions,
- and diminishing aesthetic and natural values.

The city's SEPA review does not analyze how long-term accumulation may impair these uses.

D. Public Trust Considerations

Shorelines and tidelands are subject to public trust principles that prioritize public access, use, and environmental protection. While SEPA is not a public trust statute, it requires disclosure and evaluation of impacts that undermine public trust values.

Degradation of shoreline conditions through unmanaged pollutant accumulation conflicts with these values and constitutes an environmental impact requiring analysis.

E. Failure to Evaluate Irreversible or Irretrievable Impacts

Long-term contamination of sediments and shoreline substrates may be difficult or impossible to fully remediate. SEPA requires consideration of irreversible and irretrievable commitments of environmental resources. The city's MDNS does not address whether shoreline degradation may become permanent.

F. Pillar 7 Conclusion

The Woods at Viewcrest proposal may result in long-term degradation of Mud Bay's shoreline, impairing recreation, public access, and public trust values. Because these impacts were not evaluated, and because they may be irreversible, the city's issuance of an MDNS is clearly erroneous. An Environmental Impact Statement is required.

PART III — Summary

1. The Woods at Viewcrest proposal is a residential subdivision located on steep, geologically constrained terrain that drains directly toward Mud Bay.

2. Mud Bay is a low-energy pocket estuary characterized by extensive mudflats, estuarine wetlands, and shoreline areas designated as Critical Saltwater Habitat.

3. Mud Bay has limited tidal flushing and fine-grained sediments that cause pollutants and sediments to accumulate rather than disperse.

4. The city of Bellingham issued a Mitigated Determination of Nonsignificance (MDNS) for the proposal under SEPA.

5. The MDNS relies on application materials, assumptions, and mitigation measures without comprehensive analysis of post-development conditions.

Pillar 1 — Mud Bay as a Highly Sensitive Receiving Environment

6. Mud Bay supports ecological functions including benthic invertebrate habitat, forage fish use, avian foraging, nutrient cycling, and transitional estuarine processes.

7. Estuarine wetlands and mudflats within Mud Bay have limited assimilative capacity and are particularly sensitive to changes in sediment quality, hydrology, and pollutant loading.

8. The city's SEPA review characterizes Mud Bay in generic terms and does not analyze its specific sensitivity as a mudflat-dominated estuarine system.

9. Failure to accurately characterize the receiving environment affects conclusions regarding stormwater, flow control, treatment effectiveness, and environmental significance.

Pillar 2 — Stormwater Treatment Failures and Toxic Pollutants

10. Residential stormwater runoff contains pollutants including metals, hydrocarbons, nutrients, microplastics, tire-derived particles, and chemical transformation products such as 6PPD-quinone.

11. The proposal relies on Modular Wetland System (MWS) devices classified as providing "enhanced treatment."

12. MWS devices are not designed to sufficiently remove pollutants present in stormwater, including dissolved pollutants and emerging contaminants such as 6PPD-quinone.

13. The city's SEPA review does not evaluate which pollutants will remain after treatment or their fate in Mud Bay.

14. Residual pollutants discharged to Mud Bay are likely to accumulate in sediments and biota over time.

15. The city did not evaluate potential human exposure pathways associated with pollutant accumulation along the Mud Bay shoreline.

Pillar 3 — Improper Flow-Control Exemption and Stormwater Non-Compliance

16. Ecology stormwater guidance requires protection of estuarine wetlands and receiving waters sensitive to hydrologic change.

17. Flow-control exemptions are context-dependent and assume receiving waters can tolerate altered flow regimes without adverse impact.

18. Mud Bay does not function as a high-energy receiving water capable of assimilating increased or altered flows without environmental harm.

19. The city treated the proposal as eligible for flow-control exemptions without conducting receiving-water-specific analysis.

20. The application materials lack quantitative modeling necessary to evaluate pre- and post-development flow regimes.

21. PMBC's April 24, 2024 public comment submittal at Exhibit J documents failures to demonstrate compliance with stormwater minimum requirements.

Pillar 4 — Geologic and Landslide Hazard Risks

22. The project site contains steep slopes and geologic conditions associated with instability risks documented in the 2009 Geologic Feasibility Investigation.

23. Geologic stability is influenced by hydrologic conditions, including runoff, infiltration, and concentrated discharge.

24. The application materials do not include a comprehensive post-development slope stability analysis.

25. The city relied on future engineering controls and deferred geotechnical review to later permitting stages.

26. Slope failure could result in mass wasting, erosion, and sediment delivery to Mud Bay.

27. The city's SEPA review does not evaluate the ***severe*** consequences of potential slope failure.

Pillar 5 — Application Deficiencies

28. WAC 197-11-080 requires applicants to provide information reasonably sufficient to identify and evaluate probable environmental impacts.

29. The application materials contain errors, omissions, and unsupported assertions across multiple disciplines.

30. Critical analyses, including stormwater modeling and post-development geotechnical evaluation, are absent.

31. The city relied on assumptions and regulatory compliance statements in place of analysis.

32. The absence of reliable information increases uncertainty regarding environmental impacts.

Pillar 6 — Traffic, Pedestrian, and Public Safety Impacts

33. Existing conditions in the Edgemoor neighborhood include documented traffic and pedestrian safety concerns.

34. With the adoption of the city's Middle Housing ordinance, the proposal has the potential to significantly increase vehicle trips associated with residential use and construction.

35. Increased traffic volume would increase exposure to safety risks on constrained local streets.

36. The city's SEPA review does not evaluate how increased traffic interacts with existing safety vulnerabilities.

Pillar 7 — Recreation, Shoreline Use, and Public Trust Impacts

37. Mud Bay's shoreline is used by the public for walking, wildlife observation, and informal recreation.

38. Long-term accumulation of pollutants and sediments degrades shoreline access and recreational suitability.

39. Shoreline degradation may impair public trust values and be difficult or impossible to fully remediate.

40. The city's SEPA review does not evaluate long-term recreational or public trust impacts.

B. CONCLUSION

General SEPA Conclusions

1. SEPA requires preparation of an Environmental Impact Statement where a proposal may have significant adverse environmental impacts or where uncertainty prevents informed decision-making (RCW 43.21C; WAC 197-11-330).

2. An MDNS is clearly erroneous where the lead agency fails to take a "hard look" at environmental consequences or relies on assumptions, deferral, or speculative mitigation.

PILLAR 1 — Mud Bay as a Highly Sensitive Receiving Environment

3.1 (Procedural Error).
The city committed procedural error under SEPA by failing to accurately characterize Mud Bay as a highly sensitive receiving environment composed of mudflats, estuarine wetlands, and designated Critical Saltwater Habitat. This mischaracterization prevented the city from taking the required "hard look" at the context-dependent significance of stormwater, hydrologic, and pollutant impacts.

3.2 (Substantive Significance).
Because Mud Bay has limited assimilative capacity and heightened ecological sensitivity, stormwater discharges and hydrologic alterations that might be insignificant in other settings may be significant here. The city's failure to analyze impacts in this context creates a reasonable likelihood of significant adverse environmental impacts and unresolved uncertainty. Issuance of an MDNS under these circumstances is clearly erroneous.

PILLAR 2 — Stormwater Treatment Failures, Toxic Pollutants, and 6PPD-Quinone

4.1 (Procedural Error).
The city erred procedurally by relying on stormwater treatment classifications and mitigation assumptions without evaluating treatment effectiveness, pollutant non-removal, and site-specific limitations of the proposed Modular Wetland System devices, contrary to SEPA's requirement that mitigation be analyzed and not merely assumed.

4.2 (Substantive Significance).
The record demonstrates that pollutants not removed by the proposed treatment systems, including toxic constituents such as 6PPD-quinone, will be discharged directly to Mud Bay's sensitive estuarine environment. Given the receiving environment's propensity for pollutant accumulation, there is a reasonable likelihood of significant adverse ecological and human

health impacts. At minimum, the extent of harm is uncertain. Either condition independently requires preparation of an EIS.

PILLAR 3 — Improper Flow-Control Exemption and Stormwater Non-Compliance

5.1 (Procedural Error).
The city committed procedural error by treating the proposal as eligible for flow-control exemptions without conducting a receiving-water-specific analysis, and by accepting incomplete stormwater documentation that fails to demonstrate compliance with applicable minimum requirements.

5.2 (Substantive Significance).
Alteration of runoff volumes, peak flows, and flow timing into a low-energy estuarine system may cause erosion, sediment redistribution, and degradation of wetland functions. The absence of hydrologic modeling and demonstrated compliance creates substantial uncertainty regarding these impacts. Under SEPA, such uncertainty at the threshold stage requires issuance of a Determination of Significance.

PILLAR 4 — Geologic and Landslide Hazard Risks

6.1 (Procedural Error).
The city violated SEPA by deferring analysis of post-development geologic and landslide hazards to later permitting stages, despite credible evidence of instability risks and known interactions between hydrology and slope stability.

6.2 (Substantive Significance).
Potential slope failure, erosion, and mass wasting present a reasonable likelihood of significant and ***severe*** adverse environmental impacts, including downstream sedimentation and public safety risks. Where such hazards have not been evaluated under post-development conditions, an MDNS is clearly erroneous as a matter of law.

PILLAR 5 — Application Deficiencies and Information Insufficiency (WAC 197-11-080)

7.1 (Procedural Error).
The city erred by issuing an MDNS based on application materials that do not contain information reasonably sufficient to identify and evaluate the proposal's probable environmental impacts, in violation of WAC 197-11-080.

7.2 (Substantive Significance).
Where critical analyses are missing and conclusions are unsupported, SEPA requires

preparation of an EIS to resolve uncertainty. The city's reliance on incomplete and unreliable information rendered informed decision-making impossible and independently mandates a Determination of Significance.

PILLAR 6 — Traffic, Pedestrian, and Public Safety Impacts

8.1 (Procedural Error).
The city committed procedural error by failing to evaluate foreseeable traffic, pedestrian, and public safety impacts associated with increased vehicle trips in an area with documented existing safety hazards.

8.2 (Substantive Significance).
Increased exposure to traffic and pedestrian safety risks constitutes a significant adverse environmental impact under SEPA. The city's failure to analyze how the proposal exacerbates known vulnerabilities renders the MDNS clearly erroneous.

PILLAR 7 — Recreation, Shoreline Use, and Public Trust Impacts

9.1 (Procedural Error).
The city erred by failing to evaluate impacts to recreation, shoreline use, and public trust values arising from long-term pollutant accumulation and shoreline degradation at Mud Bay.

9.2 (Substantive Significance).
Degradation of shoreline conditions that impairs public access, recreation, and aesthetic values — particularly where impacts may be irreversible — constitutes a significant adverse environmental impact. The city's omission of this analysis requires preparation of an EIS.

CUMULATIVE AND INTERACTING IMPACTS

10 (Cumulative Error).
The city failed to evaluate how multiple unresolved impacts — including stormwater pollution, altered hydrology, geologic instability, and public safety risks — interact and compound one another.

11 (Cumulative Significance).
Even if individual impacts were uncertain or marginal in isolation, their interaction creates a reasonable likelihood of significant adverse environmental impacts. SEPA does not require certainty of harm; uncertainty combined with potential severity mandates an EIS.

CONCLUSION SUMMARY

12. The city's issuance of an MDNS for the Woods at Viewcrest proposal was clearly erroneous under SEPA.

13. The city must withdraw the MDNS, issue a Determination of Significance, and prepare a full Environmental Impact Statement.

Cumulative Impact Conclusion

14. Each Pillar independently demonstrates a reasonable likelihood of significant adverse environmental impacts.

15. Considered cumulatively, the proposal presents multiple interacting risks that amplify environmental harm.

16. The city's MDNS is clearly erroneous as a matter of law.

17. SEPA requires issuance of a Determination of Significance and preparation of an Environmental Impact Statement.

Kathy M Bell

From:	DCLongwell <DCLongwell@comcast.net>
Sent:	Wednesday, January 7, 2026 4:14 PM
To:	G.Proj.Wood at Viewcrest
Cc:	LvanRubens@comcast.net
Subject:	Hearing Examiner Case HE-25-PL-027 Re The Woods at Viewcrest
Attachments:	Woods at Viewcrest - Longwell Public Comment.pdf

Hello,

The attached PDF File contains my Pre-hearing Public comments for the Woods at Viewcrest project.
Please forward my comments to the Hearing Examiner so the Examiner can provide a careful review of the following:

Critical issues:

1. The developer has NOT secured a written consent to feed stormwater contaminants to MRC owned livestock (living restoration oysters) which were placed in North Chuckanut Bay City Park in 2018.
    a. The Whatcom County Marine Resource Committee (MRC) purchased the restoration livestock (living oyster spat) from the Puget Sound Restoration Fund (PSRF) in 2018.
    b. The City has NOT secured permission to feed these oysters with increased amounts of stormwater contaminants from the MRC, or Whatcom County's Public Works – Natural Resources Department, or the Indian tribe's which assisted or provided the restoration oysters through a partnership with the Puget Sound Restoration Fund.
2. Whatcom County's Public Works – Natural Resources Department and the MRC, in a joint effort placed restoration oysters in North Chuckanut Bay in 2018.
3. The Puget Sound Restoration Fund (PSRF) provided the restoration oysters to the MRC for only one purpose: Restoring a living shoreline with a resource of cultural importance.
    a. Nine Treaty Tribes are noted by the PSRF as Partners and Funders; the City and the developer are thus required to comply with the "Elliott Point Treaty of 1855" which permanently protects a tribe's welfare in exchange for NOT going to war with the United States in 1855. In this instant case, a tribe's cultural benefit is the welfare a tribe receives when a tribe participates or is linked in some way to a restoration project of cultural importance.
4. The Developer's non-compliance with Bellingham Municipal Codes BMC 8.04.100.A and BMC 8.04.100.D which prohibits the disposal of all waste materials in a city park which, tends to create a nuisance which annoys, injures, or endangers the health, safety, or comfort of the public in a city park.
    a. In this instant case, these city codes permanently protect the MRC's restoration oysters from pollution because the oysters are located in the middle of North Chuckanut Bay City Park.
    b. These BMC Sections do NOT make an exception for known or unknown stormwater contaminants when they are harmful to human health.
5. Non consideration of Whatcom County Ordinance Chapter 2.112 which provided the formalized procedures and criteria for placing living livestock (restoration oysters) of cultural significance in a Bellingham City Park.
    a. The 2018 JARPA permit for placing livestock in a city park includes an approval signature from the 2018 Mayor of Bellingham.
    b. The developer (Anne Jones & The Jones Family) had 14 days to appeal the issuance of the permit in 2018 and failed to appeal the permit.

Thank you

Dean Longwell(Architect – Retired)
621 Linden Road
Bellingham, WA 98225

Date: December 26, 2025

To:
Hearing Examiner's Office
City Hall, 210 Lottie Street,
Bellingham WA 98225
Attn: Sharon Rice, Hearing Examiner

Cc:
Planning & Community Dev. Dept.
City Hall, 210 Lottie Street
Bellingham WA 98225
Attn: Kathy Bell, Senior Planner

Re: Hearing Examiner's Office Case Number: HE-25-PL-027

To avoid a potential "Cease and Desist Order" after construction has started, a careful review of the following is required.

In 2018, "Live Olympia Oyster Spat" were placed in North Chuckanut Bay, a city park which is protected by BMC 8.04.100.A and BMC 8.04.100.D. These city codes prohibit the disposal of "harmful waste materials" in every city park without exception for any type of stormwater contaminant, which tends to create a nuisance, annoys or threatens the health and safety of the public in a city park.

The developer has failed to disclose these ordinances and this fact to the Planning Department. The livestock is owned by the Whatcom County Marine Resources Committee (MRC) and the developer has NOT secured permission to feed these oysters, stormwater containing known and/or unknown pollutants.

In this instant case, the developer has just two options: Spend some money to pump their stormwater to an area outside the boundaries of a city park or spend a lot more money making their stormwater potable before it enters a city park.

For a more careful review, the attached exhibits clarifies a lack of due diligence and a lack of disclosure which needs the Hearing Examiner's attention.

Exhibit "A"; failure to disclose and a failure to comply with Bellingham Municipal Codes BMC 8.04.100.A and BMC 8.04.100.D which prohibits the placement of hazardous materials in every city park.

- Failed to supply a Department of Ecology approved solution for neutralizing a recently discovered stormwater leachate (6PPD-quinone) which has been identified by Ecology as a threat to human health and a threat to aquatic life.

Exhibit "B"; Failure to Disclose:

- Failed to Disclose the Department of Ecology does not have an approved BMP stormwater solution for neutralizing 6PPD-quinone, which Ecology has identified as the 2^{nd} most toxic chemical to aquatic life ever measured.
- Failed to disclose the Department of Health has identified 6PPD and 6PPD-quinone as a nuisance and a threat to Human Health.
- Failed to disclose the Legislature has identified 6PPD as a stormwater contaminant of concern for sensitive population groups and sensitive species.

Exhibit "C"; failed to disclose "a most likely potential" for having harmful microbial contaminants in their stormwater.

- Failed to supply a Department of Ecology stormwater solution for neutralizing every harmful microbial stormwater contaminate before it enters a city park.

Exhibit "D"; Failed to Disclose:

- Failed to disclose the existence of livestock (live oysters) in North Chuckanut Bay

- Failed to secure an agreement to feed stormwater with known and unknown pollutants to the MRC's livestock. (Live Olympia Oysters and their offspring.)

Exhibit "E"; pictures of the MRC, WDFW & the students of Bellingham's Technical College planting live oyster livestock in North Chuckanut Bay.

Exhibit "F"; failure to disclose: the restoration oysters placed in North Chuckanut Bay are an "**end product**" of a "**federal collaborative agreement**" with the "**Treaty Tribes**" of the Salish Seas. This agreement was centered on restoring self-sustaining beds of native Olympia oysters in Puget Sound **for the benefit of** the feds, the State of Washington and the **Treaty Tribes of the Salish Seas**.

- Failed to disclose the potential consequences of feeding stormwater to an oyster, when an Indian tribe can force the City into pumping a developer's stormwater to any location where the stormwater will not feed or harm an oyster. In this instant case, an oyster specifically placed in a city park for the purpose of restoring beds of native Olympia oysters to North Chuckanut Bay.

Exhibit "G"; failed to consider the consequences of feeding Olympia oysters with known and unknown stormwater pollutants when WDFW has identified these oysters as a high priority species for WDFW protection and conservation.

For the purpose of clarity:
The developer has not secured a written consent from the MRC to feed stormwater containing know and unknown pollutants to livestock owned by the MRC.

For the purpose of clarity:
The developer has not secured a written consent to increase the quantity of stormwater from the Arbutus stormwater outflow which will feed MRC's livestock in North Chuckanut Bay.

For the purpose of clarity:
Olympia oysters were placed in North Chuckanut Bay with the full protections of City Municipal Codes BMC 8.04.100.A and BMC 8.04.100.D. These city codes prohibit the disposal of "all harmful waste materials" in every city park without an exception for partially filtered or partially treated stormwater.

Yours truly,

Dean Longwell (Architect – Retired)
621 Linden Road,
Bellingham WA 98225

Exhibit “A”

Re: Hearing Examiner Case Number: HE-25-PL-027

- **Failure to Disclose: The disposal of hazardous stormwater contaminants into a city park.**
- **Failure to Comply with BMC 8.04.100.A and BMC 8.04.100.D**

The proposed Woods at Viewcrest Stormwater Discharge Proposal does NOT filter out or neutralized stormwater contaminant as required by city Municipal Codes BMC 8.04.100.A and BMC. 8.04.100.D. **Please See Exhibit “A” page 2, Exhibit “B” and Exhibit “C”.**

BMC 8.04.100, Litter in Parks Page 1 of 1

8.04.100 Litter in parks.

A. No person shall throw or deposit litter on any park property, except in public receptacles and in such a manner that the litter will be prevented from being carried or deposited by the elements upon any part of the park, or upon any street or other public place. Where public receptacles are not provided, all litter shall be carried away and properly disposed of.

B. No person shall use the parks and recreation department litter receptacles in the following manner:

1. No person shall damage, deface, abuse, or misuse any litter receptacle so as to interfere with its proper function or detract from its proper appearance.

2. No person shall deposit leaves, clippings, prunings, or gardening refuse in any litter receptacle.

3. No person shall deposit household garbage in any litter receptacle; provided, that this subsection shall not be construed to mean that wastes of food consumed on park property may not be deposited in litter receptacles.

C. Whenever litter dumped in violation of this chapter contains three or more items bearing the name of one individual, there shall be a presumption that the individual whose name appears on such items committed the unlawful act of littering.

D. For purposes of this section, “litter” means garbage, refuse, rubbish, or any other waste material which, if thrown or deposited as prohibited in this section, tends to create a nuisance which annoys, injures, or endangers the health, safety, or comfort of the public.

The City has an "all inclusive and stricter than normal" litter control ordinance which is also a "public health ordinance" and a "land use control ordinance".

The ordinance is "clear and concise" and makes no exceptions for stormwater contaminants when a contaminant is known to be a nuisance or a threat to human health. It is also an ordinance which must be view in the light of the whole when a City can have a "public health ordinance" that is more stringent than those provided by another City, the State or the Department of Ecology.

If Bellingham wanted a city ordinance limited to prohibiting bottles, broken glass, ashes, paper, cans or other rubbish in a city park then the city would have adopted an ordinance similar to the ordinance adopted by the City of Everett:

> 9.06.169.A: It is unlawful to leave, deposit, drop or scatter any bottles, broken glass, ashes, paper, cans or other rubbish, litter or refuse in any city park except in a garbage can or other receptacle designated for such purposes.

Per this regulatory review, it appears the developer has just two options: Spend some money to pump their stormwater to an area outside the boundaries of a city park or spend a lot more money making their stormwater potable.

Other Applicable Laws, Ordinances and Codes:

RCW 19.27.095
Building permit application – Consideration – Requirements
(1) A valid and fully complete building permit application for a structure, that is permitted under the zoning or other land use control ordinances in effect on the date of the application shall be considered under the building permit ordinance in effect at the time of application, and the zoning or other land use control ordinances in effect on the date of application.

- Bellingham Municipal Code BMC 8.04.100.A: Prohibits the placement of litter on park property thus the ordinance is a land use control ordinance.

BMC 17.10.020
101.2.1 Exceptions. The provisions of this code shall not apply to work primarily in a public way, public utility towers and poles and hydraulic flood control structures.

The developer cannot use this exception for the following reasons:

- A public way or ROW does not exist until the city fully accepts liability and responsibility for the structures being built for the public's benefit and a ROW is not a ROW until the easement is properly recorded within the County's Auditor's Office.
- A pollution control vault is not a utility tower or pole.
- A pollution control vault is not a hydraulic flood control structure when the vault is not designed to stop flooding.

BMC 17.10.020 Section 102: Applicability
102.1 General. Where in any specific case, different sections of this code specify different materials, methods of construction or other requirements, the most restrictive shall govern except that the hierarchy of the codes named in Chapter 19.27 RCW shall govern. Where there is a conflict between a general requirement and a specific requirement, the specific requirement shall be applicable.

- BMC 8.04.100.A and BMC 8.04.100.D are more restrictive than, Department of Ecology's stormwater discharge regulations.

