Bridge Drainage Collection and Treatment Environmental, Design and Operational Issues Guidelines

BRITISH COLUMBIA | Ministry of Transportation and Infrastructure

PURPOSE

These guidelines describe the environmental rational, engineering limitations, operational issues, and a recommended environmental Best Management Practices (BMP) approach for drainage runoff around bridges at environmentally sensitive water-courses. It also includes a case study from the Vancouver Island Highway Project (VIHP).

BACKGROUND

While environmental legislation exists to protect environmental resources and environmental BMPs advocates use of practical techniques and methods for environmental protection, there are challenging design and operational considerations that require evaluation prior to determining whether bridge runoff collection and treatment is warranted and feasible. If collection and treatment is required, various factors should be considered in the development of a cost-effective and functioning site-specific application.

In developing an overall highway environmental mitigation plan, other potential mitigation opportunities that provide a greater benefit to the natural resource, without compromising safety, should be evaluated.

On VIHP, bridge drainage collection and treatment systems were extensively used and subsequent post-project review provides learning opportunities and insight.

ENVIRONMENTAL RATIONALE

Legislative obligations do not typically dictate runoff from bridges. However, it is important to recognize that statutory requirements exist under the federal *Fisheries Act*, that prohibits serious harm to the commercial, recreational and Aboriginal fisheries and the release of deleterious substances into waters frequented by fish.

Other legislation exists to protect water and aquatic resources, including sensitive fish and wildlife habitats, recreational uses and drinking and agricultural water supplies. This legislation may include provisions under the *Water Act*, *Environmental Management Act*, *Wildlife Act* and *Species at Risk Act*.

Substances in bridge runoff that could be of concern are sediments (e.g., winter abrasives, particulates from vehicle traffic, including woodwaste from logging trucks) or chemical compounds (e.g., de-icing agents, hydrocarbons or other substances from vehicles or spills, or bridge cleaning agents).

Resource uses and values also influence the need for environmental mitigation. In some cases, a receiving water may not be sensitive to bridge runoff, such as a stream with a naturally high sediment load, limited fish and wildlife values, light recreational use and minimal or no water takings. Conversely, sensitive systems may have characteristics like excellent water quality, high-quality fish habitat, wildlife values, listed species, scientific uses, drinking water takings and/or high recreational use.

Environmental management of runoff from bridges is addressed under BMPs that protect environmental resources through cost-effective, results-based procedures and performance standards, including the Best Management Practices for Highway Maintenance Activities (MOTI 2010).

This document provides a results-based methodology to achieve compliance with applicable legislation using the proponent's determination on how to meet the end goal of compliance, rather than prescriptive or formal permitting requirements.

Environmental mitigation options for bridge crossings and associated roadways may develop that are more practical, provide better resource benefit for money, and do not provide technical design and operational challenges compared to bridge runoff collection and treatment. These options may include:

- Siting the stream crossing at a location that avoids and protects sensitive habitats.
- Positioning drains so they do not discharge directly into a waterway.

ENVIRONMENTAL RATIONALE CONTINUED

- On shorter bridge spans, consideration for elimination of deck drains provided the longitudinal gradient is adequate to accommodate drainage and collection of drainage on the approaches such that maximum ponding requirements on the bridge deck are not exceeded.
- Collecting, treating and discharging highway drainage prior to it reaching the bridge.
- Runoff management and erosion protection at bridge endfills and approach fills near watercourses (e.g., directing bridge runoff into areas where it will not create additional erosion at its impingement point, or constructing adequate armour splash pads at all runoff outfall locations).
- Revegetation, including riparian plantings and seeding areas that grow and do not require excessive maintenance.
- Stabilization/mitigation of erosion/sediment sources, including road fill and cut slopes.
- Wetted habitat restoration, including habitat construction and complexing.

Environmental BMPs and stewardship objectives encourage innovative and adaptive solutions to ensure environmental resources are protected. While the ministry strives to be a leader in environmental management, it is recognized that there are safety, financial and operational factors that should be considered in concert with the sensitivity of the receiving water to determine when and where bridge runoff treatment is appropriate.