Exhibit "B"

Re: Hearing Examiner Office Case Number: HE-25-PL-027

Failure to Disclose: A known Human Health Risk

Failure to Disclose: The Department of Ecology does not have a "time tested" BMP stormwater solution that neutralizes the 2nd most toxic stormwater chemical to aquatic life ever measured.

The following illustrates why enforcement of Bellingham Municipal Codes: BMC 8.04.100.A and BMC 8.04.100.D is prudent and required if a proposed stormwater discharge contains 6PPD or 6PPD-quinone.

1. **Snippet from Department of Ecology's 6PPD Action Plan - Executive Summary: The road tire leachate "6PPD-quinone" is the 2nd most toxic stormwater chemical to aquatic life ever found".**

2. **City of Bellingham's acknowledgement of the existence of 6PPD-quinone and 6PPD in the city's stormwater.**

3. **Snippet, from the Department of Public Health which clarifies the adverse affects of 6PPD and 6PPD-quinone on human health.**

4. **A copy of Senate Bill 5931 which identified 6PPD as a toxic chemical of concern for sensitive populations and sensitive species.**

5. **A copy of BMC 8.04.100.A and BMC 8.04.100.D prohibit the disposal of waste materials in a city park without exception for stormwater contaminants which, if deposited in a city park create a nuisance which annoys, injures or endangers the health, safety or comfort of the public in a city park.**

6. **A drawing which identifies the boundaries of Chuckanut Bay Tide Land City Park and the boundaries of the Woods at Viewcrest development.**

Snippets from the Department of Ecology's - 6PPD Action Plan

Re: Stormwater human health risks

Snippet #1

6PPD Action Plan
and Alternatives Assessment

Progress Report and Recommendations

Hazardous Waste and Toxics Reduction Program
Washington State Department of Ecology
Olympia, WA

From Page 4 of the Department of Ecology's - 6PPD Action Plan

Snippet #2

Executive Summary

N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine (6PPD) is an antioxidant and anti-ozone chemical used in motor vehicle tires to prevent tire cracking and promote longevity. It is a human skin sensitizer and reproductive toxicant. In 2020, researchers at Washington State University and the University of Washington discovered that when 6PPD reacts with ozone in the air it leads to the harmful transformation product 6PPD-quinone (6PPDQ). Researchers have identified 6PPDQ as the second most toxic chemical to aquatic life ever measured. It causes rapid mortality to species of cultural and environmental significance like Coho salmon. Researchers have found both chemicals in people.

From Page 6 of the Department of Ecology's - 6PPD Action Plan

Note to the reviewer:
The Department of Ecology has identified 6PPD and 6PPD-quinone as hazardous stormwater contaminants which means a more careful review of The Woods at Viewcrest stormwater discharge plan is required.

Conclusion to the reviewer:
Due to the above Department of Ecology statements; enforcement of Bellingham Municipal Codes BMC 8.04.100.A and BMC 8.04.100.D is prudent and required if a stormwater discharge into a city park and contains 6PPD-quinone.

Coho is the "Canary in the Creek Bed

DCLongwell

From: Eli J Mackiewicz <emackiewicz@cob.org>
Sent: Monday, May 12, 2025 4:53 PM
To: DCLongwell
Subject: Re: 6PPD-q in Bellingham question

Hi Dean,

Thanks for reaching out. As part of my work as a public servant on behalf of our community, I am the co-chair of the Washington State 6ppd-q Subgroup (6ppd-q is the chemical responsible for coho pre-spawn mortality, which we now call Urban Runoff Mortality Syndrome (URMS)). I could talk all day about the chemical and how it gets into streams, but I'm much less of an expert on the stream themselves. My job is to manage stormwater and to prevent pollution from known sources as much as possible using available technologies and scientific knowledge from ongoing and emerging research. But, that said, here's what I can say...

The phenomenon of URMS, which is evidenced by the presence of dead coho and steelhead in streams prior to spawning, was discovered in Bellingham at the BTC Fish Hatchery at Maritime Heritage Park in the late 1990's/early 2000's. At the same time, these events were occurring in other urbanized streams across the Puget Sound region, but the events that occurred at BTC's hatchery were the first to connect the dots between stormwater runoff (especially the "first flush" fall rainstorm) and the susceptibility of coho to pre-spawn mortality. So, it is safe to say that pre-spawn mortality of coho has occurred in Bellingham.

Outside of hatcheries, however, there is no standardized monitoring of the fish populations as it relates to the presence of URMS in our localized streams. It should be expected that this phenomenon continues to occur and, from what we know from other watersheds, would affect the coho and steelhead in our urbanized streams. Anecdotally, there may be reports of URMS that has been documented by the Department of Fish and Wildlife or the Department of Ecology, but it is not tracked by the City of Bellingham in any way that I'm aware of. Additionally, testing for 6ppd-q is not a standard practice both because 1) it was not a known chemical until it was discovered by University of Washington and Washington State University researchers in 2019/2020 and 2) there was not a standard procedure for detecting the chemical in water samples until 2024 (and only one lab accredited to run this process until 2025).

In short, it is reasonable to assume (and indeed predictive models have shown it is likely) that coho and steelhead in Whatcom County waterways are affected by 6ppd-q, but the source and concentration (and the number of occurrences) is not readily available in the data I have access to.

Let me know if you would like me to connect you with other experts who may be able to shed more light on the specifics of how salmon pre-spawn mortality is tracked and recorded. Or, please send along additional questions about 6ppd-q if you are interested and I can send you the primary literature on the topic. While this is an emerging issue, it has a long backstory and lots of research is currently underway.

Thanks again for reaching out.

Eli Mackiewicz (he/his)
Natural Resources Program Technician III
City of Bellingham Public Works Department

Public Works – Natural Resources: (360) 778 - 7800
Direct 778-7742
emackiewicz@cob.org

Conclusion to the reviewer:
Due to the above Public Work's statement; enforcement of Bellingham Municipal Codes BMC 8.04.100.A and BMC 8.04.100.D is prudent and required if a stormwater discharge into a city park contains 6PPD-quinone.

Urban Stormwater

Stormwater pollution is a problem associated with land utilization and development where the persistence, mobility and toxicity of a non-point source of pollution can be unknown.

6PPD and 6PPD-quinone

6PPD is one of many chemicals added to tires and other rubber products to improve their durability. 6PPD prevent s cracks in the rubber, making tires last longer and safer for driving. 6PPD reacts with the air and creates new chemicals called transformation products. One transformation product is called 6PPD-quinone (pronounced “quih-known”) and is most known for being deadly to Coho salmon (*Oncorhynchus kisutch*). We are currently learning how 6PPD and 6PPD-quinone may cause human health effects, and how effects on salmon harm human well being.

Known and Unknown Health Effects of 6PPD

Tire and other rubber product manufacturers have used 6PPD for decades, so we understand more about its human health effects than 6PPD-quinone, which was discovered more recently.

6PPD Skin Allergies

Some people have a skin allergy to 6PPD.

6PPD can cause skin allergies according to studies that looked at workers in rubber manufacturing and other similar jobs. If you’re allergic to other chemicals in the same (PPDs) class, there may be a reaction to your exposure to 6PPD.

6PPD Reproductive and Developmental Effects

6PPD may cause risk to human reproduction and development. Studies in female rats show that 6PPD can make giving birth more difficult and other research suggests it may cause reproductive problems for humans. Laboratory tests show that 6PPD may be able to alter the development of the nervous system.

6PPD Liver Effects

New research suggests that 6PPD could be bad for the liver. A study found that people with a common liver condition have more 6PPD in their blood stream than those without it, along with signs of additional liver damage. Lab tests in animals and human cells show liver harm.

Known and Unknown Health Effects of 6PPD-quinone

Most of the research on 6PPD-quinone has been focused on its harmful effects on fish and its presence in the environment. However, as interest in this chemical grows, research looking at 6PPD-quinone in humans and laboratory animals is rapidly emerging.

Overall studies in laboratory animals suggest that 6PPD-quinone may be toxic to people, and some studies have found that 6PPD-quinone is higher in people with certain diseases.

6PPD-quinone Reproductive and Developmental Effects

Researchers have found higher levels of 6PPD-quinone in people with polycystic ovarian syndrome (PCOS) compared to people without PCOS. However, we don't know if 6PPD-quinone causes PCOS. Additional laboratory experiments in human cells, rodents, and roundworms all show 6PPD-quinone can cause reproductive issues in both genders.

6PPD-quinone Liver Effects

Researchers have found high levels of 6PPD-quinone and signs of liver damage in people with liver disease. Long term studies in mice and human liver cells show that 6PPD-quinone can harm the liver. For example, research in mice found that it can cause fat to build up in the liver,

6PPD-quinone Nervous System Effects

Researchers studying people with Parkinson's disease have found higher levels of 6PPD-quinone in the brain and spinal fluid compared to those without the disease. Supporting studies in laboratory rodents show 6PPD-quinone can harm brain cells.

6PPD-quinone Intestinal Effects

Laboratory mice that ate 6PPD-quinone for several weeks had damage to their intestines. 6PPD-quinone weakened their intestinal lining and increased inflammation. Other lab experiments found similar effects, including increased intestinal leakage in roundworms and signs of intestinal damage in Zebra fish.

6PPD-quinone Cancer Effects

We don't currently know if 6PPD-quinone can cause cancer.

Conclusion to the reviewer:
Due to the above Department of Health statements; enforcement of Municipal Codes BMC 8.04.100.A and BMC 8.04.100.D is prudent and required if a stormwater discharge into a city park contains 6PPD-quinone.

With the enactment of Senate Bill SSB 5931, it appears The Woods at Viewcrest stormwater discharge plan requires a review for being out of compliance with Bellingham's Municipal Codes: BMC 8.04.100.A and BMC 8.04.100.D.

SUBSTITUTE SENATE BILL 5931

AS AMENDED BY THE HOUSE

Passed Legislature - 2024 Regular Session

State of Washington **68th Legislature** **2024 Regular Session**

By Senate Environment, Energy & Technology (originally sponsored by Senators Salomon, Kauffman, Billig, Frame, Lovelett, Pedersen, Shewmake, and Wellman)

READ FIRST TIME 01/29/24.

AN ACT Relating to addressing 6PPD in motorized vehicle tires through safer products for Washington; amending RCW 70A.350.010 and 70A.350.050; adding a new section to chapter 70A.350 RCW; and creating a new section.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF WASHINGTON:

NEW SECTION. **Sec. 1.** (1) The legislature finds that 6PPD is a chemical commonly used in motor vehicle tires to keep them flexible and prevent them from degrading quickly. 6PPD works by moving to the surface of the tire and forming a film that protects the tire. As the film breaks down, it produces 6PPD-quinone. When it rains, tire particles containing 6PPD-quinone are washed into streams, rivers, and other water bodies through stormwater runoff.

(2) The legislature also finds that 6PPD-quinone is directly linked to urban runoff mortality syndrome, a condition where Coho salmon die prior to spawning. 6PPD-quinone is known to be toxic to aquatic species and is the primary causal toxicant for Coho salmon. In June 2023, the department of ecology identified 6PPD as a draft priority chemical under safer products for Washington, cycle 2. Additionally, 6PPD has been identified as a hazardous substance under the model toxics control act and as a chemical of concern for sensitive populations and sensitive species.

p. 1 SSB 5931.PL

With the enactment of Senate Bill SSB 5931, it appears The Woods at Viewcrest stormwater discharge plan requires a review for being out of compliance with Bellingham's Municipal Codes: BMC 8.4.100.A and BMC 8.04.100.D.

(3) The legislature finds it important to reduce sources and uses of 6PPD in Washington to protect aquatic life, particularly salmon. Since 6PPD is ubiquitous in motorized vehicle tires, the legislature intends to identify 6PPD as a priority chemical and certain motorized vehicle tires containing 6PPD as priority consumer products under safer products for Washington.

Sec. 2. RCW 70A.350.010 and 2020 c 20 s 1451 are each amended to read as follows:

The definitions in this section apply throughout this chapter unless the context clearly requires otherwise.

(1) "6PPD" means the chemical compound N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine.

(2) "Consumer product" means any item, including any component parts and packaging, sold for residential or commercial use.

((~~(2)~~)) (3) "Department" means the department of ecology.

((~~(3)~~)) (4) "Director" means the director of the department.

((~~(4)~~)) (5) "Electronic product" includes personal computers, audio and video equipment, calculators, wireless phones, game consoles, and handheld devices incorporating a video screen that are used to access interactive software, and the peripherals associated with such products.

((~~(5)~~)) (6) "Inaccessible electronic component" means a part or component of an electronic product that is located inside and entirely enclosed within another material and is not capable of coming out of the product or being accessed during any reasonably foreseeable use or abuse of the product.

((~~(6)~~)) (7) "Manufacturer" means any person, firm, association, partnership, corporation, governmental entity, organization, or joint venture that produces a product or is an importer or domestic distributor of a product sold or offered for sale in or into the state.

((~~(7)~~)) (8)(a) "Motorized vehicle" means, for purposes of 6PPD as a priority chemical, a motorized vehicle intended for on-highway or off-highway use.

(b) "Motorized vehicle" does not include, for purposes of 6PPD as a priority chemical, the tires equipped on the vehicle nor tires sold separately for replacement purposes.

(9) "Organohalogen" means a class of chemicals that includes any chemical containing one or more halogen elements bonded to carbon.

With the enactment of Senate Bill SSB 5931, it appears The Woods at Viewcrest stormwater discharge plan requires a review for being out of compliance with Bellingham's Municipal Codes: BMC 8.04.100.A and BMC 8.04.100.D.

((~~(8)~~)) (10) "Perfluoroalkyl and polyfluoroalkyl substances" or "PFAS chemicals" means a class of fluorinated organic chemicals containing at least one fully fluorinated carbon atom.

((~~(9)~~)) (11) "Phenolic compounds" means alkylphenol ethoxylates and bisphenols.

((~~(10)~~)) (12) "Phthalates" means synthetic chemical esters of phthalic acid.

((~~(11)~~)) (13) "Polychlorinated biphenyls" or "PCBs" means chemical forms that consist of two benzene rings joined together and containing one to ten chlorine atoms attached to the benzene rings.

((~~(12)~~)) (14) "Priority chemical" means a chemical or chemical class used as, used in, or put in a consumer product including:

(a) Perfluoroalkyl and polyfluoroalkyl substances;

(b) Phthalates;

(c) Organohalogen flame retardants;

(d) Flame retardants, as identified by the department under chapter 70A.430 RCW;

(e) Phenolic compounds;

(f) Polychlorinated biphenyls; ((~~or~~))

(g) 6PPD; or

(h) A chemical identified by the department as a priority chemical under RCW 70A.350.020.

((~~(13)~~)) (15) "Safer alternative" means an alternative that is less hazardous to humans or the environment than the existing chemical or chemical process. A safer alternative to a particular chemical may include a chemical substitute or a change in materials or design that eliminates the need for a chemical alternative.

((~~(14)~~)) (16) "Sensitive population" means a category of people that is identified by the department that may be or is disproportionately or more severely affected by priority chemicals, such as:

(a) Men and women of childbearing age;

(b) Infants and children;

(c) Pregnant women;

(d) Communities that are highly impacted by toxic chemicals;

(e) Persons with occupational exposure; and

(f) The elderly.

((~~(15)~~)) (17) "Sensitive species" means a species or grouping of animals that is identified by the department that may be or is

With the enactment of Senate Bill SSB 5931, it appears The Woods at Viewcrest stormwater discharge plan requires a review for being out of compliance with Bellingham's Municipal Codes: BMC 8.04.100.A and BMC 8.04.100.D.

disproportionately or more severely affected by priority chemicals, such as:

(a) Southern resident killer whales;

(b) Salmon; and

(c) Forage fish.

Sec. 3. RCW 70A.350.050 and 2022 c 264 s 2 are each amended to read as follows:

(1)(a) By June 1, 2020, and consistent with RCW 70A.350.030, the department shall identify priority consumer products that are a significant source of or use of priority chemicals specified in RCW 70A.350.010((~~(12)~~)) (14) (a) through (f).

(b) By June 1, 2022, and consistent with RCW 70A.350.040, the department must determine regulatory actions regarding the priority chemicals and priority consumer products identified in (a) of this subsection. The deadline of June 1, 2022, does not apply to the priority consumer products identified in RCW 70A.350.090.

(c) By June 1, 2023, the department must adopt rules to implement regulatory actions determined under (b) of this subsection.

(2)(a) By June 1, 2024, and every five years thereafter, the department shall select at least five priority chemicals specified in RCW 70A.350.010((~~(12)~~)) (14) (a) through ((~~(g)~~)) (h) that are identified consistent with RCW 70A.350.020.

(b) By June 1, 2025, and every five years thereafter, the department must identify priority consumer products that contain any new priority chemicals after notifying the appropriate committees of the legislature, consistent with RCW 70A.350.030.

(c) By June 1, 2027, and every five years thereafter, the department must determine regulatory actions for any priority chemicals in priority consumer products identified under (b) of this subsection, consistent with RCW 70A.350.040.

(d) By June 1, 2028, and every five years thereafter, the department must adopt rules to implement regulatory actions identified under (c) of this subsection.

(3)(a) The designation of priority chemicals by the department does not take effect until the adjournment of the regular legislative session immediately following the identification of chemicals, in order to allow an opportunity for the legislature to add to, limit, or otherwise amend the list of priority chemicals to be considered by the department.

With the enactment of Senate Bill SSB 5931, it appears The Woods at Viewcrest stormwater discharge plan requires a review for being out of compliance with Bellingham's Municipal Codes: BMC 8.04.100.A and BMC 8.04.100.D.

(b) The designation of priority consumer products by the department does not take effect until the adjournment of the regular legislative session immediately following the identification of priority consumer products, in order to allow an opportunity for the legislature to add to, limit, or otherwise amend the list of priority consumer products to be considered by the department.

(c) The determination of regulatory actions by the department does not take effect until the adjournment of the regular legislative session immediately following the determination by the department, in order to allow an opportunity for the legislature to add to, limit, or otherwise amend the regulatory determinations by the department.

(d) Nothing in this subsection (3) limits the authority of the department to:

(i) Begin to identify priority consumer products for a priority chemical prior to the effective date of the designation of a priority chemical;

(ii) Begin to consider possible regulatory actions prior to the effective date of the designation of a priority consumer product; or

(iii) Initiate a rule-making process prior to the effective date of a determination of a regulatory action.

(4)(a) When identifying priority chemicals and priority consumer products under this chapter, the department must notify the public of the selection, including the identification of the peer-reviewed science and other sources of information that the department relied upon, the basis for the selection, and a draft schedule for making determinations. The notice must be published in the Washington State Register. The department shall provide the public with an opportunity for review and comment on the regulatory determinations.

(b)(i) By June 1, 2020, the department must create a stakeholder advisory process to provide expertise, input, and a review of the department's rationale for identifying priority chemicals and priority consumer products and proposed regulatory determinations. The input received from a stakeholder process must be considered and addressed when adopting rules.

(ii) The stakeholder process must include, but is not limited to, representatives from: Large and small business sectors; community, environmental, and public health advocacy groups; local governments; affected and interested businesses; an expert in scientific data analysis; and public health agencies.

p. 5 SSB 5931.PL

With the enactment of Senate Bill SSB 5931, it appears The Woods at Viewcrest stormwater discharge plan requires a review for being out of compliance with Bellingham's Municipal Codes: BMC 8.04.100.A and BMC 8.04.100.D.

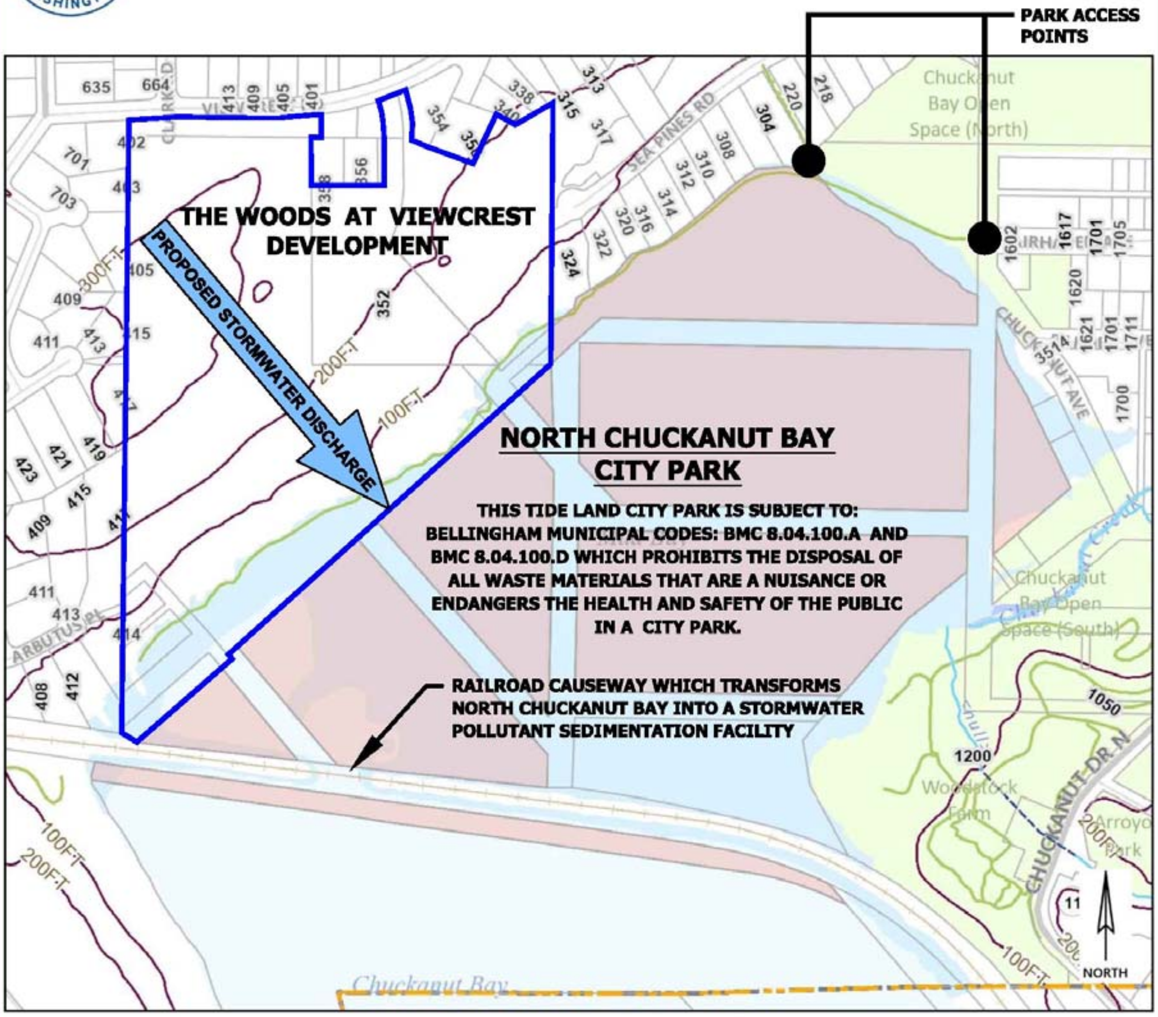
<u>NEW SECTION.</u> **Sec. 4.** A new section is added to chapter 70A.350 RCW to read as follows:

For the purposes of the regulatory process established in this chapter, a motorized vehicle tire containing 6PPD that is equipped on or intended to be installed as a replacement tire on a motorized vehicle for on-highway use is a priority consumer product. For these priority products, the department must determine regulatory actions and adopt rules to implement those regulatory determinations consistent with the process established in RCW 70A.350.040 and 70A.350.050. In determining regulatory actions under this section, the department must specifically consider the effect of the regulatory actions on driver and passenger safety.