BRIDGE DESIGN

From the highway design, traffic safety and maintenance perspective, conveying water quickly and efficiently off of bridge decks, while requiring as little maintenance as possible, is desirable. A primary design goal is to ensure a safe roadway by avoiding human safety risks caused by ice formation and water ponding on the bridge decks and approaches.

The drainage system needs to have the capacity to convey water off of the bridge prior to any encroachment of pooling water into driving lanes as this poses a safety hazard and can increase deck deterioration if the water remains for an extended period of time (Alberta Transportation, 2010). Highway bridge decks are usually designed with slopes and cross fall to ensure efficient runoff drainage. Typically, the runoff is directed to downspouts on the bridge deck that discharge the water directly from the deck to below.

There are design and downslope items to consider for direct downspout discharges, including:

Hydraulic Sizing

Spacing of standard deck drains to convey runoff.

Plumbing

Elbows and joints create plugging and require extensive maintenance. Therefore, straighter, shorter, and smoother plumbing is preferred to reduce maintenance.

Debris Plugging

Downspout grates are susceptible to plugging. Larger openings or double grates reduces this tendency.

Downspout discharges sometimes require collection (e.g., to avoid fill erosion or saturation). Open channels typically function better than enclosed (e.g., culverts) in resisting plugging and provide easier maintenance access.

Climate

Consideration of precipitation and temperature (e.g., freezing, freeze-thaw cycles, snowload) regimes.

Discharge Spray Pattern

Dissipaters that disperse downspouts discharges at 45˚ may be used in areas where a direct spray is undesirable, for example to avoid endfill erosion or saturation.

Discharge Spray Location

Avoiding discharges that cause fill erosion, saturation of endfills or damage on the bridge structure (e.g., stringers, piers, bearings).

Maintenance Requirements

Drainage structures should be readily accessible for operational and maintenance activities like cleanout.

Durability

Drainage structures should be long-lasting, ideally lasting the 75-year design lifecycle of the bridge.

The Canadian Highway Bridge Design Code and the ministry's BC Supplement to CHBDC S6-06, Section 1.8.2.3 provides standards for these and other related items: http://www.th.gov.bc.ca/publications/eng_publications/bridge/standards/BSM-Volume-1_2007/BSM_Vol-1_All_Sections_Aug_2007.pdf

Through input from technical and operational staff and research of other jurisdictions, during development of these guidelines, it was determined that bridge drainage collection is only feasible in extremely limited conditions.

Collection and treatment systems are only functional and possible in areas of the province with temperate climates with infrequent sub-freezing weather and snowfall.Within these geographic regions, there are specific and limited applications where systems are practical and warranted, as well as design and operational challenges. The appended VIHP case study provides some detail on this.

RECOMMENDED ENVIRONMENTAL BEST MANAGEMENT PRACTICES

Environmental, design, operational, and maintenance issues are considered in the following suggested approach, or BMP, for bridge drainage collection and treatment:

1. Evaluate whether bridge drainage collection and treatment is practical and warranted, considering design limitations in concert with the sensitivity of the receiving water.

2. During a bridge design, assess the bridge with the associated roadway in developing an overall environmental mitigation plan.

3. Consider sensitive receptors, downstream ecosystem and habitats, the cost-effectiveness of the environmental mitigation plan components, mitigation of habitat limiting factors, regional variables and operational issues in determining whether runoff collection and treatment is warranted.

4. Where practical and justified, incorporate drainage collection and treatment along the road grade prior to runoff reaching bridge decks, or at corners of bridges, to partially reduce environmental and operational concerns from water, debris, and contaminant runoff.

5. If practical and feasible, implement on-the-ground and instream environmental restoration and/or habitat enhancements associated with the bridge watercourse.

6. Consider softer treatments to stabilize exposed areas and filter runoff, including establishment of vegetation through seeding, plantings and bioengineering.

7. If runoff treatment is required, site-specific conditions require evaluation to develop a functional, long-lasting collection and treatment system that is straight forward to maintain.

8. Adhere to other current environmental BMPs during operational and maintenance phase of the bridge to protect downstream values such as fish and wildlife and their habitats, water takings and recreational uses.