--- END ---

p. 6 SSB 5931.PL

Land Parcel Report for 370213151409



Assessor Property Info		Appraised Property Value	
Property ID:	19686	Land value:	$54,040
Assessor address:		Improvement value:	$0
Owner name:	CITY OF BELLINGHAM FINANCE DEPT	Total value:	$54,040
Land use:	SALTWTR TIDE		

Conclusion to the reviewer:

It appears enforcement of Bellingham Municipal Codes BMC 8.04.100.A and BMC 8.04.100.D is prudent and required if a stormwater discharge into North Chuckanut Bay contains 6PPD-quinone.

Exhibit "C"

Note to the Reviewer: The proposed Woods at Viewcrest Stormwater Discharge System does NOT comply with Bellingham Municipal Codes: BMC 8.04.100.A and BMC .8.04.100.D for stopping or neutralizing hazardous stormwater chemicals and/or microbial contaminants

Science of the Total Environment 692 (2019) 1304–1321

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Review

A review on microbial contaminants in stormwater runoff and outfalls: Potential health risks and mitigation strategies

Warish Ahmed [a,*,1], Kerry Hamilton [b,1], Simon Toze [a], Stephen Cook [c], Declan Page [d]

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HIGHLIGHTS

- Stormwater has been considered as an alternative water source.
- Microbial contamination hinders stormwater reuse.
- WSUD is effective in removing pathogens but requires more validation.
- QMRA analysis can facilitate decision making and risk management efforts.

GRAPHICAL ABSTRACT

ARTICLE INFO

Article history:
Received 22 May 2019
Received in revised form 27 June 2019
Accepted 4 July 2019
Available online 5 July 2019

Editor: Patricia Holden

Keywords:
Fecal indicator bacteria
Zoonotic pathogens
Microbial source tracking
Stormwater
WSUD
BMPS

ABSTRACT

Demands on global water supplies are increasing in response to the need to provide more food, water, and energy for a rapidly growing population. These water stressors are exacerbated by climate change, as well as the growth and urbanisation of industry and commerce. Consequently, urban water authorities around the globe are exploring alternative water sources to meet ever-increasing demands. These alternative sources are primarily treated sewage, stormwater, and groundwater. Stormwater including roof-harvested rainwater has been considered as an alternative water source for both potable and non-potable uses. One of the most significant issues concerning alternative water reuse is the public health risk associated with chemical and microbial contaminants. Several studies to date have quantified fecal indicators and pathogens in stormwater. Microbial source tracking (MST) approaches have also been used to determine the sources of fecal contamination in stormwater and receiving waters. This review paper summarizes occurrence and concentrations of fecal indicators, pathogens, and MST marker genes in urban stormwater. A section of the review highlights the removal of fecal indicators and pathogens through water sensitive urban design (WSUD) or Best Management Practices (BMPs). We also discuss approaches for assessing and mitigating health risks associated with stormwater, including a summary of existing quantitative microbial risk assessment (QMRA) models for potable and non-potable reuse of stormwater. Finally, the most critical research gaps are identified for formulating risk management strategies.

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E-mail address: Warish.Ahmed@csiro.au (W. Ahmed).
[1] Contributed equally to this review.

Contents

1. Introduction

Water authorities worldwide are exploring alternative water sources to meet ever-increasing demands for potable and non-potable water due to the adverse impacts of climate change on water supplies. Stormwater has been considered as an alternative water source for both potable (drinking) and non-potable uses (gardening, landscaping, and irrigation) (McArdle et al., 2011; Page et al., 2014c; Page et al., 2015). There are several advantages to using stormwater, including (i) reducing demands on the urban potable water supply (ii) diversification of water supplies (iii) reducing discharge of untreated urban stormwater to urban streams and marine outfalls. Despite these advantages, stormwater has not been widely adopted as an alternative water due to a perceived lack of information on the presence and risk from microbial and chemical contaminants.

The chemical quality of stormwater has been reviewed and indicated the presence of numerous contaminants including heavy metals, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, halogenated aliphatics, halogenated ethers, monocyclic aromatics, phenols and cresols, phthalate esters, nitrosamines, pesticides, and other organics, especially in urban and/or industrialized areas (Makepeace et al., 1995; Eriksson et al., 2005; Baun et al., 2006; Huber et al., 2016). Risk assessments of chemical contaminants in stormwater have suggested that in some cases, contaminants may exceed concentrations in the environment that are relevant for ecological endpoints, but may be lesser contributors to human health risks (Eriksson et al., 2005; Baun et al., 2006; Eriksson et al., 2007). Non-carcinogenic risks due to ingestion of fish in stormwater-contaminated waterbodies have been identified as a potential concern (Bickford et al., 1999). Iron levels exceeding Australian guidelines and elevated (but below guideline) levels of Arsenic have also been identified as potential risks for managed aquifer recharge with stormwater, with overall chemical risks from various compounds posited to be low (Page et al., 2010a, 2010b). Heavy metals and pathogens are thought to be the drivers of human health risks for exposure to stormwater (Page et al., 2010a, 2010b, 2010c, 2010d; Chong et al., 2013; Ma et al., 2016). Indeed, public perception of microbial risks, in particular, remains a crucial barrier to the expansion of water recycling and reuse (Higgins et al., 2002). Therefore, the current review will focus on microbiological contaminants in stormwater and their associated risks.

Pathogenic bacteria, viruses and protozoa can be found in stormwater runoff and subsequently transported to environmental water bodies through sewer overflows, defective septic systems, agricultural runoff, defecation from wild animals and discharge of treated sewage (Ahmed et al., 2005; Noble et al., 2006; Rajal et al., 2007). The pathogens present in various animal fecal sources will differ from those in sewage (Schoen and Ashbolt, 2010; Soller et al., 2015; Federigi et al., 2019), and therefore stormwater is likely to contain a different pathogen profile than sewage. Studies have reported a high prevalence of fecal indicator bacteria (FIB) and enteric pathogens in stormwater (Noble et al., 2006; Rajal et al., 2007; AWQC, 2008; Sidhu et al., 2012a; Cizek et al., 2008). The microbial quality of water is assessed by FIB such as *Escherichia coli* (*E. coli*) and *Enterococcus* spp. (USEPA, 2000). These indicators are abundant in the intestine of warm-blooded animals, and their presence in waters indicates fecal contamination and the likely presence of potential pathogens.

One major limitation of FIB is their poor correlation with the presence of pathogens, especially protozoans and enteric viruses (Hörman et al., 2004; Selvakumar and Borst, 2006; McQuaig et al., 2009). Another limitation of FIB is that they cannot provide information regarding the sources of fecal contamination (Field and Samadpour, 2007; Stoeckel and Harwood, 2007). Remediation strategies can be more effectively implemented if the potential sources of fecal contamination and pathogens are known in stormwater (Sidhu et al., 2012b). Since the monitoring of FIB in water does not provide information on origin, e.g., human or animal feces, researchers have developed a set of analytical tools collectively known as "microbial source tracking (MST) tools." These tools can be used to obtain information on whether the fecal contamination in water came from human or animal wastewater or both (Harwood et al., 2014).

Epidemiological studies indicated that the risks of gastrointestinal illness (GI) among swimmers can be high when the water is contaminated with untreated sewage, as presumably indicated by the presence of elevated levels of FIB (Cabelli et al., 1982; Wade et al., 2006; Marion et al., 2010). However, mixed sources of fecal contamination (human and animal feces) are often expected to be found in stormwater. Epidemiological data are lacking regarding the human health impacts from mixed source of fecal contamination, which may pose different human health risks.

Several studies in the research literature have provided quantitative data on potential pathogens in roof-harvested rainwater stored in tanks (Ahmed et al., 2008a; Ahmed et al., 2014a; Dobrowsky et al., 2014). However, pathogen abundance data in stormwater runoff and outfalls are still scarce. Therefore, the objective of this review is to summarize the concentrations of traditional and alternative fecal indicators, MST marker genes and potential pathogens in stormwater runoff and outfalls. A section of this review has been dedicated to summarizing available quantitative microbial risk assessments (QMRAs) for potable and non-potable uses of stormwater. The focus for reviewing available QMRA models is to summarize the types of assumptions used to model pathogen fate, transport, and exposure in order to identify data gaps and areas where further attention is warranted. Additionally, a review of fecal indicators and pathogen log removal values (LRVs) through Water Sensitive Urban Design (WSUD) or Best Management Practices (BMPs) of stormwater runoff has been compiled. Finally, risk mitigation approaches and the most critical research gaps are identified concerning the public health aspects of stormwater reuse.

Peer-reviewed journal articles, reports, conference proceedings, and guidelines published from 2005 to 2018 were taken into consideration. Electronic databases including PubMed, Google Scholar, and Web of Knowledge were used to obtain the information. The literature search samples during storm events compared to low flow periods (3.53 $\log_{10}$ GC/100 mL of HB and 3.71 $\log_{10}$ GC/100 mL of Lachno2). A further increase in the order of a magnitude of marker genes was observed during the combined sewer overflow (CSO) event compared to storm events. The marker gene contamination level was high enough to exceed acceptable GI risk benchmark of 32 to 36 per 1000 primary contact recreators in rivers or swimming at nearby beaches (USEPA, 2012a).

Staley et al. (2016) quantified *Bacteroides* HF183 in storm water outfalls and several sites along the Humber River in Toronto, Canada. HF183 was detected at all sites, with greater concentrations in outfall samples (mean outfall concentrations of 6.22 $\log_{10}$ GC/L). Their results indicated ubiquitous sewage contamination at storm water outfalls and throughout the Humber River. Steele et al. (2018) used digital PCR to quantify the HF183 marker gene in samples collected from multiple storm events from San Diego River ($n = 23$) and Tourmaline Creek ($n = 21$) that discharge to popular surf beaches in San Diego, CA, USA. The authors noted 6.45–6.95 $\log_{10}$ GC HF183/L in stormwater discharges from Tourmaline Creek and 5.30–6.24 $\log_{10}$ GC/100 mL in stormwater discharges from the San Diego River. The HF183 marker was consistently detected with human pathogen NoV (96% positive agreement in San Diego River and 72% positive agreement in Tourmaline Creek).

Ahmed et al., 2018c examined the extent of sewage contamination in an urban recreational lake located in Sydney, Australia that receives wet weather overflows using two human feces-associated crAssphage marker genes (CPQ_056 and CPQ_064). The concentrations of both markers were higher (CPQ_056 ranging from 3.40 to 7.62 $\log_{10}$ GC/L

Table 1
Prevalence and concentrations ($\log_{10}$ GC/L) of sewage and animal-associated marker genes in stormwater runoff and outfall samples.

Marker genes (host)	Country	Number of samples tested (% occurrence)	Mean/median ± SD (range) in positive samples* ($\log_{10}$ GC/L)	References
HF183 (human)	Qld, Australia	7 (57)	–	Ahmed et al., 2007
HF183 (human)	Qld, Australia	10 (40)	–	Ahmed et al., 2008b
HF183 (human)	Qld, Australia	11 (54.5)	–	Ahmed et al., 2012
HF183 (human)	Tampa, USA	12 (58.3)	$3.79^a \pm 0.33$ (3.38–4.21)	Ahmed et al., 2018a
HF183 (human)	Virginia, USA	130 (100)	4.00^b-5.47^b	Liao et al., 2015
HF183 (human)	Philadelphia, USA	14 (100)	3.50^b (0.11–6.91)	McGinnis et al., 2018
HF183 (human)	North Carolina, USA	37 (13.5)	(4.05- >4.69)	Parker et al., 2010
HF183 (human)	Boston, USA	18 (94.4)	$6.23^a \pm 1.01$ (3.50–7.50)	Paar 3rd et al., 2015
HF183 (human)	California, USA	14 (43)	$5.27^a \pm 1.43$ (3.59–7.17)	Sercu et al., 2011
HF183 (human)	Qld, Australia	12 (92)	–	Sidhu et al., 2012a, 2012b
HF183 (human)	Qld, NSW, Victoria, Australia	23 (96)	–	Sidhu et al., 2013
HF183 (human)	Ontario, Canada	NM	(2.73–4.17)	Staley et al., 2015
HF183 (human)	Toronto, Canada	59 (69.5)	4.22^a (2.55–8.65)	Staley et al., 2016
HF183 (human)	California, USA	44 (97.7)	3.49 ± 0.69^a (2.30–5.09)	Steele et al., 2018
HF183 (human)	California, USA	26 (27)	4.69 ± 1.69^a (2.61–7.17)	van De Werfhorst et al., 2014
HF134 (human)	Qld, Australia	7 (71)	–	Ahmed et al., 2007
HF134 (human)	Qld, Australia	10 (70)	–	Ahmed et al., 2008b
BacHum-UCD (human)	California, USA	14 (92.9)	$5.47^a \pm 5.83$	Bambic et al., 2015
HF183, BacHum-UCD (human)	Milwaukee, USA	828 (57)	3.51^a-6.61^a	Sauer et al., 2011
HuBac (human)	North Carolina, USA	45 (100)	$4.82^a - 6.89^a$	Gentry-Shields et al., 2012
nifH (human)	Australia	11 (18.2)	–	Ahmed et al., 2012
nifH (human)	North Carolina, USA	45 (31.1)	$1.23^a - 4.11^a$	Gentry-Shields et al., 2012
nifH (human)	California, USA	14 (43)	–	Sercu et al., 2011
nifH (human)	Qld, NSW, Victoria, Australia	23 (43)	–	Sidhu et al., 2013
nifH (human)	California, USA	26 (19.2)	–	van De Werfhorst et al., 2014
Enterococcus surface protein (*esp*) (human)	Qld, Australia	7 (71)	–	Ahmed et al., 2007
Enterococcus surface protein (*esp*) (human)	Qld, Australia	11 (18)		Ahmed et al., 2012
Enterococcus surface protein (*esp*) (human)	Qld, Australia	12 (58)	–	Sidhu et al., 2012a, 2012b
Lachno2 (human)	Milwaukee, USA	NM	$4.98^a \pm 1.71$ (4.27–6.43)	Olds et al., 2018
Lachno2 (human)	Milwaukee, USA	10 (70)	$4.94^a \pm 1.02$ (3.50–6.73)	Feng et al., 2018
Lachno12 (human)	Milwaukee, USA	10 (90)	$3.56^a \pm 0.78$ (3.12–5.60)	Feng et al., 2018
Lachno3 (human)	Milwaukee, USA	10 (70)	$3.85^a \pm 1.20$ (2.65–6.23)	Feng et al., 2018
Human *Bacteroides* (human)	Milwaukee, USA	10 (60)	$4.21^a \pm 0.52$ (3.35–4.93)	Feng et al., 2018
Human *Bacteroides* (human)	Milwaukee, USA	NM	$4.78^a \pm 0.45$ (4.25–5.74)	Olds et al., 2018
HPyV (human)	Qld, Australia	11 (18.2)	–	Ahmed et al., 2012
HPyV (human)	Philadelphia, USA	14 (28.6)	(0.27–1.29)	McGinnis et al., 2018
HPyV (human)	Australia	12 (41.6)	–	Sidhu et al., 2012a, 2012b
HPyV (human)	Qld, NSW, Victoria, Australia	23 (52)	–	Sidhu et al., 2013
CrAssphage CPQ_056 (human)	Tampa, USA	12 (41.6)	$4.19^a \pm 0.52$ (3.62–4.91)	Ahmed et al., 2018a
CrAssphage CPQ_064 (human)	NSW, Australia	20 (100)	$4.55^a \pm 0.89$ (3.40–6.03)	Ahmed et al., 2018c
CrAssphage CPQ_064 (human)	NSW, Australia	20 (90)	$4.15^a \pm 0.77$ (3.13–5.47)	Ahmed et al., 2018c
PMMoV (human)	Philadelphia, USA	14 (100)	2.99^b (1.34–4.62)	McGinnis et al., 2018
BacCow (cow)	California, USA	15 (86.7)	$4.75^a \pm 5.17$	Bambic et al., 2015
BacCan (dog)	USA	15 (100)	$4.67^a \pm 4.74$	Bambic et al., 2015
DG37 (dog)	Toronto, Canada	59 (16.9)	–	Staley et al., 2016
DG3 (dog)	California, USA	44 (70.4)	$2.44^a \pm 0.47$ (1.53–3.57)	Steele et al., 2018
DogBact (dog)	Milwaukee, USA	10 (40)	$4.43^a \pm 0.79$ (3.61–5.28)	Feng et al., 2018
Gull4 (seagull)	Toronto, Canada	59 (37.3)	(2.15–4.52)	Staley et al., 2016
LeeSeagull (seagull)	California, USA	44 (93.2)	$3.42^a \pm 0.62$ (1.80–4.47)	Steele et al., 2018

-: Quantitative data were not provided; NM: Not mentioned; *: where available; ^{a} = mean (overall mean concentrations were calculated by authors from the available data); ^{b} = median.

and CPQ_064 ranging from 2.90 to 6.95 $\log_{10}$ GC/L) in 20 of 20 (for CPQ_056) and 18 of 20 (for CPQ_064) samples collected after storm events compared to a dry weather event (10 of 10 samples were qPCR negative for the CPQ_056 and 8 of 10 were negative for the CPQ_064 marker genes) suggesting that sewage contamination was transported by urban stormwater runoff to the studied lake.

In addition to human-feces associated bacterial markers, viruses such as HAdV species A-F and HPyV (urine indicator) have been used to detect human fecal contamination in stormwater runoff (Brownell et al., 2007; Ahmed et al., 2012; Sidhu et al., 2013). However, none of these studies provided the concentrations of these viruses in stormwater samples. Quantifying viral markers in stormwater samples can be difficult due to factors such as their low numbers in sewage, dilution and loss due to recovery and DNA extraction (Horswell et al., 2010; Wong et al., 2012).

Compared to human feces-associated markers, less information is available on the prevalence and concentrations of animal feces-associated marker genes. Staley et al. (2016) determined the concentrations of seagull-associated Gull4 marker gene in a river and stormwater outfall samples in Ontario, Canada. River sites were frequently (5 of 7 sites where gull fecal contamination was detected) impacted by gull fecal contamination. Two of five storm outfalls were also positive for gull feces. Bambic et al. (2015) reported the moderate occurrence of cattle and dog markers in stormwater samples ranging from 4.67 and 4.75 $\log_{10}$ GC/L. Storm events led to an increase (4.67 and 4.75 $\log_{10}$ GC/L) in cattle and dog feces-associated *Bacteroides* marker genes compared to dry events (3.23 and 3.20 $\log_{10}$ GC/L).

Corsi et al. (2014) tested 63 samples over a 17-month period across the three sampling locations in Milwaukee River, WI, USA for human and bovine viruses. Twenty samples were collected during low-flow periods and 43 were collected during rainfall or snowmelt runoff periods. Three of the seven bovine viruses analyzed were detected during the study period. Bovine polyomavirus was present most often (32%) followed by bovine rotavirus group A (19%), and bovine viral diarrhea virus type 1 (5%). Bovine viruses were present in 46% of runoff samples resulting from precipitation and snowmelt and 14% of low-flow samples. Maximum concentrations for these three viruses ranged from 6.7 to 11 GC/L. Bovine viral diarrhea virus type 2, coronavirus, enterovirus, and adenovirus were not detected. The results suggested the presence of bovine fecal contamination in stormwater runoff. This is particularly important because a recent study reported the high risks of gastrointestinal illness from cattle feces contaminated water due to protozoan pathogens *Cryptosporidium* and *Giardia* spp. (Soller et al., 2010).

Fecal contamination in stormwater originate from point and non-point sources, and this is supported by the fact that a number of stormwater outfall samples had high FIB with low or no human *Bacteroides*, suggesting that FIB may have originated from non-human sources (Sauer et al., 2011). Therefore, markers targeting different animal species of zoonotic pathogen potential need to be employed to obtain more information on the magnitude of animal fecal contamination in addition to sewage contamination.

Most of the stormwater studies provided MST results in the presence/absence form. The presence/absence results of any given marker in a sample should be interpreted with care. Mere presence of a marker does not represent any risk as the marker concentrations are generally greater in sewage or animal feces compared to pathogens. In contrast, lack of detection of a marker does not necessarily indicate the sample is free from other contaminants and safe for human exposure. Multiple lines of evidence (i.e., a toolbox approach) are required before implementing remediation or assessing human health risk (Ahmed et al., 2012; Mauffret et al., 2012).

4. Pathogens in stormwater

Increased urbanisation will increase the dissemination of water-borne pathogens in the environments (Hofstra, 2011). Information on the concentrations of pathogens in stormwater is needed for risk assessment and management for beneficial reuse. However, the data on the occurrence and levels of pathogens in stormwater runoff is limited. This is because collecting stormwater samples during storm events can be challenging. Grab samples are easy to collect, and the cost associated with sampling is low, but only represent a snapshot of the water quality at the time of collection (Harmel et al., 2010). Automated samples are more accurate and appropriate for stormwater sampling as they collect representative samples. However, it has to be installed at a specific location, requiring construction of infrastructure and regular maintenance. Other factors such as the presence of high concentrations of suspended solids, grease and PCR inhibitors make it difficult to detect pathogens with molecular based methods (USEPA, 1999; Stenstrom et al., 1984; Rajal et al., 2007).

Table 2 shows the occurrence and concentrations (where available) of bacterial, protozoa, and viral pathogens in stormwater. Sidhu et al. (2012a) investigated the presence of human pathogens in the urban stormwater runoff in Australia. HAdV was frequently detected from all sampling sites during wet weather conditions suggesting their widespread presence. *Campylobacter jejuni*, *Campylobacter coli*, and *Salmonella enterica* were also detected during wet weather conditions. Based on the results, the authors suggested that some degree of treatment of captured stormwater would be required if it were to be used for non-potable purposes. However, the authors did not mention LRVs that would be required for the safe use of stormwater.

Corsi et al. (2014) studied the prevalence, as well as hydrological and seasonal variations of enteric viruses in an urban watershed, a rural sub watershed and the Milwaukee River mouth, WI, USA. The authors processed large volumes of water samples (56–2800 L) over a 17 months duration to account for variability throughout changing hydrologic and extended (24-h) low-flow periods. Human and bovine viruses were detected in 49 and 41% of samples ($n = 63$), respectively. All human viruses analyzed were detected at least once including HAdV (40% of samples), norovirus (NoV) GI (10%), enterovirus (EV) (8%), rotavirus (RoV) (6%), NoV GII (1.6%) and hepatitis A virus (HAV) (1.6%). Human viruses were present in 63% of runoff samples resulting from precipitation and snowmelt, and 20% of low-flow samples. Maximum human virus concentrations were >2.47 $\log_{10}$ GC/L.

Steele et al. (2018) used digital qPCR to quantify a number of bacterial and viral pathogens in stormwater samples from multiple storm events from two different watersheds that discharge to popular surf beaches in San Diego, CA, USA. This is the most comprehensive study reviewed that determined the concentrations of several human health significant pathogens in stormwater discharges in the USA. Among the enteric viruses tested, NoV were highly prevalent in both the San Diego River and Tourmaline Creek with concentration ranging from 1.39 to 2.69 $\log_{10}$ GC/100 mL of water. The prevalence of HAdV were much lower than NoV; 9% of the samples in Tourmaline creek and 22% of the samples in San Diego River were positive for HAdV with concentration ranging from 1.14 to 1.61 $\log_{10}$ HAdV GC/100 mL of water. Enterovirus was not detected in any of the water samples tested. Among the two bacterial pathogens (*Campylobacter* spp., and *Salmonella* spp.), *Campylobacter* spp. was the most commonly detected pathogens (100 and 45% samples were positive at San Diego River and Tourmaline Creek, respectively compared to 25 and 10% samples were positive for *Salmonella* spp. at San Diego River and Tourmaline Creek, respectively. *C. coli* (87%) and *C. lari* (78%) were the most frequently detected species in stormwater discharges from San Diego River, while *C. lari* (48%) and *C. jejuni* (29%) were the most commonly detected in Tourmaline Creek. The authors stated that such data is an important step forward for assessing risk associated with stormwater.

Data generated using qPCR need to be interpreted carefully because qPCR assays quantify both viable and dead pathogens and do not provide information on the infectivity status of the pathogen tested. Also, complex water matrix such as stormwater generally contain various organic substances, salts, acid and detergents which may inhibit PCR was performed using the keywords "(stormwater OR sensitive urban design OR WSUD OR green infrastructure OR low impact development OR Low impact urban design and development) AND (pathogen OR microb- OR bacter- OR protozoa OR source tracking OR MST OR fecal indicator OR fecal contamination OR health risk OR QMRA) and included studies that are reported in English.

2. Fecal indicators

Routine monitoring of stormwater quality focuses on quantification of *E. coli* and *Enterococcus* spp. High concentrations (>4 $\log_{10}$ CFU/100 mL) of FIB are generally found in stormwater runoff and receiving waters (Jiang et al., 2015). Most of the stormwater or outfall samples often exceed the sample threshold value of FIB for the designated recreational use of waters by one or more orders of magnitude. For example, if we consider the 95th percentile value for *Enterococcus* spp./100 mL water, many stormwater samples will exceed the threshold value classified as Class D (i.e., > 501 CFU/100 mL) by the National Health & Medical Research Council (NHMRC) Guidelines for Recreational Use of Water (NHMRC, 2008). The NHMRC used information from WHO (2003) and Kay et al. (2004) to estimate that in Class D there would be greater than a 10% chance of illness per single exposure.

Storm events have the potential to resuspend sediment-bound FIB and pathogens back into water column resulting in elevated contamination levels (An et al., 2002; Cizek et al., 2008; Krometis et al., 2010; Sidhu et al., 2012a). The elevated FIB concentrations generally occur at or just before the peak inflow of the storm hydrograph. Stumpf et al. (2010) determined the loading of FIB over dry and wet weather conditions in tidal creeks in North Carolina, USA. The authors reported 30 and 37 times greater loadings of *E. coli* and *Enterococcus* spp. in storm flow compared to base flow. *E. coli* and *Enterococcus* spp. were weakly correlated ($r^2 = 0.13$ to 0.32) with total suspended solids, while strong associations ($r^2 = 0.40$ to 0.78) were observed between FIB and streamflow rate and various stages (base, rising, peak and falling) of the hydrograph. The authors also noted a large intra-storm variability in FIB concentrations and recommended intensive sampling throughout a storm in order to accurately quantify FIB rather than collecting a single grab sample.

Rural or high density residential areas are reported to contribute 30–50 times greater *E. coli* levels in stormwater compared to light or sparsely populated residential area (McCarthy et al., 2006). Paule-Mercado et al. (2016) investigated the variability of FIB concentrations in agricultural, mixed land use and urban catchments with variable catchment area, land use, and land cover. The urban site had the greatest level (*E. coli* 7.39 $\log_{10}$ MPN/100 mL; fecal streptococci 7.21 $\log_{10}$ CFU/100 mL) of FIB concentrations compared to agricultural site (*E. coli* 2.51 $\log_{10}$ MPN/100 mL; fecal streptococci 2.48 $\log_{10}$ CFU/100 mL) because of runoff from commercial markets and impervious cover, sewer and septic overflows. The authors noted intra-event variability of FIB across the monitoring sites. FIB concentrations increased during the peak flow and then decreased as the storm progressed. Levels of FIB significantly ($p < 0.05$) varied between early and late summer seasons with higher FIB concentrations observed in early summer. Anthropogenic activities and impervious cover were found to influence positive correlations ($r > 0.6$) between FIB numbers and environmental parameters such as temperature, turbidity, and total suspended solids.

Although, FIB monitoring in stormwater is a common practice, there are uncertainties associated with stormwater flow and *E. coli* (McCarthy et al., 2008; Harmel et al., 2006). Uncertainties of discrete *E. coli* samples and flow measurements were >30 and 97%, respectively. *E. coli* event mean concentration uncertainties varied between 10 and 52% and that uncertainties relating to site mean concentrations ranged from 35 to 55% (McCarthy et al., 2008). Sample collection procedures (5–30%), laboratory analysis, preservation/storage, and flow also contributed substantial (14–28%) uncertainties (Harmel et al., 2006; Harmel et al., 2010, 2016).

Another limitation of FIB is that they do not often correlate well with the presence of pathogens in environmental waters. The appropriateness of using FIB to indicate the presence of pathogens especially viruses and protozoa in stormwater has been questioned (Jiang et al., 2001; Schroeder et al., 2002; Jiang, 2004; Robertson and Nicholson, 2005; Signor et al., 2005; AWQC, 2008). This is somewhat expected as FIB in stormwater are sourced from feces of both human and animals, while human pathogens especially enteric viruses in urban stormwater mainly derived from sewage. In addition, the decay rates of FIB may be significantly different than those of viruses (Ahmed et al., 2014b). Hence, monitoring of FIB and interpreting their concentrations in terms of human health risks may not yield any meaningful outcomes.

As a result of these limitations, FIB are generally not used directly for risk estimation. However, some *E. coli* strains such as enteropathogenic *E. coli* (EPEC), enterohemorrhagic *E. coli* (*E. coli* O157:H7 or other EHEC), enterotoxigenic *E. coli* (ETEC), and others are pathogenic to humans and can be used for risk estimation purposes. Although these subsets are not routinely measured, general FIB can be used as a preliminary screening tool prior to testing for other pathogens. Additionally, ratios of FIB to pathogens are used occasionally for risk assessment purposes (Petterson et al., 2016).

3. MST marker genes in stormwater

Fecal contamination in stormwater can originate from point and non-point sources. Human health risk will be different depending on the sources. Untreated sewage poses the greatest risks to humans and the environment due to high concentrations of enteric viruses (EC, 2000; Fong et al., 2010; Soller et al., 2010). Sewage may be introduced into stormwater through illicit connections, cross connection between sewer pipes, storm drains and leakages into sewers through broken lines or poor pipe joints (Pitt, 2004). The presence of sewage in stormwater can be problematic due to the likely co-presence of pathogens. Identifying the presence of sewage in stormwater using is not straightforward due to dilution, infiltration, and lack of sensitive detection methods (Panasiuk et al., 2015). However, microbial source tracking (MST) marker genes are used to identify human feces and other sources of animal fecal contamination such as cattle, dogs, pigs, and birds in water (Harwood et al., 2014; Ahmed et al., 2016).

Human feces-associated marker genes such as *Bacteroides* HF183 (HF183), crAssphage CPQ_056 and CPQ_064, pepper mild mottle viruses (PMMoV), human polyomaviruses (HPyV), and Lachno3 are currently being used to determine the presence of human fecal contamination in environmental waters by research laboratories and water quality managers. These marker genes are sensitive and accurate analytical approaches of human fecal contamination due to high host-specificity and abundance in human and animal feces (Boehm et al., 2013). Several studies have reported the presence of human feces-associated marker genes in stormwater runoff and outfall samples (Table 1). Sidhu et al. (2012a) reported the presence of the *Bacteroides* HF183 (16 of 21 samples were positive for HF183 during both dry and wet weather samples) and *Enterococcus faecium* enterococci surface protein (*esp*) marker gene (8 of 23 samples were positive for *esp* during both dry and wet weather samples) in stormwater run-off samples and suggested the ubiquitous presence of sewage in the urban environment.

MST field studies have identified aging infrastructure as a contributor to sewage intrusion into stormwater system (Marsalek and Rochfort, 2004; Sauer et al., 2011; Guérineau et al., 2014). Several studies have reported the greater concentrations of the HF183 marker gene in stormwater samples (Sercu et al., 2011; Van De Werfhorst et al., 2014; Paar 3rd et al., 2015) (Table 1). Olds et al. (2018) observed high levels of human *Bacteroides* (HB) and Lachno2 in the Milwaukee estuary and at the lower reaches of the three major rivers forming the estuary in Milwaukee, WI, USA after storm events. Concentrations of these marker genes were one to three orders of magnitude higher (4.04–5.59 $\log_{10}$ GC/L of HB and 4.04–6.27 $\log_{10}$ GC/100 mL of Lachno2) in stormwater

Table 2 (*continued*)

Potential pathogens	Country	Land use characteristics	Methods used	No. of samples tested (% of sample positive)	Mean/median ± SD (range) in positive samples [95% CI upper limit]*	References
C. parvum or hominis	Sydney, Australia	Untreated sewered urban	NM	59 (8.47)	$0.77^b \pm 1.07$ (NM-1.83) [1.25] oocysts/10 L	AWQC, 2008
Giardia spp. Raw samples	New York, USA	Five sites representing various landuse such as little anthropogenic impacts, suburban woodlots and high degree of impervious surfaces and developed areas	IMS and microscopy	–	0.59 ± 0.28 (0.00–0.86) cysts/100 mL	Cizek et al., 2008
Giardia spp. Centrifuged				–	0.01 ± 0.16 (−0.09–0.17) cysts/100 mL	
Giardia spp.	Sydney, Australia	Untreated sewered urban		59 (18.6)	$2.00^b \pm 2.53$ (NM-3.40) [2.34] cysts/10 L	AWQC, 2008
Giardia spp.	Atlanta, Louisville, USA	Highly impervious commercial and various land uses	IMS and microscopy	24 (96)	$3.55^a \pm 0.98$ (2.30–4.47) [4.33] cysts/100 L	Arnone and Walling, 2006
Enteric viruses						
HAdV	California, USA	Highly urbanized	qPCR	8 (12.5)	3.98^d GC/L	Ahn et al., 2005
HAdV	Milwaukee, USA	Highly urbanized	qPCR	1 (100)	3.11^d GC/L	Sauer et al., 2011
HAdV	Sydney, Australia	Untreated sewered urban	PCR	59 (3.38)	–	AWQC, 2008
HAdV	California, USA		Nested-PCR	(7)	–	Surbeck et al., 2006
HAdV	Brisbane, Australia	Mainly residential and commercial	PCR	23 (91.3)	–	Sidhu et al., 2013
HAdV	San Diego, USA	Tourmaline Creek – Highly urban residential and commercial	Digital qPCR	21 (9)	$1.18^a \pm 0.03$ (1.15–1.20) [1.20] GC/100 mL	Steele et al., 2018
		San Diego River – Urban residential, commercial and industrial		23 (22)	$1.30^a \pm 0.17$ (1.20–1.61) [1.61] GC/100 mL	
HAdV	Brisbane, Australia	Highly urbanized	PCR	7 (71.4)	–	Ahmed et al., 2012
HAdV 40/41	California, USA	Urban, agricultural and natural	qPCR	21 (4.76)	1.36^d GC/100 mL	Rajal et al., 2007
HAdV A	Philadelphia, USA	Residential and green space	qPCR	14 (7.14)	$<0.01^{c,d}$	McGinnis et al., 2018
HAdV C, D, F	Philadelphia, USA	Residential and green space	qPCR	14 (14.28)	(0.1–1.41) GC/L	McGinnis et al., 2018
HAdV	California, USA	Agricultural (25%), Urban (25%) and open space (50%)	qPCR	15 (6.70)	–	Bambic et al., 2015
HAdV	Brisbane, Australia	Urban residential, industrial, agricultural and rural	PCR	12 (91.6)	–	Sidhu et al., 2012a
Enterovirus	California, USA	Highly urbanized	RT-PCR	8 (12.5)	–	Ahn et al., 2005
Enterovirus	Sydney, Australia	Untreated sewered urban	PCR	59 (22.0)	–	AWQC, 2008
Enterovirus	Milwaukee, USA	Highly urbanized	qPCR	1 (100)	4.28^d GC/L	Sauer et al., 2011
Norovirus GI + GII	South coast, England	Arable (42%), woodland (21%), grassland (18%), urban (6.4%)	qRT-PCR	5 (100)	(2.93–4.87) GC/L	Campos et al., 2015
NoV GI	Milwaukee, USA	Highly urbanized	qRT-PCR	1 (100)	3.18^d GC/L	Sauer et al., 2011
NoV GI	Philadelphia, USA	Residential and green space	qRT-PCR	1 (14)	1.86^d GC/L	McGinnis et al., 2018
NoV GII	San Diego, USA	Tourmaline Creek – Highly urban residential and commercial	Digital qPCR	21 (72)	$2.04^a \pm 0.33$ (1.39–2.72) [2.72] GC/100 mL	Steele et al., 2018
		San Diego River – Urban residential, commercial and industrial		23 (96)	$2.07^a \pm 0.32$ (1.58–2.69) [2.66] GC/100 mL	

NM: Not mentioned; —: Quantitative data not available; *: where available; ^{a} = mean (overall mean concentrations were calculated by authors from the available data); ^{b} = median ^{c}: data not log transformed; ^{d}: single quantifiable sample.

reaction. PCR inhibitory substances may produce false negative results of pathogens in stormwater samples. For example, Corsi et al. (2014) reported a 63% inhibition rate across virus analysis, while Steele et al. (2018) reported 10–15% inhibition rate. This problem can be overcome by including a sample processing control (SPC) (Shanks et al., 2016). Digital qPCR may also offer an advantage over qPCR when dealing with samples with inhibitory substances (Dingle et al., 2013; Cao et al., 2016). This is because in digital qPCR sample is partitioned into many wells are droplets unlike qPCR which measures the target as it occurs with comparison with a standard curve.

Cizek et al. (2008) characterized the partitioning behaviour of *Cryptosporidium* and *Giardia* with traditional and alternative fecal indicators (*E. coli*, *Enterococcus* spp., and *Clostridium perfringens*) and a viral surrogate (coliphage) in stormwater runoff. Both protozoa exhibited similar levels of particle association during dry weather (roughly 30%) with an increased level observed during wet weather events (*Giardia* 60% and *Cryptosporidium* 40%). During wet weather events, FIB, coliphage and protozoa concentrations increased (~1–2 orders of magnitude) in tributaries examined in the Kensico Reservoir. FIB did not exhibit a strong one-to-one relationship with *Cryptosporiduum* or *Giardia* in terms of total concentration or the settleable fraction in the Kensico Reservoir. The authors also found *C. perfringens* spores (Spearman $r = 0.13$ and coliphage $r = 0.11$) were the best indicators for *Cryptosporidium*. This is because the inactivation rates of *C. perfringens* and *C. parvum* were reported to be in the same order of magnitude (Hijnen et al., 2000).

In general, concentrations of pathogens in stormwater are poorly reported and some data may not be useful to infer risk or for quantitative microbial risk assessment (QMRA). For example, several studies have failed to detect or provided the percentage of samples positive for pathogens without giving quantitative numbers (Surbeck et al., 2006; Rajal et al., 2007; Sidhu et al., 2012a; Bambic et al., 2015). Most of the stormwater studies determined the concentrations of genus *Cryptosporidium* and *Giardia*. However, in urban stormwater there is evidence that most samples do not contain human infectious genotypes that are capable of causing illnesses in humans rather contain genotypes that infect animals. For instance, data from Jiang (2004) studying three United States sewered urban stormwater catchments found that only about 5% of around 100 *Cryptosporidium* oocyst types characterized were potentially human-infective.

Recent studies reported high risks due to *Campylobacter* spp. through reuse of stormwater in the Netherlands (Sales-Ortells and Medema, 2015) and Australia (Murphy et al., 2017). These studies, however, only measured members of the genus *Campylobacter* to estimate risk. Genus *Campylobacter* is comprised of 25 species, two provisional species and eight sub-species, with only a few species of human health significance (Man, 2011). Further research should focus on determining the levels of *C. jejuni*, *C. coli* or other pathogenic species such as *C. lari* and *C. upsaliensis* in stormwater for more accurate risk assessment.

Finally, the persistence of pathogens in stormwater compared to wastewater or other matrices has not been well characterized but can provide useful information for QMRA. A systematic review by Boehm et al. (2018) of pathogen persistence in surface waters indicated few decay constants available for protozoan and viral pathogens or viral surrogates, with viruses having the greatest degree of persistence. A comparison of the HF183 MST marker with NoV indicated that the first order decay coefficient *k* was higher for HF183 than NoV. To the author's knowledge, a similar meta-analysis has not been performed for pathogens in stormwater. Sidhu et al. (2015) estimated a T_{90} value of <3 days for bacterial pathogens, and <120 days and >200 days for *Cryptosporidium* spp. oocysts and enteric viruses, respectively in recycled stormwater used for managed aquifer recharge. Due to the persistence of viral pathogens, these microorganisms are likely to drive concerns for human health risk.

5. Health risk assessment approaches

Various approaches for assessing the health risks of microbial contaminants have been applied in the stormwater context including epidemiological approaches and quantitative microbial risk assessment (QMRA) models. Epidemiological studies observe patterns of disease in conjunction with environmental exposure and provide inferences rooted in observed health outcomes, and for this reason are highly valuable for assessing health risks. The findings of several epidemiological studies have supported a relationship between stormwater exposure and waterborne illness for stormwater-impacted waterbodies (Haile et al., 1999; Colford Jr et al., 2007; Soller et al., 2017). However, due to the study sizes and expense required to achieve predictive power in epidemiological studies and difficulty attributing risks to a particular exposure source and/or pathway, often QMRA approaches are used to assess risks where effect sizes are projected to be small due to low environmental concentrations. QMRA uses a process of hazard identification, exposure assessment, dose response analysis, and risk characterization to predict the risk of an infection or disease- related outcome based on an exposure to environmental media (Haas et al., 2014). To the author's knowledge, there has not been an epidemiological study for potable or non-potable uses of stormwater resources. However, studies by Ashbolt and Bruno (2003) and Soller et al. (2017) have demonstrated the utility of combining both epidemiological and QMRA information where feasible for stormwater-affected waterbodies.

Undertaking QMRA for various exposures to stormwater can nevertheless be challenging due to difficulties in discerning the sources and concentrations of pathogen contamination in stormwater, and assumptions regarding pathogen sources, fate, and transport are needed depending on the availability of site-specific information. Several ($n = 16$) QMRA studies have relied upon concentrations of pathogens observed in stormwater-impacted coastal, recreational waters, or drinking source waters for assessment of health risks (Donovan et al., 2008; Soller et al., 2010; ten Veldhuis et al., 2010; Fewtrell et al., 2011; Tseng and Jiang, 2012; Andersen et al., 2013; McBride et al., 2013; de Man et al., 2014; Sales-Ortells and Medema, 2014; Schoen et al., 2014; Soller et al., 2014; Adell et al., 2016; Krkosek et al., 2016; Lim et al., 2017; Soller et al., 2015; Soller et al., 2017), and two have used other modelling approaches for microbial health risks such as Bayesian network modelling (Goulding et al., 2012) or disease transmission models (Soller et al., 2006). These recreational water QMRAs are reviewed in detail by Federigi et al. (2019). However, few studies have conducted a QMRA for potable and non-potable reuse exposures to stormwater (Table 3). The focus on potable and non-potable uses here is due to the difficulty of comparing recreational exposures with multiple non-point as well as point sources of contamination with stormwater-only exposures. Stormwater-impacted recreational waterbody exposures using FIB as well as pathogens as index pathogens were very high in some cases, up to 1.0 for a homeless population ingesting *Giardia*, for example (Donovan et al., 2008). The risks from potable and non-potable uses of stormwater in Table 3 varied substantially depending on the target pathogen and exposure scenario. Risks were considered highest for viral pathogens, in most cases exceeding risk benchmarks for potable and non-potable use with the exception of toilet flushing in some cases (Lim et al., 2015; Murphy et al., 2017). The studies summarized in Table 3 indicate that potable and non-potable exposures to stormwater are likely to exceed water quality targets [e.g. up to a geometric 240 CFU/ mL for recycled water (USEPA, 2012b)] and risk benchmarks (10^{-4} probability of infection or 10^{-6} disability adjusted life years per person per year (pppy) in the absence of additional treatment and/or BMPs depending on the area, end use, and source water. Microbial risks from harvested rainwater are considered as captured stormwater but have been reviewed elsewhere (Hamilton et al., 2019).

Factors such as temporal, regional, and compositional complexity of stormwater can make the quantification of pathogens more difficult than for some other matrices. Once concentration values are obtained, values can be corrected for recovery efficiency in a QMRA, however, low or variable recovery efficiencies can also complicate QMRA analysis. Furthermore, concentrations observed at the point of exposure may not be indicative of realistic exposure scenarios over time as they typically are not observed after a rainfall event during presumably peak pathogen concentrations, or dilution occurs at the point of exposure that in some cases will render concentrations of pathogens below the analytical detection limit (McBride et al., 2013). These factors must be taken into account when constructing QMRA models. Previous studies of pathogens in stormwater discharges have relied upon small samples sizes (Sidhu

Table 3
Quantitative microbial risk assessments (QMRA) for potable and non-potable reuse of stormwater resources

Pathogen	Applications	Exposure routes	Exposure frequency and duration	Risk Mean/Median (95th percentile or upper bound) or calculated LRV	References
Campylobacter *Cryptosporidium* Rotavirus	Stormwater treated in wetland used for managed aquifer recharge	Ingestion	Ingestion 2 L/day	*C. parvum* - 1.5×10^{-3} DALY *Campylobacter* 4.6×10^{-3} DALY Rotavirus 8.4×10^{-3} DALY	Page et al., 2008
Campylobacter *Cryptosporidium* Rotavirus	Irrigation, toilet flushing, laundry, irrigation, firefighting	Ingestion	Municipal irrigation and nonpotable construction activities (50 mL/year); dual reticulation for indoor and outdoor use (toilet, laundry, irrigating food crops, ornamental garden irrigation) (670 mL/person/year); firefighting (1 L/person/year); commercial food crops (490 mL/person/year); non-food crops (50 mL/person/year)	Log removals to achieve target concentrations associated with a 10^{-6} DALYs/person/year calculated (0.8 log [*Cryptosporidium* spp.]- 2.6 log [rotavirus])	NRMMC-EPHC-NHMRC, 2009
Campylobacter *Cryptosporidium* Rotavirus	Managed aquifer recharge with captured urban stormwater	Aerosol ingestion, routine ingestion, and accidental ingestion	Ingestion of irrigation sprays 0.1 mL, 90/person/year; routine ingestion of irrigation sprays 1 mL, 90/person/year; accidental ingestion during irrigation 100 mL 1/person/year.	*Campylobacter* spray ingestion $4.6 \times 10^{-7}/<1.0 \times 10^{-10}$ (95th $<1.0 \times 10^{-10}$) DALY; routine ingestion 1.5×10^{-6} /$<1.0 \times 10^{-10}$ (95th $<1.0 \times 10^{-10}$) DALY; accidental ingestion $1.2 \times 10^{-7}/<1.0 \times 10^{-10}$ (95th $<1.0 \times 10^{-10}$) DALY *Cryptosporidium* spray ingestion $6.2 \times 10^{-8}/1.6 \times 10^{-8}$ (95th 2.5×10^{-7}) DALY; routine ingestion $6.2 \times 10^{-7}/1.6 \times 10^{-7}$ (95th 2.5×10^{-6}) DALY; accidental ingestion $6.8 \times 10^{-7}/1.8 \times 10^{-7}$ (95th 2.8×10^{-6}) Rotavirus spray ingestion $4.3 \times 10^{-6}/4.9 \times 10^{-7}$ (95th 7.0×10^{-4}); routine ingestion $2.8 \times 10^{-5}/4.0 \times 10^{-6}$ (95th 1.4×10^{-4}); accidental ingestion 4.2 $\times 10^{-5}/3.9 \times 10^{-6}$ (95th 1.6×10^{-4})	Toze et al., 2010
Campylobacter *Cryptosporidium* Rotavirus	Stormwater treated in wetland used for managed aquifer recharge	Ingestion	Ingestion 2 L/day	*C. parvum*: $2.8 \times 10^{-8}/<1 \times 10^{-10}$ DALY (95th 1.1×10^{-8}, max 1.7×10^{-4}) *Campylobacter* : $<1 \times 10^{-10}$ DALY Rotavirus: $3.0 \times 10^{-7}/<1.0 \times 10^{-10}$ DALY (95th 6.6×10^{-8}, 8.4 $\times 10^{-4}$)	Page et al., 2009; Page et al., 2010a; Page et al., 2010c; Page et al., 2010d
Campylobacter *Cryptosporidium* Rotavirus	Stormwater treated in wetland used for managed aquifer recharge	Ingestion	Not specified	*C. parvum*: $<1 \times 10^{-10}$-1.5×10^{-3}/ $<1 \times 10^{-10}$-1.5×10^{-3} DALY (95th $<1 \times 10^{-10}$-1.5×10^{-3}). *Campylobacter*: : $<1 \times 10^{-10}$ DALY all parameters. Rotavirus $<1.0 \times 10^{-10}$-8.4×10^{-4}/$<1.0 \times 10^{-10}$-8.4×10^{-4} (95th $<1.0 \times 10^{-10}$-8.4×10^{-4}).	Page et al., 2010b
Campylobacter *Cryptosporidium* Rotavirus	Stormwater treated in wetland used for managed aquifer recharge	Ingestion	Ingestion 2 L/day	*C. parvum*: Log reduction credits for 10^{-6} DALY risk open space irrigation 0.8-4.8, drinking 4.9- >6.0 (Page et al. 2012) *Campylobacter*: Log reduction credits for 10^{-6} DALY risk open space irrigation 1.3- >6.0, drinking 5.5->6.0 (Page et al. 2012)	Page et al., 2012

Table 3 (*continued*)

Pathogen	Applications	Exposure routes	Exposure frequency and duration	Risk Mean/Median (95^{th} percentile or upper bound) or calculated LRV	References
				Rotavirus: Log reduction credits for 10^{-6} DALY risk open space irrigation 1.3-3.4, drinking 5.5->6.0 (Paget al. 2012)	
HAdV	Irrigation[a]	Aerosol ingestion, accidental ingestion	Boating 1 mL 52 times/year; irrigation aerosols 1 mL 90 times/year; irrigation accidental ingestion 100 mL 1 time/year.	Log removal credits calculated to achieve 10^{-6} DALY for adenovirus for irrigation (aerosol) 2.3-3.2/1.4-2.5 (95^{th} 2.9-3.8), irrigation (accidental ingestion) 2.4-3.2/1.5-2.5 (95^{th} 2.9-3.8)	Sidhu et al., 2012b
E. coli O157:H7	Riverbank filtration managed aquifer recharge	Ingestion	3.12 ± 1.17 L/day (Normal distribution)	0.115 (no treatment) - 0.00165 DALYs/person/year (with treatment)	Bartak et al., 2015
HAdV NoV	Toilet flushing, showering, and consumption of irrigated lettuce	Aerosol inhalation, aerosol ingestion, lettuce consumption	Four flushes/day, one 20 min shower/ day; Lettuce consumed 90, 180, or 270 times/year. Toilet and shower inhalation volumes calculated based on aerosols produced by fixtures and aerosol volumes.	Adenovirus: Toilet flushing annual infection risk 1.1×10^{-7}-8.9×10^{-7} (95^{th} 2.7×10^{-7}-1.2×10^{-6}); DALY risk 3.0×10^{-9}-2.4×10^{-8} (95^{th} 7.2×10^{-8}-3.1×10^{-8}). Showering annual infection risk 3.6×10^{-7}-5.3×10^{-5} (95^{th} 1.3×10^{-6}-3.5×10^{-4}); DALY risk 1.1×10^{-8}-1.6×10^{-6} (95^{th} 3.5×10^{-8}- 9.3×10^{-6}). Norovirus: Toilet flushing annual infection risk 5.3×10^{-7}- 1.3×10^{-4} (95^{th} 1.6×10^{-6} - 1.34×10^{-4}); DALY risk 1.0×10^{-20}-1.5×10^{-16} (95^{th} 5.3×10^{-19} - 3.2×10^{-15}). Showering annual infection risk 3.4×10^{-4}-4.3×10^{-2} (95^{th} 1.6×10^{-3}- 1.9×10^{-1}); DALY risk 1.1×10^{-14}-6.3×10^{-11} (95^{th} 1.4×10^{-10}- 1.0×10^{-7}). Food crop annual infection risk 8.0×10^{-4}-9.8×10^{-1} (95^{th} 2.6×10^{-2}); DALY risk 8.0×10^{-14}-1.1×10^{-6} (95^{th} 3.3×10^{-10}- 1.8×10^{-5})	Lim et al., 2015
Campylobacter *Cryptosporidium* RoV	Managed aquifer recharge with stormwater	Ingestion	Open space irrigation 1mL, 50/year; toilet flushing 0.01 mL, 1,100/year; drinking 2L/day	Log removals calculated to meet health targets for viruses (1.0-8.6), protozoa (0->10.8), and bacteria (0.5->16.0)	Page et al., 2015
Campylobacter spp. (human) *Campylobacter* spp. (zoonotic) *L. pneumophila*	Recreational exposure to urban stormwater plaza receiving street and roof runoff	Ingestion, inhalation	Ingestion: exposure volume triangular (0, 0.051, 5) mL/event; Inhalation: aerosolization ratio Normal (mean, SD $10^{-8.07}$, $10^{0.3}$), inhalation rate normal (mean log (22.7), SD 0.06 L/min), exposure duration 21 ± 5 min, exposure frequency mean 2.7 events/year for high rainfall, mean 6.5 events/year for low rainfall	*Campylobacter* spp. (human): 4.5×10^{-2} (95% 1.2×10^{-1})/person/event *Campylobacter* spp. (zoonotic): 2.5×10^{-3} (95% 9.2×10^{-3})/person/event *L. pneumophila*: 1.2×10^{-9} (95% 5.2×10^{-9})/person/event	Sales-Ortells and Medema, 2014, Sales-Ortells and Medema, 2015
Campylobacter[a] *Salmonella* spp. RoV HAdV *Cryptosporidium*[a]	Stormwater harvesting system in residential development, car park, or large urban catchment with ageing infrastructure; avian- or human sewage- driven contamination	Aerosol ingestion by community residents, Hand-to mouth exposure by participants in sporting activities, Hand-to-mouth exposure of council workers watering trees, Accidental drinking incident	Aerosol ingestion 0.1 mL, weekly; hand-to-mouth exposure during sporting activities 1 mL, weekly; hand-to-mouth exposure of tree watering council workers 1 mL, daily; accidental drinking 100 mL, single exposure. Various sources of *E. coli* assumed.	*Campylobacter* aerosols 2.7×10^{-9}-0.1 (95^{th} 1.5×10^{-7}-7.0×10^{-2}); hand-to-mouth 2.7×10^{-8}-0.15 (95^{th} 1.5×10^{-6}-0.12); accidental ingestion 2.7×10^{-6}-0.24 (95^{th} 1.5×10^{-4}-0.21) *Salmonella* spp. aerosols 1.3×10^{-12}-5.0×10^{-5} (95^{th} 4.1×10^{-10}-7.0×10^{-2}); hand-to-mouth 1.3×10^{-11}-0.15 (95^{th} 4.1×10^{-9}-0.12)	Petterson et al., 2016

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Table 3 (*continued*)

Pathogen	Applications	Exposure routes	Exposure frequency and duration	Risk Mean/Median (95th percentile or upper bound) or calculated LRV	References
				Rotavirus: Log reduction credits for 10^{-6} DALY risk open space irrigation 1.3-3.4, drinking 5.5->6.0 (Paget al. 2012)	
HAdV	Irrigation*	Aerosol ingestion, accidental ingestion	Boating 1 mL 52 times/year; irrigation aerosols 1 mL 90 times/year; irrigation accidental ingestion 100 mL 1 time/year.	Log removal credits calculated to achieve 10^{-6} DALY for adenovirus for irrigation (aerosol) 2.3-3.2/1.4-2.5 (95th 2.9-3.8), irrigation (accidental ingestion) 2.4-3.2/1.5-2.5 (95th 2.9-3.8)	Sidhu et al., 2012b
E. coli O157:H7	Riverbank filtration managed aquifer recharge	Ingestion	3.12 ± 1.17 L/day (Normal distribution)	0.115 (no treatment) - 0.00165 DALYs/person/year (with treatment)	Bartak et al., 2015
HAdV NoV	Toilet flushing, showering, and consumption of irrigated lettuce	Aerosol inhalation, aerosol ingestion, lettuce consumption	Four flushes/day, one 20 min shower/ day; Lettuce consumed 90, 180, or 270 times/year. Toilet and shower inhalation volumes calculated based on aerosols produced by fixtures and aerosol volumes.	Adenovirus: Toilet flushing annual infection risk 1.1×10^{-7}-8.9×10^{-7} (95th 2.7×10^{-7}-1.2×10^{-6}); DALY risk 3.0×10^{-9}-2.4×10^{-8} (95th 7.2×10^{-8}-3.1×10^{-8}). Showering annual infection risk 3.6×10^{-7}-5.3×10^{-5} (95th 1.3×10^{-6}-3.5×10^{-4}); DALY risk 1.1×10^{-8}-1.6×10^{-6} (95th 3.5×10^{-8}- 9.3×10^{-6}). Norovirus: Toilet flushing annual infection risk 5.3×10^{-7}- 1.3×10^{-4} (95th 1.6×10^{-6} - 1.34×10^{-4}); DALY risk 1.0×10^{-20}-1.5×10^{-16} (95th 5.3×10^{-19} - 3.2×10^{-15}). Showering annual infection risk 3.4×10^{-4}-4.3×10^{-2} (95th 1.6×10^{-3}- 1.9×10^{-1}); DALY risk 1.1×10^{-14}-6.3×10^{-11} (95th 1.4×10^{-10}- 1.0×10^{-7}). Food crop annual infection risk 8.0×10^{-4}-9.8×10^{-1} (95th 2.6×10^{-2}); DALY risk 8.0×10^{-14}-1.1×10^{-6} (95th 3.3×10^{-10}- 1.8×10^{-5})	Lim et al., 2015
Campylobacter *Cryptosporidium* RoV	Managed aquifer recharge with stormwater	Ingestion	Open space irrigation 1mL, 50/year; toilet flushing 0.01 mL, 1,100/year; drinking 2L/day	Log removals calculated to meet health targets for viruses (1.0-8.6), protozoa (0->10.8), and bacteria (0.5->16.0)	Page et al., 2015
Campylobacter spp. (human) *Campylobacter* spp. (zoonotic) *L. pneumophila*	Recreational exposure to urban stormwater plaza receiving street and roof runoff	Ingestion, inhalation	Ingestion: exposure volume triangular (0, 0.051, 5) mL/event; Inhalation: aerosolization ratio Normal (mean, SD $10^{-8.07}$, $10^{0.3}$), inhalation rate normal (mean log (22.7), SD 0.06 L/min), exposure duration 21 ± 5 min, exposure frequency mean 2.7 events/year for high rainfall, mean 6.5 events/year for low rainfall	*Campylobacter* spp. (human): 4.5×10^{-2} (95% 1.2×10^{-1})/person/event *Campylobacter* spp. (zoonotic): 2.5×10^{-3} (95% 9.2×10^{-3})/person/event *L. pneumophila*: 1.2×10^{-9} (95% 5.2×10^{-9})/person/event	Sales-Ortells and Medema, 2014, Sales-Ortells and Medema, 2015
Campylobacter[a] *Salmonella* spp. RoV HAdV *Cryptosporidium*[a]	Stormwater harvesting system in residential development, car park, or large urban catchment with ageing infrastructure; avian- or human sewage- driven contamination	Aerosol ingestion by community residents, Hand-to mouth exposure by participants in sporting activities, Hand-to-mouth exposure of council workers watering trees, Accidental drinking incident	Aerosol ingestion 0.1 mL, weekly; hand-to-mouth exposure during sporting activities 1 mL, weekly; hand-to-mouth exposure of tree watering council workers 1 mL, daily; accidental drinking 100 mL, single exposure. Various sources of *E. coli* assumed.	*Campylobacter* aerosols 2.7×10^{-9}-0.1 (95th 1.5×10^{-7}-7.0×10^{-2}); hand-to-mouth 2.7×10^{-8}-0.15 (95th 1.5×10^{-6}-0.12); accidental ingestion 2.7×10^{-6}-0.24 (95th 1.5×10^{-4}-0.21) *Salmonella* spp. aerosols 1.3×10^{-12}-5.0×10^{-5} (95th 4.1×10^{-10}-7.0×10^{-2}); hand-to-mouth 1.3×10^{-11}-0.15 (95th 4.1×10^{-9}-0.12)	Petterson et al., 2016

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Table 3 (*continued*)

Pathogen	Applications	Exposure routes	Exposure frequency and duration	Risk Mean/Median (95^{th} percentile or upper bound) or calculated LRV	References
				Rotavirus aerosols 1.4×10^{-3} (95^{th} 4.3×10^{-1}); hand-to-mouth 1.3×10^{-2} (95^{th} 0.21); accidental ingestion 0.31 (95^{th} 1.0) Adenovirus aerosols 1.3×10^{-3} (95^{th} 4.3e-1); hand-to-mouth 1.3×10^{-2} (95^{th} 0.35); accidental ingestion 0.72 (95^{th} 1.0) *Cryptosporidium*[a] aerosols 2.9×10^{-8} (95^{th} 7.7×10^{-7}); hand-to-mouth 2.9×10^{-7} (95^{th} 7.7×10^{-6}); accidental ingestion 2.9×10^{-5} (95^{th} 7.6×10^{-4})	
Campylobacter	Toilet flushing, irrigation, and swimming in stormwater wetland using different stormwater treatments (wetlands, biofilters, and traditional treatment trains)	Aerosol ingestion, routine ingestion (hand-to-mouth)*	Garden irrigation aerosol ingestion 0.1 mL/event, 90 events/person/year; garden irrigation (routine hand-to-mouth exposure) 1 mL/event, 90 events/person/year; Municipal irrigation 100 mL/event, 1 event/person/year; toilet flushing 0.01 mL/event, 1100 events/person/year. Multiple treatment options and dose response models evaluated.	Garden irrigation aerosol ingestion: per infection 1.1×10^{-9} -3.1×10^{-3}, annual risk 1.0×10^{-7}-1.4×10^{-1} (95^{th} 1.4×10^{-7}-7.0×10^{-1}), DALY risk 1.3×10^{-10}-2.2×10^{-1} (95^{th} 2.2×10^{-10}-1.1×10^{-3}) Garden irrigation routine ingestion hand-to-mouth: per infection 1.1×10^{-6} -2.4×10^{-1}, annual risk 1.0×10^{-6}-2.4×10^{-1} (95^{th} 1.6×10^{-6}-4.9×10^{-1}), DALY risk 1.4×10^{-9}-3.9×10^{-4} (95^{th} 2.5×10^{-9}-9.5×10^{-4}) Garden irrigation accidental ingestion: per infection 1.1×10^{-10} -3.7×10^{-4}, annual risk 1.2×10^{-7}-1.7×10^{-1} (95^{th} 1.7×10^{-7}-7.8×10^{-1}), DALY risk 1.6×10^{-10}-2.7×10^{-4} (95^{th} 2.7×10^{-10}-1.2×10^{-3}) Municipal irrigation: per infection 1.1×10^{-8} -2.6×10^{-3}, annual risk 1.0×10^{-6}-1.4×10^{-1} (95^{th} 1.4×10^{-6}-6.1×10^{-1}), DALY risk 1.3×10^{-9}-2.3×10^{-4} (95^{th} 2.2×10^{-9}-2.3×10^{-4}) Toilet flushing: per infection 1.1×10^{-8} -2.4×10^{-1}, annual risk 5.6×10^{-7}-2.4×10^{-1} (95^{th} 7.9×10^{-7}-4.7×10^{-1}), DALY risk 7.2×10^{-10}-3.9×10^{-4} (95^{th} 1.2×10^{-9}-9.3×10^{-4})	Murphy et al., 2017
Mastadenovirus (adenovirus) Norovirus *Campylobacter* spp. *Salmonella* spp. *Giardia* spp. *Cryptosporidium* spp.	Indoor use (toilet flushing and clothes washing), accidental ingestion of treated non-potable water (cross-connection with potable water), unrestricted outdoor irrigation, drinking	Ingestion	Toilet flushing (3×10^{-5} L/day, 365 d/y), clothes washing (1×10^{-5} L/day, 365 d/y), irrigation and dust suppression (1×10^{-3} L/day, 50 d/y), Cross-connection of treated water with potable water (2 L/day, 1 day/year, 10% of population exposed), potable consumption (2 L/day, 365 days). Multiple dose response models used.	Log removals to achieve target concentrations associated with a 10^{-4} annual infection risk calculated: Norovirus: toilet flushing 2.5-7.3, unrestricted irrigation 3.2-8.0, indoor use 5.0-7.9, drinking 9.3-12.4. Mastadenovirus: toilet flushing 2.1-4.1, unrestricted irrigation 2.8-4.8, indoor use 3.9-5.9, drinking 6.9-8.9 *Cryptosporidium* spp.: toilet flushing 0.8-3.8, unrestricted	Schoen et al., 2017

Table 3 (*continued*)

Pathogen	Applications	Exposure routes	Exposure frequency and duration	Risk Mean/Median (95th percentile or upper bound) or calculated LRV	References
				irrigation 1.6-4.5, indoor use 2.8-5.7, drinking 5.7-8.6	
				Giardia spp.: toilet flushing 0.5-2.5, unrestricted irrigation 1.3-3.3, indoor use 2.5-4.5, drinking 5.4-7.4	
				Campylobacter spp.: toilet flushing 1.4-3.4, unrestricted irrigation 2.1-4.1, indoor use 3.1-5.1, drinking 6.2-8.2	
				Campylobacter spp.: toilet flushing 0-1.8, unrestricted irrigation 0.6-2.6, indoor use 1.8-3.8, drinking 4.6-6.6	

[a] Species not specified and based on surrogate data; dose response models for *C. jejuni*, *S. enterica*, *Cryptosporidium* spp. were used; *only potable and non-potable exposure scenarios included

et al., 2012a, 2012b; McBride et al., 2013; Sales-Ortells and Medema, 2015), limiting the ability to capture the large variability in stormwater pathogen concentrations due to potentially diverse fecal contamination sources (human and multiple animal fecal wastes, affecting the types of index pathogens chosen for the QMRA), rainfall patterns, decay rates, and other factors.

Monitoring efforts conducted to inform QMRAs by Petterson et al. (2016) and McBride et al. (2013) confirmed that variability in pathogen concentration is indeed high between rainfall and baseline events. There is therefore a need to look at a scenario-conditional risk estimate (sometimes referred to as "conditional risk"), rather than averaging or annualizing over time without regard to rainfall events. Pathogens can survive on urban surfaces and building materials, for example, and could furthermore be introduced into stormwater during subsequent rain events without the presence of an ongoing fecal source. This further supports the need for comparison of stormwater wet-weather risks with dry event (baseline) risks (Taylor et al., 2013).

Some of the principal challenge in conducting a QMRA for stormwater is determining the concentration of pathogens in stormwater discharges or harvesting systems, and addressing the complexities of their transport and inactivation prior to arrival at a human receptor. In lieu of a detailed hydrodynamic or fate and transport models for pathogens, simplified assumptions of decay and dilution between a pathogen source and human receptor are often made. Dilution factors are sometimes applied to estimate pathogen loads between stormwater and receiving recreational bodies; for example, McBride et al. (2013) used a 30-fold dilution factor applied to the concentrations of pathogens observed in stormwater discharges. Other studies have applied an estimated microbial decay factor for particular pathogens or indicators as surrogates for pathogens in stormwater, sometimes also coupled with a dilution factor (Petterson et al., 2016; Lim et al., 2015). The use of hydrodynamic mixing and inactivation models such as those applied by Andersen et al. (2013) could be used to obtain more accurate site-specific dilution information, or a distribution of dilution factors could be incorporated into a Monte Carlo approach in QMRA models as performed in Soller et al., 2017.

Improved characterization of different removal values for bacteria, protozoans and viruses in stormwater treatment processes can also improve QMRA estimates, as previous estimates have been based on FIB rather than pathogens themselves due to limited data (Davies et al., 2008; Page et al., 2010a, 2010b, 2010c, 2010d; Petterson et al., 2016). Limited information is available for pathogen removal by stormwater treatment barriers and would be informative for conducting risk analyses. Additionally, these values can be compared with theoretical LRVs necessary to meet health risk targets (NRMMC-EPHC-AHMC, 2009; Page et al., 2015; Schoen and Garland, 2015; Schoen et al., 2017).

As stormwater concentrations of pathogens cannot always be directly measured, impacts to stormwater can also be estimated; Petterson et al. (2016) modelled avian contamination of stored stormwater resources with birds colonized by *Campylobacter* and *Salmonella* as well as pathogen inputs from human sewage using an epidemiologic approach, making use of information about disease incidence, pathogen excretion and known sewage flow rates to approximate loading rates in a typical sewage. Several recent studies used QMRA analysis to determine HF183 concentrations that represent human health risks to swimmers based on the recreational water quality criteria (RWQC) risk benchmark of 36/1000 primary contact recreators (USEPA, 2012a; Boehm et al., 2015; Ahmed et al., 2018d). Such approaches can also be undertaken to determine the health risks associated with different stormwater end use where the pathogen data is lacking or not available.

QMRA can be a useful tool for examining the potential human health risks related to rainfall events and can inform risk management practices (Bichai and Ashbolt, 2017). These assessments show that there are non-trivial risks associated with the use of stormwater resources to supplement water portfolios and in some cases guidelines are not sufficient to mitigate risks (Murphy et al., 2017). This is needed as stormwater harvesting areas can create new opportunities for comingling of potential animal habitats or reservoirs for animal fecal material and human recreational environments, where transmission of fecal pathogens can occur (Sales-Ortells and Medema, 2015; Petterson et al., 2016). While acknowledging the utility of QMRA, caution must be exercised when comparing risk estimates from QMRAs employing different methodologies. For example, a direct comparison of annual infection risks and annual disability adjusted life years (DALYs) (pppy) should be interpreted carefully as these methodologies can lead to different risk conclusions when compared to guideline values (Lim et al., 2015). Furthermore, it has been suggested that drinking water benchmarks could be too stringent for comparison with alternative water uses in some cases and warrants consideration of the development of more applicable guideline values (Mara, 2011; Schoen and Garland, 2015).

6. Reduction of microbial contaminants through WSUD/BMPs

Elevated levels of microbial contaminants in stormwater is of great concern for water safety. As a result, there is regulatory pressure to remove contaminants so that risk benchmarks can be met. A variety of microbial contaminant mitigation measures can be used including the implementation of various types of stormwater infrastructure (Thurston et al., 2001; Struck et al., 2008). Fletcher et al. (2015) undertook a review of terminology associated with urban stormwater management in different countries. The terms reviewed included: WSUD, BMPs, Integrated Urban Water Management (IUWM), Low Impact Urban Design and Development (LIUDD), Low Impact Development (LID), Green Infrastructure, and Sustainable Urban Drainage Systems (SUDS). Their review identified that whilst the concepts are all underpinned by the principles of reducing disturbance to natural hydrology and mitigating the water quality impacts of urbanisation, there are subtle differences in the scope and focus of terms (Fletcher et al., 2015). However, for the purposes of this review the terms can be considered broadly analogous and are hereafter referred to as "WSUD".

WSUD takes an integrated approach to managing stormwater that protects public health, while also mitigating the environmental impacts of urban development and provides for improved community amenity. WSUD has the objective of reducing the impact of urbanisation on the natural water cycle, and its principles can be applied at a range of scales (Lloyd et al., 2002). Davies (1996) proposed that, fundamentally, WSUD strives to maintain the water balance and water quality of an urbanized environment in much the same state as prior to urbanisation.

The approaches taken to implement WSUD will depend upon the development context and drivers for the adoption of WSUD. WSUD approaches often use a 'treatment train' where a series of treatment approaches are used to meet stormwater objectives. The approaches applied will depend upon the catchment characteristics, climate conditions and discharge requirements. Often the initial stages of a WSUD treatment train will focus on the removal of coarse sediments, which can help improve the treatment effectiveness of subsequent stages that use filtration and/or biological processes. In addition to the WSUD treatment approaches summarized below, non-structural catchment-scale approaches can be used to improve quality of runoff discharged to receiving waters (Wong, 2006). This can include buffers around waterways that limit potentially polluting land uses, and the revegetation of riparian zones. For example, Bryan et al. (2009) described the use of an adaptive management framework to reduce *Cryptosporidium* risk in an agricultural catchment in South Australia.

Although information regarding the degree of pathogen removal from various WSUDs can help for water quality managers and urban planners to design and maintain systems that adequately protect public health, data available on specific LRVs of pathogens through WSUD is limited (NRMMC-EPHC-NHMRC, 2009). Most studies have employed FIB to derive the LRVs of microbial removal in specific WSUD treatment processes and as such, and there is much less information on the removal of specific pathogens such as viruses and protozoa which have very different physico-chemical characteristics. A range of factors have an impact on the treatment capability of WSUD systems. The removal of pathogens varies from system to system and therefore, it may be useful to assess individual systems *in-situ* to account for local variability resulting from factors such as sedimentation, sunlight exposure, water temperature, and adsorption/desorption with biofilms (Jiang et al., 2015). Peng et al., 2016 highlighted that most microbe focused studies of stormwater biofilters focus on FIB, which are measured by culture-based methods, and less frequently by molecular based methods. These studies may be difficult to extrapolate to pathogens. There are few studies on the removal of pathogens, particularly viruses, in stormwater by biofiltration. Peng et al. (2016) also noted the need for more studies that use field-based measurements, rather than laboratory settings, as it captures the more variable and complex features of the urban environment that influences how effective WSUD approaches are likely to be in reducing pathogen loads.

One key resource for LRV in WSUD is the International Stormwater BMP Database. The database contains approximately 600 pairs of influent and effluent data for fecal coliforms and *E. coli*. Among the 600 pairs, 100 pairs belong to *E. coli* from 12 sites in Portland, Oregon and the remaining 500 pairs are fecal coliform collected from 61 sites in California, Florida, Virginia, Ontario, New York, Texas, Georgia, North Carolina, and Oregon. Clary et al. (2008) analyzed the fecal coliform and *E. coli* datasets in the International Stormwater BMP database and provided results on how BMPs can effectively reduce fecal indicator concentrations in order to assist in meeting total maximum daily load (TMDL) goals. Swales and detention basins did not appear to effectively reduce FIB in effluent samples. Datasets for wetlands and manufactured devices were not of adequate size to draw meaningful conclusions. The authors concluded that the ability of BMPs to reduce FIB varies widely within BMP categories. No single BMP appears to be able to consistently reduce FIB in effluent to levels below instream primary contact recreation standard. Among the BMPs, retention pond and media filters appeared to have potential for bacteria removal in effluent.

Chandrasena et al. (2016) studied the removal of *E. coli* and *Campylobacter* spp. from urban stormwater by field-scale biofilters. *E. coli* LRVs (average 1.23–1.39 LRVs) were greater than that of *Campylobacter* spp. (average 0.88–0.99 LRVs) in both biofilters. The authors did not find any correlation between *E. coli* and *Campylobacter* spp. log removal performance suggesting that single organisms should not be employed to understand pathogen removal in urban stormwater treatment systems.

Such variations may affect performance evaluation as well as the impact of other factors including the selection of plants, use of a submerged zone in biofilters, and operation under wet vs. dry conditions (Jiang et al., 2015; Chandrasena et al., 2016). Generally, a one $\log_{10}$ removal of FIB and pathogens can be expected if biofilters are properly designed accordingly to local guidance (Bichai and Ashbolt, 2017). However, the performance of such systems can be site specific, and therefore, undertaking in situ validation of specific devices has been recommended (Payne et al., 2015). While individual WSUD technologies performances are available, there is an expectation that there would be an improved or increased performance for the removal of contaminants when water is passed through a series of WSUD technologies prior to (re)use (Vogel et al., 2015).

This not only can increase the amount of contaminants removed, but can also enable a level of redundancy to be built in so that if treatment of an individual WSUD technologies declines, the resulting reduction in treatment capacity is covered by the rest of the WSUD treatment system. In addition, residence time is important for the removal of microorganisms, so the longer water is held within a WSUD treatment system, the greater the pathogen removal rates.

Table 4 provides information on the studied removal capacity of a range of WSUD treatment systems. While there is variability in the removal capacity of the different reported WSUD systems, in general all of these systems achieved 0.5 to 1 LRV for FIB and the bacterial pathogen *Campylobacter*. The results also show that bacterial removal is faster (or higher) than viral and protozoan pathogens, which tend to be more resistant to treatment processes, and therefore more able to survive through the different WSUD treatments. This is due to the differences in size surface characteristics, mode of reproduction and life cycle of viruses and protozoa which are different than those of bacteria (Hoff and Akin, 1986). In general, sequential treatment systems with a series of ponds, wetlands or combinations tend to improve pathogen removal from source water. For example, Reinoso et al. (2008) evaluated the removal of a variety of traditional and alternative fecal indicators such as coliphages, total coliform, *E. coli*, fecal streptococci and *C. perfringens* and pathogens such as *Cryptosporidium* spp. and *Giardia* spp. from domestic sewage in a treatment train including pond storage followed by surface and subsurface wetlands, with the overall *Cryptosporidium* and *Giardia* removal efficiency found to be as high as two $\log_{10}$. A new potential WSUD treatment component currently being studied is the addition of heavy metal (e.g., copper) labelled zeolite to filtration bed media. Laboratory research has demonstrated that copper coated zeolite can have LRV capability for bacteria such as *E. coli* greater than three $\log_{10}$ (Li et al., 2012). Stormwater can also be contaminated with viral and protozoan pathogens, both of which have higher treatment requirements than bacteria. However, the information on the effect of zeolites coated with heavy metals on these enteric non-bacterial pathogens is very limited. Silver/copper coated zeolites could reduce coronavirus by 2–3 LRVs (Bright et al., 2009) and silver-impregnated filtration pots reduced *Giardia* and *Cryptosporidium* by at least 96% (~1.5 LRV) (Adeyemo et al., 2015). More research would be needed to assess the treatment potential of copper-coated zeolite on a range of enteric viruses and protozoa under in-field conditions before its use could be justified as beneficial for the cost, particularly for the removal of pathogens.

7. Stormwater treatment and risk mitigation

Stormwater harvesting systems generally require some level of treatment to minimise operational risks. Additional treatment may also be required for higher exposure uses to manage human health and environmental risks. The operational risks relating to stormwater quality are usually managed by the use of BMPs/WSUDs. For example gross pollutant traps and vegetated swales to remove sediment and leaves entering the stormwater harvesting scheme and potentially blocking pipes, irrigation nozzles or drip irrigation systems, or damaging pumps. Use of wetlands and bio retentive systems can also assist in reducing high loads of organic matter (e.g. leaf fall) as well as removing nitrogen and phosphorus through phytoremediation. Additional levels of treatment are often required to manage human health risks, where stormwater from a sewered residential catchment is used for public, open-space irrigation (e.g. in schools and sporting ovals). Here, human health risks can be managed by the use of on-site access controls to minimise exposure to irrigation water. For example, the use of withholding periods on public recreation ovals has been recommended to reduce the risks from pathogens (Page et al., 2014b).

Additional treatments may be required for higher exposure usages, for example the Australian Guidelines for Stormwater Harvesting and Reuse (NRMMC-EPHC-NHMRC, 2009) describes the derivation of these criteria in terms of LRVs and also lists default LRV values for a range of engineered treatments. These accepted default LRV tables can be then used along with catchment specific knowledge where possible exposure controls are used to determine the required level of treatment for pathogens. For example, Page et al. (2012) reported that risks from viruses have the highest required LRV targets and if they are met then protozoan and bacterial LRV targets will also be met. It was reported that for open space irrigation requires <2.0 LRV is sufficient for stormwater recycled via an aquifer and this can potentially be managed using chlorination and exposure controls. However, if in the same system where stormwater is recycled via an aquifer were to be used for drinking water, a LRV of 5.5 would be required to manage human health risks from viruses (Page et al., 2014c). Generally these default LRVs apply where there has been no stormwater catchment-specific assessment of the health risks posed by the quality of the stormwater. Where such a site specific risk assessment has been performed, alternative treatment could be adopted (e.g., lower LRV targets may be adopted where microbial source tracking has found negligible sewage contamination in a catchment).

8. Research gaps and conclusions

- Monitoring of FIB in stormwater may not be useful unless synergistically used with MST marker genes such as HF183, crAssphage or Lachno3 which are able to differentiate between sources of fecal contamination. This will provide additional information on the human health risks associated with stormwater from point and non-point sources of fecal contamination. Identifying and quantifying sources of human sewage in stormwater is most important followed by cattle due to the presence of a wide array of enteric viruses and zoonotic pathogens in these sources.
- The concentration of pathogens in stormwater, outfalls and receiving environmental waters can be high, especially in urban areas. Monitoring of traditional FIB takes 24–48 h and does not provide real-time information on the quality of recreational water. This is important from a human health perspective. Swimming area closure causes economic losses. Therefore, it is recommended that a rapid pathogen monitoring toolbox and standardized methods need to be developed that are able to quantify a number of reference pathogens in waterbodies with increased accuracy, reliability, and less technical training under various conditions. The toolbox can be used either in the laboratory or in the field to provide a rapid assessment whether the stormwater from a particular storm event presents a hazard to public health.
- Most of the stormwater quality monitoring studies focused on determining the concentrations of pathogens in urban stormwater. However, more data is required on the concentration of pathogens in stormwater sourced from a range of land uses. While sewage discharges are relatively well characterized, there remain gaps in our understanding of runoff from nonpoint sources. More studies are required to determine the concentrations of zoonotic pathogens in stormwater.
- Fecal contamination in stormwater is largely dependent on the land uses and mostly include sewage, septage and various animal feces. Therefore it is imperative to determine the sources of contamination. This will in turn provide a basis for cost-effective remediation and information on the immediate human health risks in stormwater impacted waters. Currently used FIB monitoring approaches are inadequate due to their presence in both human and animal feces. An MST toolbox comprised of various human and animal feces-associated marker genes needs to be employed which will allow managers to quickly identify the relative contribution of point and non-point sources of fecal contamination.
- The quality of stormwater in terms of microbial contaminants is poorly understood. Microbial risk will be the dominant acute health risks on stormwater reuse due to the risk of waterborne pathogens (Hrudey and Hrudey, 2014). However, in some cases, chemical risks may be the driving health concern and relationships between multi-contaminant exposures should be explored. Few QMRA studies addressing potable and non-potable exposures to stormwater were available. Most of the QMRA studies are based on conservative assumptions. More data are required on the concentrations of pathogens and recovery from water samples across sites and stormwater hydrographs. In addition, improved understanding of the influence of catchment characteristics and baseline levels of pathogens, meteorological factors, and decay of pathogens is required for accurate QMRA estimates.
- Different types of WSUD and BMPs are able to reduce microbial contamination, however, reliable information is still lacking on the performance of these treatment barriers. Standardized natural treatment validation protocol needs to be developed. Most studies determined the efficacy of WSUD or BMPs on the removal of microorganisms using FIB, while one or two studies investigated the LRVs of protozoa pathogens such as *Cryptosporidium* spp. or *Giardia* spp. Given the differences in size and characteristics of different groups of pathogens, it is unlikely that FIB LRVs will be representative for pathogens especially enteric viruses. Therefore, studies should focus on determining the removal of enteric viruses and other pathogens (i.e., bacterial and protozoans) of interest to determine the removal rates through different types of WSUD and BMPs, simultaneously. These data will be important for evaluating the effectiveness of WSUD/BMPs for reducing microbial contaminants in the receiving environments and can support improved QMRA models. The evaluation will focus not only on the performance of individual component of WSUD/BMPs but also on a series of different types of BMPs.
- Little is known regarding the decay of pathogens in stormwater or outfalls, and the relative differences in persistence between FIB, pathogens, and host-associated markers. As stormwater becomes aged,

Table 4
Percentage of log reduction values (LRVs) of FIB and pathogens through WSUD.

WSUD approach	Study description	Location (climate)	Development setting	FIB and pathogens (influent concentrations)	% or Log Reduction Value(LRVs)	Notes and Reference
Retention ponds	Experimental testing of retention pond to investigate environmental mechanisms that influence microbial removal efficiency	Edison, N.J., USA (humid continental)	Experimental design with prepared bacterially loaded stormwater	*E. coli* (approx. 5.30 $\log_{10}$ CFU/100 mL)	1	Highlights importance of detention time, where concentration decreases exponentially with time (up to 50 h residence) Struck et al., 2008
	A wet pond monitored as part of a WSUD (BMPs) pilot evaluation (waterfowl freq. observed)	North Carolina, USA (humid subtropical)	Residential catchment of 48.6 ha	*E. coli* (3.95 $\log_{10}$ CFU/100 mL) Fecal coliform (3.32 $\log_{10}$ CFU/100 mL)	0.26 0.52	Log reduction value from geometric mean of influent and effluent samples Hathaway et al., 2009
Constructed wetland	Constructed wetland monitored as part of a WSUD (BMPs) pilot evaluation	North Carolina, USA (humid subtropical)	Residential catchment of 6.4 ha	*E. coli* (3.98 $\log_{10}$ CFU/100 mL) Fecal coliform (3.38 $\log_{10}$ CFU/100 mL)	0.18 0.35	Log reduction value from geometric mean of influent and effluent samples Hathaway et al., 2009
	Secondary treated sewage flows into duckweed pond followed (6 days HRT) followed by subsurface flow wetland (3.8 days HRT)	Arizona (very hot summers and mild winters)	Secondary treated sewage flows into duckweed pond followed by subsurface flow wet land	*Giardia* (1.14 $\log_{10}$ cysts/100 L) Coliphage (2.39 $\log_{10}$ PFU/mL) Fecal coliforms (3.86 $\log_{10}$ CFU/100 mL)	87% 95% 98%	subsurface flow wetland cells have a maximum depth of 1.4 m and are 61 m long and 8.2 m wide, planted with *Typha domingenisis*, *Scirpus olneyi*, and *Populus fremontii*, total HRT of 10 days Thurston et al., 2001
	Trickling filter process treated sewage flows into surface flow wetland	Arizona (very hot summers and mild winters)	Urban sewage	Adenovirus (2.79–5.17 $\log_{10}$ GC/L)	<1	The wetlands ~0.03 km2 in size, consisting of planted bulrush and cattails, 7 days HRT, removal calculated from inflow and outflow virus data Rachmadi et al., 2016
	Surface flow wetland, where outflow is harvested, where it undergoes comprehensive treatment train, then used for non-potable uses. This study reports on pathogen reductions from wetland inflow to outflow	Melbourne, Australia (temperate)	Mixed-use catchment of 1020 ha mostly low-density residential (23% impervious)	*Campylobacter* spp. (2.23–2.99 $\log_{10}$ MPN/L) *E. coli* (2.60–4.00 $\log_{10}$ MPN/L)	0.05 (−0.9–1.25) 0.96 (0.19–1.79)	*E. coli* found to poor indicator for *Campylobacter* as a reference pathogen Direct fecal deposition by waterfowl feces was a microbial source to stormwater wetlands, and explained variable results. Meng et al., 2018
Biofilter	Stormwater harvesting scheme that supplements irrigation water to suburban golf club	Melbourne, Australia (temperate)	SW collected from 17 ha residential catchment (70% impervious)	*Campylobacter* spp. (1.00 $\log_{10}$ CFU/L) *E. coli* (4.79 $\log_{10}$ CFU/L)	0.78 (0.35–1.57) 1.38 (0.4–1.84)	Median values with min and max in parentheses Chandrasena et al., 2016
	Field-scale testing system	Melbourne, Australia (temperate)	Treating runoff from 0.5 ha university car park (100% impervious)	*Campylobacter* spp. (1.47 $\log_{10}$ CFU/L) *E. coli* (5.30 $\log_{10}$ CFU/L)	0.90 (−0.28–2.05) 1.18 (0.82–1.80)	Median values with min and max in parentheses Chandrasena et al., 2016
	Laboratory experimental set-up	Melbourne, Australia (temperate)	Water taken from nearby wetland, then dosed with pathogen seed cultures	*Clostridium perfringens* (3.79 $\log_{10}$ CFU/100 mL) *E. coli* (4.95 $\log_{10}$ CFU/100 mL)	3.20 1.30	Mean values for all sampling runs. Performance was significantly reduced for samples taken following dry period compared to wet periods. Li et al., 2012

pathogens will start to decay and as result, the human health risks will also decrease. Studies should focus on determining the decay of pathogens in stormwater and outfalls or recreational water contaminated with stormwater. *In-situ* decay studies are preferable over laboratory microcosm studies where it is difficult to mimic real world scenarios.

9. Conclusions

Stormwater reuse can contribute to water conservation and water quality improvement and be a great water source to meet the ever-increasing demand on water supplies. However, human and environmental health risks associated with stormwater need to be assessed carefully. This is due to the presence of fecal pollution and associated pathogen in stormwater that are capable of causing illnesses in humans. The research gaps discussed in this paper and other uncertainties associated with the performance of stormwater treatment systems needs to be investigated. Health risks can be assessed using a QMRA analysis, thus facilitating decision-making and risk management efforts. This may, in turn, increase the confidence of regulators and public health managers for adopting stormwater practice widely.

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Exhibit “D”

Re: Hearing Examiner Case Number: HE-25-PL-027

Failure to Disclose: The existence of privately owned livestock in North Chuckanut Bay. See page 3 of 16 of the attached JARPA Permit.

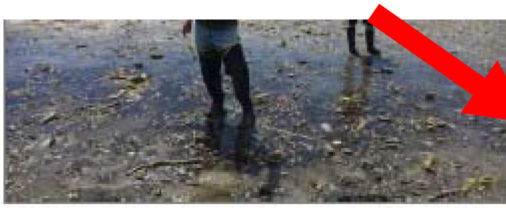
Exhibit “D” clarifies the ownership of livestock (Live Oysters and their offspring) which were placed in North Chuckanut Bay in 2018.

Exhibit “D” contains the following:

1. **Email cover sheet from Cindy Coffelt, Permit Clerk, of the Planning & Community Department.** This email was provided in response to a public records request.
   a. **Copy of JARPA Permit: Authorized “a designated use in water” per the requirements of the Clean Water Act. In this instant case, the designated use was the placement of MRC owned livestock (Live Juvenile Olympia Oyster Spat) in the waters of North Chuckanut Bay.**
   b. **Copy of City of Bellingham Shoreline Use Permit: Authorized the placement of MRC owned livestock (Live Juvenile Olympia Oyster Spat) in a city tide flat park.**
2. **The following Snippet is from:**

   Page 4 of a copy of “Oly oysters MRC notes.pdf”.

   a. **This snippet indicates the MRC purchased the “livestock” from the Puget Sound Restoration Fund. This information was provided to the Planning Department for the benefit of the Planning Department.**



information on feasibility of restoration in the seven habitat patches identified.

The MRC purchased 35 bags of seed on Pacific Oyster shell from the Puget Sound Restoration Fund (PSRF). Each bag had a minimum of 250 shells and 3-5 spat (or seed) per shell. On May 11, 2017, the bags were delivered to Whatcom MRC members and placed at a secure location in Fidalgo Bay for overwintering (Figure B), as suggested by PSRF staff and Dr. Paul Dinnel, who has led Olympia oyster restoration projects for the Skagit MRC. The MRC aims to deploy the seed in Chuckanut Bay by Spring 2018. The actual restoration design if pursued would attempt to address any factors identified from the test plot results that may limit success. Identifying those potential limiting factors ahead of time will be very helpful when evaluating what is observed from the

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2018 JARPA Permit and Shoreline Use Permit info for the placement of MRC owned livestock (Live Olympia Oysters Spat) in North Chuckanut Bay.

1. The following email was provided in response to a public records request.
2. This email provided copies of the "issued permits" and a copy of Whatcom County Marine Resource Committee document "**Oly oysters MRC notes.pdf**".

DCLongwell

From: Cindy L Coffelt <clcoffelt@cob.org>
Sent: Wednesday, August 20, 2025 11:40 AM

Subject: SHR2018-0010
Attachments: SHR2018-0010.pdf; OLY oysters JARPA.pdf; OLY oysters MRC notes.pdf; SHR2018-0010 EXEMPTION APPROVAL.pdf

Find Additional Permit Center Resources at: https://www.cob.org/services/permits

The Permit Center is open for in-person services during the following hours:
Mon, Tues, Thurs 8:30am – 3:30pm/Wed: 9:30am – 3:30pm/Fri: Closed to in-person services
We are available by phone 360.778.8300 and email permits@cob.org Mon-Fri 8am-5pm and eTRAKiT portal https://permits.cob.org/etrakit 24/7.

Cindy Coffelt
Permit Clerk
Planning and Community Development
360-778-8309
clcoffelt@cob.org

City of Bellingham WASHINGTON

Tell us how we're doing!
Permit Center survey

Please note: My incoming and outgoing email messages are subject to public disclosure requirements per RCW 42.56

See page 1 of 20 of Exhibit "D" for a Snippet of page 4 of:

- **Oly oysters MRC notes.pdf**

This Snippet clarifies: The MRC purchased their livestock from the Puget Sound Restoration Fund.

There are no indications of transfer or grant of ownership of MRC owned livestock (Live Olympia Oysters or their offspring) to The Woods at Viewcrest permit applicant (The Jones Family) or to the City of Bellingham on this page.

AGENCY USE ONLY

Date received:

Agency reference #: ____________

Tax Parcel #(s): ____________

WASHINGTON STATE

Joint Aquatic Resources Permit Application (JARPA) Form[1,2] [help]

US Army Corps of Engineers Seattle District

USE BLACK OR BLUE INK TO ENTER ANSWERS IN THE WHITE SPACES BELOW.

Part 1–Project Identification

1. Project Name (A name for your project that you create. Examples: Smith's Dock or Seabrook Lane Development) [help]
North Chuckanut Bay Pilot Olympia Oyster Restoration Project

Part 2–Applicant

The person and/or organization responsible for the project. [help]

2a. Name (Last, First, Middle)			
Austin Rose			
2b. Organization (If applicable)			
Whatcom County Marine Resources Committee			
2c. Mailing Address (Street or PO Box)			
322 N. Commercial St.			
2d. City, State, Zip			
Bellingham, WA 98225-4042			
2e. Phone (1)	**2f.** Phone (2)	**2g.** Fax	**2h.** E-mail
360-778-6286			arose@co.whatcom.wa.us

[1]Additional forms may be required for the following permits:

- If your project may qualify for Department of the Army authorization through a Regional General Permit (RGP), contact the U.S. Army Corps of Engineers for application information (206) 764-3495.
- If your project might affect species listed under the Endangered Species Act, you will need to fill out a Specific Project Information Form (SPIF) or prepare a Biological Evaluation. Forms can be found at http://www.nws.usace.army.mil/Missions/CivilWorks/Regulatory/PermitGuidebook/EndangeredSpecies.aspx.
- Not all cities and counties accept the JARPA for their local Shoreline permits. If you need a Shoreline permit, contact the appropriate city or county government to make sure they accept the JARPA.

[2]To access an online JARPA form with [help] screens, go to http://www.epermitting.wa.gov/site/alias__resourcecenter/jarpa_jarpa_form/9984/jarpa_form.aspx.

For other help, contact the Governor's Office for Regulatory Innovation and Assistance at (800) 917-0043 or help@oria.wa.gov.

There are no indications of transfer or grant of ownership of MRC owned livestock (Live Olympia Oysters or their offspring) to The Woods at Viewcrest permit applicant (The Jones Family) or to the City of Bellingham on this page.

Part 3–Authorized Agent or Contact

Person authorized to represent the applicant about the project. (Note: Authorized agent(s) must sign 11b of this application.) [help]

3a. Name (Last, First, Middle)			
Rose, Austin			
3b. Organization (If applicable)			
Whatcom County Public Works			
3c. Mailing Address (Street or PO Box)			
322 N. Commercial St.			
3d. City, State, Zip			
Bellingham, WA 98225-4042			
3e. Phone (1)	**3f.** Phone (2)	**3g.** Fax	**3h.** E-mail
360-778-6286			arose@co.whatcom.wa.us

Part 4–Property Owner(s)

Contact information for people or organizations owning the property(ies) where the project will occur. Consider both **upland and aquatic** ownership because the upland owners may not own the adjacent aquatic land. [help]

☐ Same as applicant. (Skip to Part 5.)

☐ Repair or maintenance activities on existing rights-of-way or easements. (Skip to Part 5.)

☐ There are multiple upland property owners. Complete the section below and fill out JARPA Attachment A for each additional property owner.

☐ Your project is on Department of Natural Resources (DNR)-managed aquatic lands. If you don't know, contact the DNR at (360) 902-1100 to determine aquatic land ownership. If yes, complete JARPA Attachment E to apply for the Aquatic Use Authorization.

4a. Name (Last, First, Middle)			
n/a			
4b. Organization (If applicable)			
City of Bellingham Finance Dept.- Asset Division			
4c. Mailing Address (Street or PO Box)			
210 Lottie St.			
4d. City, State, Zip			
Bellingham, WA 98225-4009			
4e. Phone (1)	**4f.** Phone (2)	**4g.** Fax	**4h.** E-mail

There are no indications of transfer or grant of ownership of MRC owned livestock (Live Olympia Oysters or their offspring) to The Woods at Viewcrest permit applicant (The Jones Family) or to the City of Bellingham on this page.

The Woods at Viewcrest permit applicant (The Jones Family) "Failure to Disclose" the existence of MRC owned livestock (Live Olympia Oysters and their offspring) in North Chuckanut Bay. See Box 5h below.

Part 5–Project Location(s)

Identifying information about the property or properties where the project will occur. [help]

☐ There are multiple project locations (e.g. linear projects). Complete the section below and use JARPA Attachment B for each additional project location.

5a. Indicate the type of ownership of the property. (Check all that apply.) [help]

☐ Private
☐ Federal
☒ Publicly owned (state, county, city, special districts like schools, ports, etc.)
☐ Tribal
☐ Department of Natural Resources (DNR) – managed aquatic lands (Complete JARPA Attachment E)

5b. Street Address (Cannot be a PO Box. If there is no address, provide other location information in 5p.) [help]

5c. City, State, Zip (If the project is not in a city or town, provide the name of the nearest city or town.) [help]

Bellingham, WA

5d. County [help]

Whatcom

5e. Provide the section, township, and range for the project location. [help]

¼ Section	Section	Township	Range
	13	T37N	R02E

5f. Provide the latitude and longitude of the project location. [help]

- Example: 47.03922 N lat. / -122.89142 W long. (Use decimal degrees - NAD 83)

48.699142, -122.50408

5g. List the tax parcel number(s) for the project location. [help]

- The local county assessor's office can provide this information.

3702131514090000

5h. Contact information for all adjoining property owners. (If you need more space, use JARPA Attachment C.) [help]

Name	Mailing Address	Tax Parcel # (if known)
Lori L. Lawler	P.O. Box 885 Granite Falls, WA 98252-0885	370213017397
Elizabeth A. & Susan H. Jones	807 Chuckanut Shore Rd. Bellingham, WA 98229-8925	370213083499
Edward P. McAllister	608 E. Galloway Ave. Weiser, ID 83672-1424	370213112500
Ann C. Jones Family	807 Chuckanut Shore Rd. Bellingham, WA 98229-8925	370213113550

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There are no indications of transfer or grant of ownership of MRC owned livestock (Live Olympia Oysters or their offspring) to The Woods at Viewcrest permit applicant (The Jones Family) or to the City of Bellingham on this page.

5i. List all wetlands on or adjacent to the project location. [help]
Chuckanut Village Marsh, Chuckanut Creek Marsh
5j. List all waterbodies (other than wetlands) on or adjacent to the project location. [help]
Chuckanut Bay (Mud Bay), Chuckanut Creek (adjacent to)
5k. Is any part of the project area within a 100-year floodplain? [help]
☒ Yes ☐ No ☐ Don't know
5l. Briefly describe the vegetation and habitat conditions on the property. [help]
North Chuckanut Bay is characterized as mostly mud/sand/silt mixture. Barnacles, oysters, clams, snails, mussels, and sand dollars can be found in the project area, with some areas heavily covered by these organisms while others very sparse. Eelgrass can be found at sites closer to the trestle. Macroalgae can cover the bay at low tides, but is ephemeral and is not a dominate presence.
5m. Describe how the property is currently used. [help]
N Chuckanut Bay is a rich and biologically diverse estuary within Bellingham city limits. Visitors to the area enjoy birding, beach walks, wildlife, shoreline geology, botanical observation, and shellfish gathering as allowed within State permit and Health regulations.
5n. Describe how the adjacent properties are currently used. [help]
The South Hill and Edgemoor neighborhoods are located to the north of the bay. Woodstock Farm Park, owned by the City of Bellingham, lies south of the bay.
5o. Describe the structures (above and below ground) on the property, including their purpose(s) and current condition. [help]
n/a
5p. Provide driving directions from the closest highway to the project location, and attach a map. [help]
From I5 North, take exit 250, head west on Old Fairhaven Parkway. Take a left of 30th St. and follow to Old Samish Rd., take a right. Heading north on Old Samish Rd. merges with Chuckanut Drive. Turn west off Chuckanut Drive (SR11) at 21st Street behind the Chuckanut Bay Art and Sculpture Gallery and then immediately turn west (right) on Fairhaven Avenue. Proceed straight to the shoreline of the bay.

There are no indications of transfer or grant of ownership of MRC owned livestock (Live Olympia Oysters or their offspring) to The Woods at Viewcrest permit applicant (The Jones Family) or to the City of Bellingham on this page.

Part 6–Project Description

6a. Briefly summarize the overall project. You can provide more detail in 6b. [help]

WDFW identified N. Chuckanut Bay as an ideal area for establishing a population of native oysters given the existing habitat conditions. A field evaluation was conducted in 2016, and seven test (pilot) plots were identified. The test plots are not intended as restoration themselves but only to provide information on feasibility of restoration in the seven habitat patches identified. The MRC purchased Olympia Oyster seed from the Puget Sound Restoration Fund and hope to place the seed in N. Chuckanut Bay by Spring 2018

6b. Describe the purpose of the project and why you want or need to perform it. [help]

Marine Resources Committees, in partnership with multiple organizations, are working to restore native Olympia oyster populations in their historic range in the Northwest Straits region. Native oyster beds create complex, three-dimensional habitat for invertebrates and small fishes and foraging locations for larger animals. Filter-feeding bivalves such as Olympia oysters feed on phytoplankton by filtering large volumes of water thereby improving water quality, removing pollutants and nutrients from the water column, and maintaining the water clarity necessary for eelgrass and kelp growth. Restoration and enhancement of this foundation species will provide significant benefits throughout the Northwest Straits marine ecosystem. Historic middens indicate past populations of Olympia oysters in N. Chuckanut Bay, but none are known to be present today.

6c. Indicate the project category. (Check all that apply) [help]

☐ Commercial ☐ Residential ☐ Institutional ☐ Transportation ☐ Recreational

☐ Maintenance ☒ Environmental Enhancement

6d. Indicate the major elements of your project. (Check all that apply) [help]

☒ Aquaculture	☐ Culvert	☐ Float	☐ Retaining Wall (upland)
☐ Bank Stabilization	☐ Dam / Weir	☐ Floating Home	☐ Road
☐ Boat House	☐ Dike / Levee / Jetty	☐ Geotechnical Survey	☐ Scientific Measurement Device
☐ Boat Launch	☐ Ditch	☐ Land Clearing	☐ Stairs
☐ Boat Lift	☐ Dock / Pier	☐ Marina / Moorage	☐ Stormwater facility
☐ Bridge	☐ Dredging	☐ Mining	☐ Swimming Pool
☐ Bulkhead	☐ Fence	☐ Outfall Structure	☐ Utility Line
☐ Buoy	☐ Ferry Terminal	☐ Piling/Dolphin	
☐ Channel Modification	☐ Fishway	☐ Raft	

☐ Other:

There are no indications of transfer or grant of ownership of MRC owned livestock (Live Olympia Oysters or their offspring) to The Woods at Viewcrest permit applicant (The Jones Family) or to the City of Bellingham on this page.

6e. Describe how you plan to construct each project element checked in 6d. Include specific construction methods and equipment to be used. [help]

- Identify where each element will occur in relation to the nearest waterbody.
- Indicate which activities are within the 100-year floodplain.

35 bags of seed on shell will be distributed within six test plots, each a 20'x20' square in size. Shell will not be placed within the seventh test plot as it will act as a reference site and will be monitored to see if there is any distribution of seed on native substrate. Each bag of seed has a minimum of 250 shells per bag and 3-5 spat or seed per shell. The seed used for the test plots will be on Pacific oyster shell and will be fairly robust from over-wintering in Fidalgo Bay; this also provides protection from trampling. Shell will be scattered evenly within plots at low tide, and routinely monitored for predators or other problems. The test plot area is located within a Special Flood Hazard Area (SFHA) or specifically Flood Zone "A" with a Community Determined Base Flood Elevation (BFE) of 12.0 feet (NAVD88).

6f. What are the anticipated start and end dates for project construction? (Month/Year) [help]

- If the project will be constructed in phases or stages, use JARPA Attachment D to list the start and end dates of each phase or stage.

Start Date: April 2018 End Date: ? April 2023 ☐ See JARPA Attachment D

6g. Fair market value of the project, including materials, labor, machine rentals, etc. [help]

Approx. $10,000

6h. Will any portion of the project receive federal funding? [help]

- **If yes**, list each agency providing funds.

☒ Yes ☐ No ☐ Don't know (Environmental Protection Agency)

Part 7–Wetlands: Impacts and Mitigation

☒ Check here if there are wetlands or wetland buffers on or adjacent to the project area.
(If there are none, skip to Part 8.) [help]

7a. Describe how the project has been designed to avoid and minimize adverse impacts to wetlands. [help]

☒ Not applicable

The project does not impact the wetlands. Wetlands are adjacent to Chuckanut Bay. All activities are located within the marine waters and tidelands of the bay.

7b. Will the project impact wetlands? [help]

☐ Yes ☒ No ☐ Don't know

7c. Will the project impact wetland buffers? [help]

☐ Yes ☒ No ☐ Don't know

There are no indications of transfer or grant of ownership of MRC owned livestock (Live Olympia Oysters or their offspring) to The Woods at Viewcrest permit applicant (The Jones Family) or to the City of Bellingham on this page.

7d. Has a wetland delineation report been prepared? [help]

- **If Yes**, submit the report, including data sheets, with the JARPA package.

☐ Yes ☒ No

7e. Have the wetlands been rated using the Western Washington or Eastern Washington Wetland Rating System? [help]

- **If Yes**, submit the wetland rating forms and figures with the JARPA package.

☐ Yes ☒ No ☐ Don't know

7f. Have you prepared a mitigation plan to compensate for any adverse impacts to wetlands? [help]

- **If Yes**, submit the plan with the JARPA package and answer 7g.
- **If No, or Not applicable**, explain below why a mitigation plan should not be required.

☐ Yes ☒ No ☐ Don't know

As noted above, wetlands are not impacted by the project therefore no mitigation plan is required.

7g. Summarize what the mitigation plan is meant to accomplish, and describe how a watershed approach was used to design the plan. [help]

Not applicable.

7h. Use the table below to list the type and rating of each wetland impacted, the extent and duration of the impact, and the type and amount of mitigation proposed. Or if you are submitting a mitigation plan with a similar table, you can state (below) where we can find this information in the plan. [help]

Activity (fill, drain, excavate, flood, etc.)	Wetland Name[1]	Wetland type and rating category[2]	Impact area (sq. ft. or Acres)	Duration of impact[3]	Proposed mitigation type[4]	Wetland mitigation area (sq. ft. or acres)

[1] If no official name for the wetland exists, create a unique name (such as "Wetland 1"). The name should be consistent with other project documents, such as a wetland delineation report.
[2] Ecology wetland category based on current Western Washington or Eastern Washington Wetland Rating System. Provide the wetland rating forms with the JARPA package.
[3] Indicate the days, months or years the wetland will be measurably impacted by the activity. Enter "permanent" if applicable.
[4] Creation (C), Re-establishment/Rehabilitation (R), Enhancement (E), Preservation (P), Mitigation Bank/In-lieu fee (B)

Page number(s) for similar information in the mitigation plan, if available: ______________________

There are no indications of transfer or grant of ownership of MRC owned livestock (Live Olympia Oysters or their offspring) to The Woods at Viewcrest permit applicant (The Jones Family) or to the City of Bellingham on this page.

7i. For all filling activities identified in 7h, describe the source and nature of the fill material, the amount in cubic yards that will be used, and how and where it will be placed into the wetland. [help]

Not applicable

7j. For all excavating activities identified in 7h, describe the excavation method, type and amount of material in cubic yards you will remove, and where the material will be disposed. [help]

Not applicable.

Part 8–Waterbodies (other than wetlands): Impacts and Mitigation

In Part 8, "waterbodies" refers to non-wetland waterbodies. (See Part 7 for information related to wetlands.) [help]

☒ Check here if there are waterbodies on or adjacent to the project area. (If there are none, skip to Part 9.)

8a. Describe how the project is designed to avoid and minimize adverse impacts to the aquatic environment. [help]

☐ Not applicable

The project is a pilot project to determine if Olympia oyster restoration can be successful at this site. Placement of the shell with spat will enhance the aquatic environment and is supplemental to natural shell that already exists within Chuckanut Bay. Shell will be scattered evenly within plots, each a 20'x20' square in size, at low tide. Each plot will be routinely monitored to quantify abiotic and biotic changes that may occur due to the presence of native oyster beds. It is assumed, based on current knowledge of oyster ecosystem services, that this oyster species will enhance denitrification rates, increase fish and invertebrate abundance and diversity, filter the water column, provide food, and protect coastlines (Blake & Bradbury 2012; PSRF 2009).

8b. Will your project impact a waterbody or the area around a waterbody? [help]

☒ Yes ☐ No

There are no indications of transfer or grant of ownership of MRC owned livestock (Live Olympia Oysters or their offspring) to The Woods at Viewcrest permit applicant (The Jones Family) or to the City of Bellingham on this page.

8c. Have you prepared a mitigation plan to compensate for the project's adverse impacts to non-wetland waterbodies? [help]

- **If Yes**, submit the plan with the JARPA package and answer 8d.
- **If No, or Not applicable,** explain below why a mitigation plan should not be required.

☐ Yes ☒ No ☐ Don't know

The project is intended to determine if Olympia oyster restoration is feasible within Chuckanut Bay. An extensive citizen-science monitoring plan will be implemented to gauge success of the project and changes in the habitat structure and function. A draft plan is included as an attachment to this document.

8d. Summarize what the mitigation plan is meant to accomplish. Describe how a watershed approach was used to design the plan.

- If you already completed 7g you do not need to restate your answer here. [help]

Not applicable.

8e. Summarize impact(s) to each waterbody in the table below. [help]

Activity (clear, dredge, fill, pile drive, etc.)	Waterbody name[1]	Impact location[2]	Duration of impact[3]	Amount of material (cubic yards) to be placed in or removed from waterbody	Area (sq. ft. or linear ft.) of waterbody directly affected
Shell placement (fill)	Chuckanut Bay	In	Permanent	1.46	Six plots of 400 sq ft each

[1] If no official name for the waterbody exists, create a unique name (such as "Stream 1") The name should be consistent with other documents provided.
[2] Indicate whether the impact will occur in or adjacent to the waterbody. If adjacent, provide the distance between the impact and the waterbody and indicate whether the impact will occur within the 100-year flood plain.
[3] Indicate the days, months or years the waterbody will be measurably impacted by the work. Enter "permanent" if applicable.

8f. For all activities identified in 8e, describe the source and nature of the fill material, amount (in cubic yards) you will use, and how and where it will be placed into the waterbody. [help]

The seed used for the test plots will be on Pacific oyster shell and will be fairly robust from over-wintering both of which provides protection from trampling. 35 bags of oyster spat on shell (200-300 shell per bag and approx. 10 spat per shell) provided by the Puget Sound Restoration Fund hatchery will be dispersed within the test plots. 35 bags of shell equal to roughly 1.46 cubic yards. All seven test plots are located within in north end of the bay.

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8g. For all excavating or dredging activities identified in 8e, describe the method for excavating or dredging, type and amount of material you will remove, and where the material will be disposed. [help]

Not applicable.

Part 9–Additional Information

Any additional information you can provide helps the reviewer(s) understand your project. Complete as much of this section as you can. It is ok if you cannot answer a question.

9a. If you have already worked with any government agencies on this project, list them below. [help]

Agency Name	Contact Name	Phone	Most Recent Date of Contact
WA Department of Fish and Wildlife	Brady Blake, Shellfish Biologist	360-302-3030 x301	August, 2017
City of Bellingham	Steve Sundin	360-778-8359	January 2018
Army Corps of Engineers, Seattle District Regulatory NW Field Office	Randel Perry	360-734-3165	August, 2017

9b. Are any of the wetlands or waterbodies identified in Part 7 or Part 8 of this JARPA on the Washington Department of Ecology's 303(d) List? [help]

- **If Yes,** list the parameter(s) below.
- If you don't know, use Washington Department of Ecology's Water Quality Assessment tools at: http://www.ecy.wa.gov/programs/wq/303d/.

☒ Yes ☐ No

Chuckanut Creek – bacteria, dissolved oxygen

9c. What U.S. Geological Survey Hydrological Unit Code (HUC) is the project in? [help]

- Go to http://cfpub.epa.gov/surf/locate/index.cfm to help identify the HUC.

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17110004

9d. What Water Resource Inventory Area Number (WRIA #) is the project in? [help]

- Go to http://www.ecy.wa.gov/water/wria/index.html to find the WRIA #.

WRIA 1

9e. Will the in-water construction work comply with the State of Washington water quality standards for turbidity? [help]

- Go to http://www.ecy.wa.gov/programs/wq/swqs/criteria.html for the standards.

☐ Yes ☐ No ☒ Not applicable

9f. If the project is within the jurisdiction of the Shoreline Management Act, what is the local shoreline environment designation? [help]

- If you don't know, contact the local planning department.
- For more information, go to: http://www.ecy.wa.gov/programs/sea/sma/laws_rules/173-26/211_designations.html.

☒ Urban ☒ Natural ☐ Aquatic ☐ Conservancy ☐ Other: ______

9g. What is the Washington Department of Natural Resources Water Type? [help]

- Go to http://www.dnr.wa.gov/forest-practices-water-typing for the Forest Practices Water Typing System.

☒ Shoreline ☐ Fish ☐ Non-Fish Perennial ☐ Non-Fish Seasonal

9h. Will this project be designed to meet the Washington Department of Ecology's most current stormwater manual? [help]

- **If No**, provide the name of the manual your project is designed to meet.

☒ Yes ☐ No

Name of manual: ______

9i. Does the project site have known contaminated sediment? [help]

- **If Yes**, please describe below.

☐ Yes ☒ No

9j. If you know what the property was used for in the past, describe below. [help]

Historic use of the bay for fishing or tribal use is not known.

There are no indications of transfer or grant of ownership of MRC owned livestock (Live Olympia Oysters or their offspring) to The Woods at Viewcrest permit applicant (The Jones Family) or to the City of Bellingham on this page.

9k. Has a cultural resource (archaeological) survey been performed on the project area? [help]

- **If Yes**, attach it to your JARPA package.

☐ Yes ☒ No

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There are no indications of transfer or grant of ownership of MRC owned livestock (Live Olympia Oysters or their offspring) to The Woods at Viewcrest permit applicant (The Jones Family) or to the City of Bellingham on this page.

9l. Name each species listed under the federal Endangered Species Act that occurs in the vicinity of the project area or might be affected by the proposed work. [help]

Fish Species ESU/DPS	ESA Listing Status/Date	ESA Critical Habitat	Jurisdiction
Coastal/Puget Sound Bull Trout *(Salvelinus confluentus)*	Threatened November 1, 1999 (64 FR 58910)	Designated: September 26, 2005 (70 FR 56212) Revised Final Rule: October 18, 2010 (75 FR 63898)	U.S Fish and Wildlife Service (USFWS)
Puget Sound Steelhead (Rainbow Trout) *(Oncorhynchus mykiss)*	Threatened May 11, 2007 (72 FR 26722) Updated April 14, 2014 (79 FR 20802)	Designated: September 2, 2005 (70 FR 52630) February 24, 2016 (81 FR 9252) **Not Applicable to Action Area**	NOAA Fisheries & National Marine Fisheries Service (NMFS)
Puget Sound Chinook Salmon *(Oncorhynchus tshawytscha)*	Threatened June 28, 2005 (70 FR 37160) Updated April 14, 2014 (79 FR 20802)	Designated: September 2, 2005 (70 FR 52630)	
Puget Sound/Georgia Basin DPS of Bocaccio *(Sebastes paucispinis)*	Endangered April 28, 2010 (75 FR 22276) Effective July 27, 2010	Designated: November 13, 2014 (79 FR 68042) Effective: February 11, 2015	
Puget Sound/Georgia Basin DPS of Yelloweye Rockfish *(Sebastes ruberrimus)*	Threatened April 28, 2010 (75 FR 22276) Effective July 27, 2010		
Puget Sound/Georgia Basin DPS of Canary Rockfish *(Sebastes pinniger)*	Threatened* April 28, 2010 (75 FR 22276) Effective July 27, 2010 Proposed for removal from ESA listing 2016 (81 FR 42979) July 6, 2016		
Southern DPS of Eulachon *(Thaleichthys pacificus)*	Threatened March 18, 2010 (75 FR 13012)	Designated: October, 20, 2011 (FR 76 65324) **Not Applicable to Action Area**	
Southern DPS of Green Sturgeon *(Acipenser medirostris)*	Threatened April 7, 2006 (71 FR 17757)	Designated: October 9, 2009 (74 FR 52300) **Not Applicable to Action Area**	
Birds:			
Marbled murrelet *(Brachyramphus marmoratus)*	Threatened October 1, 1992 (57 FR 45328)	Revised Final Rule October 5, 2011 (76 FR 61599) Designated: May 24, 1996 (61 FR 26255) **Not Applicable to the Site**	*USFWS*

9m. Name each species or habitat on the Washington Department of Fish and Wildlife's Priority Habitats and Species List that might be affected by the proposed work. [help]

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Hardshell clam
Shorebird concentrations
Estuarine and marine wetlands

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Part 10–SEPA Compliance and Permits

Use the resources and checklist below to identify the permits you are applying for.

- Online Project Questionnaire at http://apps.oria.wa.gov/opas/.
- Governor's Office for Regulatory Innovation and Assistance at (800) 917-0043 or help@oria.wa.gov.
- For a list of addresses to send your JARPA to, click on agency addresses for completed JARPA.

10a. Compliance with the State Environmental Policy Act (SEPA). (Check all that apply.) [help]

- For more information about SEPA, go to www.ecy.wa.gov/programs/sea/sepa/e-review.html.

☒ A copy of the SEPA determination or letter of exemption is included with this application.

☒ A SEPA determination is pending with City of Bellingham (lead agency). The expected decision date is ______.

☐ I am applying for a Fish Habitat Enhancement Exemption. (Check the box below in 10b.) [help]

☐ This project is exempt (choose type of exemption below).

☐ Categorical Exemption. Under what section of the SEPA administrative code (WAC) is it exempt?

______

☐ Other: ______

☐ SEPA is pre-empted by federal law.

10b. Indicate the permits you are applying for. (Check all that apply.) [help]

LOCAL GOVERNMENT

Local Government Shoreline permits:

☐ Substantial Development ☐ Conditional Use ☐ Variance

☒ Shoreline Exemption Type (explain): ______

Other City/County permits:

☐ Floodplain Development Permit ☐ Critical Areas Ordinance

STATE GOVERNMENT

Washington Department of Fish and Wildlife:

☒ Hydraulic Project Approval (HPA) ☐ Fish Habitat Enhancement Exemption – Attach Exemption Form

Washington Department of Natural Resources:

☐ Aquatic Use Authorization

Complete JARPA Attachment E and submit a check for $25 payable to the Washington Department of Natural Resources. **Do not send cash.**

Washington Department of Ecology:

☒ Section 401 Water Quality Certification

FEDERAL GOVERNMENT

United States Department of the Army permits (U.S. Army Corps of Engineers):

☒ Section 404 (discharges into waters of the U.S.) ☒ Section 10 (work in navigable waters)

United States Coast Guard permits:

☐ General Bridge Act Permit ☐ Private Aids to Navigation (for non-bridge projects)

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This page includes the signature of Kelli Linville, Bellingham Mayor.

Part 11–Authorizing Signatures

Signatures are required before submitting the JARPA package. The JARPA package includes the JARPA form, project plans, photos, etc. [help]

11a. Applicant Signature (required) [help]

I certify that to the best of my knowledge and belief, the information provided in this application is true, complete, and accurate. I also certify that I have the authority to carry out the proposed activities, and I agree to start work only after I have received all necessary permits.

I hereby authorize the agent named in Part 3 of this application to act on my behalf in matters related to this application. AR (initial)

By initialing here, I state that I have the authority to grant access to the property. I also give my consent to the permitting agencies entering the property where the project is located to inspect the project site or any work related to the project. AR (initial)

Austin Rose — Applicant Printed Name | Austin Rose — Applicant Signature | 02.12.18 — Date

11b. Authorized Agent Signature [help]

I certify that to the best of my knowledge and belief, the information provided in this application is true, complete, and accurate. I also certify that I have the authority to carry out the proposed activities and I agree to start work only after all necessary permits have been issued.

Austin Rose — Authorized Agent Printed Name | Austin Rose — Authorized Agent Signature | 02.12.18 — Date

11c. Property Owner Signature (if not applicant) [help]

Not required if project is on existing rights-of-way or easements (provide copy of easement with JARPA).

I consent to the permitting agencies entering the property where the project is located to inspect the project site or any work. These inspections shall occur at reasonable times and, if practical, with prior notice to the landowner.

Kelli Linville — Property Owner Printed Name | Kelli Linville — Property Owner Signature | 2/5/18 — Date

18 U.S.C §1001 provides that: Whoever, in any manner within the jurisdiction of any department or agency of the United States knowingly falsifies, conceals, or covers up by any trick, scheme, or device a material fact or makes any false, fictitious, or fraudulent statements or representations or makes or uses any false writing or document knowing same to contain any false, fictitious, or fraudulent statement or entry, shall be fined not more than $10,000 or imprisoned not more than 5 years or both.

If you require this document in another format, contact the Governor's Office for Regulatory Innovation and Assistance (ORIA) at (800) 917-0043. People with hearing loss can call 711 for Washington Relay Service. People with a speech disability can call (877) 833-6341. ORIA publication number: ORIA-16-011 rev. 07/2017

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Whatcom MRC Olympia Oyster Test Plots - N. Chuckanut Bay

There are no indications of transfer or grant of ownership of MRC owned livestock (Live Olympia Oysters or their offspring) to The Woods at Viewcrest permit applicant (The Jones Family) or to the City of Bellingham on this page.

The Woods at Viewcrest permit applicant (Jones Family) did not appeal this Shoreline Permit decision within 14 days of issuance thus the placement of MRC owned livestock in North Chuckanut Bay is permanent.

CITY OF BELLINGHAM • WASHINGTON •

PLANNING and COMMUNITY DEVELOPMENT DEPARTMENT
210 Lottie Street, Bellingham, WA 98225
Phone: (360) 778-8300 Fax: (360) 778-8301 TTY: (360) 778-8382
Email: planning@cob.org Web: www.cob.org

SHORELINE PERMIT EXEMPTION AUTHORIZATION for TYPE I PROJECTS

SHR2018-0010 Date Issued: 3/26/2018

Project Address and Parcel #: Generally located within the waters of Chuckanut Bay inside of the BNSF railroad causeway / trestle.

Applicant and Contact Information: Austin Rose, Whatcom County Marine Resource Committee. 360-778-6286 or arose@co.whatcom.wa.us

Project Description: Reintroduction of Olympia oysters into Chuckanut Bay as a pilot restoration project. Project is proposed by the Marine Resource Committee of Whatcom County in coordination with other local, state and federal agencies and various aquaculture organizations.

35 bags of seed shell will be distributed among six 20' x 20' test plots at low tide water-ward of the ordinary high water mark and within the waters of Chuckanut Bay. This restoration pilot project does not require any in-water structures or substantial development as defined in the city's SMP.

Shoreline Designation and Reach #: Natural - Marine reach #19.

Buffer Width: zero. In-water work. Conforming Use - N/A

Conforming Development: N/A

Associated Development Permit #(s): USACOE 404 and Section 10. WDFW H.P.A.

Exempt pursuant to BMC 22.05.020.B.1: p. Project is intended to be a restoration project.

Rationale: Please see JARPA dated 2/12/2018.

Condition(s): Implement as proposed.

Exempt from SEPA pursuant to WAC 197-11-800: N/A (No construction or structures proposed.)

Authorized By: [signature]

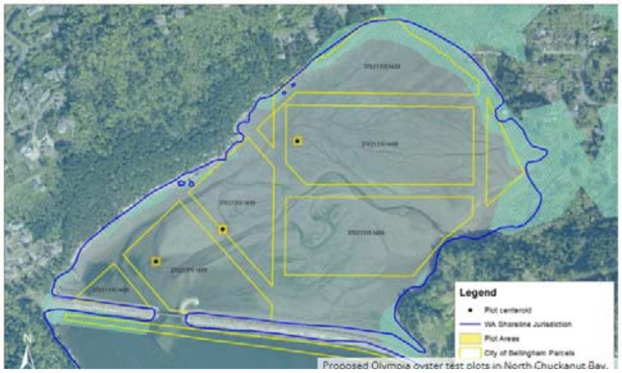
Appeal: Any party aggrieved by the decision of the Director may file an appeal within 14 days of the decision on this permit in accordance with BMC 21.10.250. Any appeal must be filed with the Planning and Community Development Department on the appropriate forms and be accompanied by a filing fee as established by the City Council.

Exhibit “E”

Re: Hearing Examiner Case Number: HE-25-PL-027

Failure to Disclose and Failed to Consider: The privately owned MRC livestock in North Chuckanut Bay.

Future Olympia oyster restoration plan for North Chuckanut Bay:



Proposed Olympia oyster test plots in North Chuckanut Bay.

In 2016, WDFW identified six plots within North Chuckanut Bay to pilot Olympia oyster restoration. In 2017, the MRC established six pilot restoration plots and one reference plot using 95,000 Olympia oyster spat on Pacific oyster shell. From 2018 to 2025, the MRC conducted annual population surveys of each of the test plots to assess restoration potential. Periodically, the substrate within the plots was enhanced with Pacific oyster shell. In 2025, WDFW conducted a site visit of the test plots with MRC staff and identified three that would be suitable for continued restoration efforts.

In 2026, the MRC plans to enhance three sites with additional oyster spat as shown in the figure. In 2027, the MRC will begin annual Olympia oyster population assessments.

"Bellingham Technical College students assisting the Whatcom MRC with distributing shell w/spat within the test plot. Photo Credit: Austin Rose, Whatcom County Public Works"

The MRC installed MRC owned Live Olympia oyster spat in North Chuckanut Bay in April of 2018.

Students with the Bellingham Technical College Fisheries and Aquaculture program help conduct an annual Olympia oyster population survey in North Chuckanut Bay. Photo credit: Dana Daniels.

The MRC installed Livestock (Live Olympia Oyster Spat) in North Chuckanut Bay with the help of Bellingham Technical College students.

Photo credit: Austin Rose, Whatcom County Public Works, North Chuckanut Bay.

Exhibit "F"

Re: Hearing Examiner Case Number: HE-25-PL-027

Failure to Disclose: the restoration oysters placed in Chuckanut Bay by the MRC were an "**end product**" of a "federal agreement" with **the Treaty Tribes of the Salish**. This agreement was centered on restoring self sustaining beds of native oysters in Puget Sound **for the benefit of** the feds, the State of Washington **and the Treaty Tribes of the Salish Seas.**

This error **"establishes a risk"** for the State of Washington for the pumping of "The Woods at Viewcrest Stormwater Discharge" to an area outside the boundaries of North Chuckanut Bay, after the discharge is built and operational.

To understand the context of this issue, one only needs to consider the context of a 2001 lawsuit filed by 21 Indian Tribes against the State of Washington. This lawsuit claimed barrier culverts violated treaty rights. The Indian Tribes were successful and achieved a federal injunction against the State of Washington. This injunction required the replacement of 400 state-owned road culverts by 2030. In 2001 the budget was 4 billion dollars. Currently, the fix is behind schedule and over budget.

Because the restoration oyster spat placed in North Chuckanut Bay are an "**end product**" of an agreement between the feds, the State of Washington and the Treaty Tribes of the Salish Seas. A careful review is required because an "**Indian Tribe can make a bad faith claim**" against the State for a non-compliance with the terms and conditions of an established agreement.

The following is input from the Puget Sound Restoration Fund's website:

Puget Sound Restoration Fund

Olympia oysters play a large part in Puget Sound's ecosystem, culture, and history. Collaborative rebuilding efforts with Treaty Tribes are a reflection of that history. Olympia oyster restoration is a collective enterprise inspired by Treaty Tribes, shellfish growers, Marine Resources Committees and countless others. Fledgling efforts began in 1999, guided by a 1998 WDFW Olympia oyster rebuilding plan. PSRF learned quickly that LOTS of people wanted to engage in this effort. After all, who wouldn't want to recover a living shoreline full of historic resources of ecological and cultural importance?

PSRF and Treaty Tribes have been facilitating this effort ever since. In addition to managing large-scale, on-the-ground restoration works, PSRF operates a conservation hatchery with was established by NOAA in 2014. This hatchery enables PSRF to produce and out-plant oyster seed to essential priority areas. This is an important precursor to restoring Olympia oyster to areas where the beds have been lost. All told, these actions help implement the recommendations of both the Blue Ribbon Panel on Ocean Acidification and the Washington Shellfish Initiative. Core team advisors for this effort, includes: WDFW, NOAA, Baywater, Inc., University of Washington, Swinomish Tribe, and the Northwest Straits Commission.

Our Olympia Oyster Partners are listed below:

- Washington Department of Fish & Wildlife (WDFW State Resource Manager)
- Tribes (Shellfish Co-Managers)

Suquamish Tribe	Samish Indian Nation
Skokomish Tribe	Nisqually Indian Tribe
Jamestown S'Klallam Tribe	Lummi Nation
Port Gamble S'Klallam Tribe	Northwest Indian College
Swinomish Indian Tribe	Northwest Indian Fisheries Commission

Olympia oysters are sparsely distributed across their historic range thus the PSRF has a trusted partnership requirement with the Treaty Tribes to increase the number of these oysters until their populations become self-sustaining. One of the primary ways PSRF does this is by producing restoration-grade Olympia oyster seed for out-planting into the wild. PSRF first collects brood-stock Olympia oysters from the geographic basins of proposed restoration projects. This brood-stock is then brought to the Kenneth K. Chew Center for Shellfish Research and Restoration hatchery at NOAA's Manchester Research Station, This hatchery is a hub for producing millions of baby oysters for out-planting.

At the hatchery, PSRF induces spawning in the brood-stock, captures larvae and rears the larvae as either single oysters, or as spat-on-shell. For the latter, PSRF pumps larval oysters into large setting tanks filled with bags of Pacific oyster shells, so the larvae can settle onto shells. During this process the larvae is fed with a continuous diet of micro-algae. Once the larvae have been transformed into oyster spat their final stop is planting into the wild onto tide-flats.

Photo credit: Puget Sound Restoration Fund

Exhibit "G"

Re: Hearing Examiner Case Number: HE-25-PL-027

Failure to Disclose and Failed to Consider: The privately owned MRC livestock in North Chuckanut Bay is a WDFW priority species for conservation in Washington State.

Washington Department of
FISH & WILDLIFE

Olympia oyster *(Ostrea lurida)*

Category: Molluscs

Family: *Ostreidae*

Common names: Oly, Shoalie, native oyster

Ecosystems: Marine shorelines

Vulnerability to climate change (More details)

Low	Low-Moderate	Moderate	Moderate-High	High

The Olympia oyster (*Ostrea lurida*) is Washington's only native oyster species. An icon of the Pacific Northwest, this small shellfish plays a vital role in local estuaries by cleaning the water and providing essential habitat for marine life.

Historically, they lived along the Pacific coast from Sitka, Alaska, to Baja California. Today, populations are scattered across this historic range. In Washington, extensive harvesting and pollution caused a severe decline, leaving as little as 5% of historical oyster bed habitat remaining by 2012. WDFW and partners are actively working to rebuild these native populations.

Photo by WDFW

Description and Range +

Climate vulnerability +

Regulations +

Conservation –

This species is identified as a **Species of Greatest Conservation Need** (SGCN) under the State Wildlife Action Plan (SWAP). SGCN-classified species include both those with and without legal protection status under the Federal or State Endangered Species programs, as well as game species with low populations. The WDFW SWAP is part of a nationwide effort by all 50 states and five U.S. territories to develop conservation action plans for fish, wildlife and their natural habitats—identifying opportunities for species' recovery before they are imperiled and more limited.

This species is identified as a **Priority Species** under WDFW's Priority Habitat and Species Program. Priority species require protective measures for their survival due to their population status, sensitivity to habitat alteration, and/or recreational, commercial, or tribal importance. The PHS program is the agency's main means of sharing fish and wildlife information with local governments, landowners, and others who use it to protect priority habitats for land use planning.

Protected Status

In 1997, Olympia oysters were listed by the Washington Department of Fish and Wildlife (WDFW) as a State Candidate species. State Candidate species are those that WDFW may review for possible future listing as State Endangered, Threatened, or Sensitive species. Olympia oysters are designated by WDFW as a Species of Greatest Conservation Need and is also included in WDFW's Priority Habitats and Species List (PHS), a catalog of habitats and species considered a priority for conservation and management.

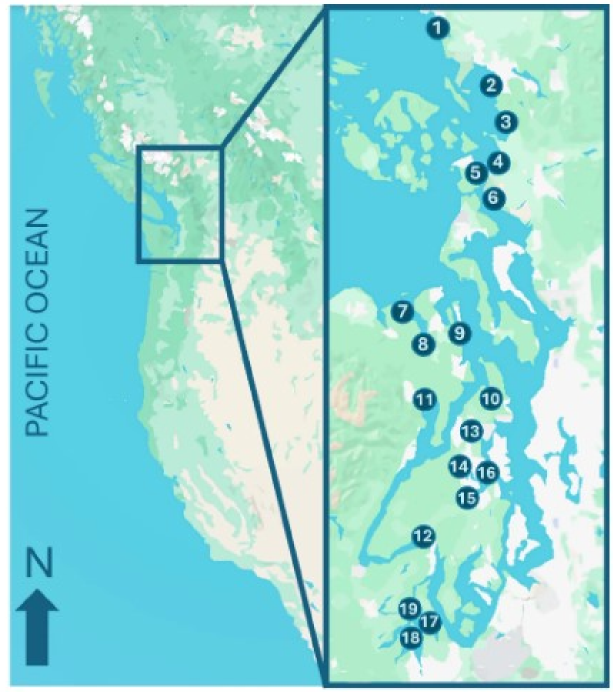
History of restoration efforts in Washington State

Restoration efforts in Puget Sound were initiated following the development of WDFW's 1998 Olympia Oyster Stock Rebuilding Plan (Cook et al. 1998). The key actions cited in the1998 Rebuilding Plan included development of survey methods, population inventories, natural restoration techniques, site selection criteria, genetic integrity investigations, water quality improvement, and habitat protection. The 1998 Rebuilding Plan was not funded as a WDFW project, however, and many aspects of the plan have been undertaken by the non-profit Puget Sound Restoration Fund (PSRF), a key WDFW partner in native shellfish research and restoration. Native oyster restoration in Puget Sound has been a collaborative partnership effort facilitated by PSRF and involving WDFW and other government agencies, Tribes, shellfish growers, non-profit organizations including the NW Straits Commission, universities, private tideland owners, and volunteers since 1999. This work has led to many successes in Olympia oyster restoration and contributed much to the understanding of the species, its place in the Puget Sound ecosystem, and how to advance its long-term recovery.

Priority areas for native oyster restoration in Washington State

In 2012, WDFW identified 19 Priority Sites at which to focus Olympia oyster restoration, based on historical occurrence and existing habitat and other favorable factors. WDFW recommended a focused restoration strategy at 19 sites within Puget Sound by 2022. This strategy was recommended for both the biological conservation of the species and as a foundation for continued rebuilding of the species by natural or artificial means. In 2022, PSRF and a multitude of partners reached their 10-year goal of restoring 100 acres of Olympia oyster habitat by 2020. WDFW, PSRF, and partners are hard at work developing goals for the next decade of Olympia oyster recovery, which still has a long way to go.

The primary objectives of this restoration strategy are the biological conservation of the species and its associated habitat. Those objectives are achieved by re-establishing, rebuilding, and enhancing natural native oyster assemblages, ensuring the species' long-term persistence in the face of changing marine and environmental conditions, and the competing uses of Puget Sound marine waters and tidelands. WDFW prioritizes habitat enhancement (by replacing oyster shell) coupled with natural oyster production, but other tools, like releasing hatchery-reared oysters, are also key to broad-scale restoration.



WDFW Priority Sites for Olympia oyster restoration. Sites are numbered and move from north to south.

1.) Drayton Harbor
2.) Bellingham and Chuckanut Bays
3.) Samish Bay
4.) Padilla Bay
5.) Fidalgo Bay
6.) Similk Bay
7.) Sequim Bay
8.) Discovery Bay
9.) Kilisut Harbor
10.) Port Gamble Bay
11.) Quilcene Bay
12.) Union River and Mission Creek Deltas
13.) Liberty Bay and sub-inlets
14.) Dyes Inlet and sub inlets
15.) Sinclair Inlet
16.) Pt. Jefferson-Orchard Pt. inlets
17.) Budd Inlet
18.) Henderson Inlet
19.) Harstine/Squaxin Island inlets.

Restoration initiatives on the West Coast

In addition to restoration efforts in Washington State, The Native Olympia Oyster Collaborative (NOOC) supports coastwide restoration efforts by coordinating science and communication across the species' range to ensure best practices and knowledge sharing among practitioners. Currently, there are active on-going restoration efforts in California, where populations are smaller than in Washington, and restoration relies on conservation aquaculture as natural recruitment is limited with a few exceptions.

Olympia oyster restoration efforts have also occurred, or are ongoing, in neighboring British Columbia and Oregon.

Threats

Restoration efforts must address significant biological stressors:

- **Non-Native Species:** Invasive oyster drills hurt native oysters through predation and competition. The larger, introduced Pacific oyster may sometimes compete with Olympia oysters for habitat.
- **Disease:** While not confirmed in Washington, a dangerous protozoan parasite, ***Bonamia ostreae***, has been identified in native oysters in California, which raises conservation concerns.

Resources +