ADDITIONAL READING AND REFERENCES:

Alberta Transportation. 2010. Bridge Deck Drainage; Best Practice Guideline.
URL: http://www.transportation.alberta.ca/Content/docType30/Production/bpg12.pdf

British Columbia Ministry of Transportation. 2010. Environmental Best Management Practices for Highway Maintenance Activities.
URL: http://www.th.gov.bc.ca/publications/eng_publications/environment/bestpractice.htm

British Columbia Ministry of Transportation. 2007, Supplement to CHBDC S6-06.
URL: http://www.th.gov.bc.ca/publications/eng_publications/bridge/standards/BSM-Volume-1_2007/BSM_Vol-1_All_Sections_Aug_2007.pdf

Canadian Standards Association. 2006. CAN/CSA-S6-06 Canadian Highway Bridge Design Code.

Fisheries and Oceans Canada. 2007. Pacific Region Operational Statement, Bridge Maintenance.

KPA Engineering Ltd. 1992. Vancouver Island Highway Project Guidelines for Environmental Design of Highway Drainage. For Province of British Columbia Ministry of Transportation and Highways.

Ministry of Transportation and Highways Vancouver Island Highway Project. 1997. Manual of Control of Erosion and Shallow Slope Movement.

Ministry of Transportation and Highways Vancouver Island Highway Project. 1998. Maintenance Guide for Water Quality Treatment Systems.

Samis, S.C., M.D. Nassichuk and B.J. Reid. 1990. Guidelines for the Protection of Fish and Fish Habitat During Bridge Maintenance Operations in British Columbia. Can. Tech. Rept. Fish. Aquat. Sci. 1692: vii + 64p. URL: http://www.dfo-mpo.gc.ca/Library/117150.pdf

British Columbia Ministry of Environment Instream Works Best Management Practices (BMP) - Bridges
URL: http://www.env.gov.bc.ca/wld/instreamworks/bridges.htm

CONTACTS

Sean Wong
Senior Biologist
(250) 952-0815

Ian Sturrock
Senior Bridge Design & Construction Engineer
(250) 356-9862

APPENDIX 1
VANCOUVER ISLAND HIGHWAY PROJECT CASE STUDY

There are no generic or standard collection and treatment systems available for the entire province of BC. It is largely VIHP where these systems were initiated and utilized as a conservative, conscientious, and pro-active measure to protect downstream resources. Design limitations and operational challenges experienced on these systems suggest that development of site-specific designs are required, rather than a generic approach, to provide an operationally functional and long-lasting, efficient system.

VIHP is situated in the moderate and temperate climate of south coast BC, which is conducive to drainage collection and treatment. Many areas of the province experience more freeze-thaw cycles and higher snow loads. Therefore, collection and treatment systems are largely impractical and would be non-functional for much of the year.

Despite a favourable climate, operational problems were encountered on some VIHP bridges where deck drains deposited water directly on endfills, requiring remedial works and drainage retrofits.

On VIHP bridges where drainage was collected and treated, collection was accomplished by conveying drainage along the inside of a solid parapet or by using parapets with scuppers, opening to a galvanized metal collection trough on the outside of the parapet.

Upon review of these two collection techniques used on VIHP, the following design recommendations, concerns and limitations were identified:

- Shoulder width,

  The bridge shoulder should be wide enough to accommodate runoff flows and debris.

- Bridge grades of about 2.5-3% and superelevations or crossfalls of about 2% are needed to direct runoff flows and avoid debris and water accumulation.
- Bridges with adequate geometrics and up to a certain span length function well to collect drainage without undue operational or maintenance concerns.
- Catch basins should have been larger to allow better sediment settling and collection from both runoff and during bridge cleaning activities.
- Directing drainage to other catchments such as sediment ponds, grassed swales or ditchlines, or vegetated filtering and buffer strips, could provide better treatment and provide easier or less maintenance than drainage to catch basins.
- Diverting drainage at the end of barrier flares to an open (asphalt) flume is preferred to reduce maintenance compared to an enclosed pipe, as an open flume is easier to maintain.
- If enclosed pipes are used for drainage collection, they require cleanouts at changes of direction or oversizing.
- Drainage trough cost, maintenance and long-term functionality:
  - Troughs are an additional design, fabrication, installation and maintenance cost.
  - Ideally, troughs would be self-cleaning through sufficient grades and flows to move debris to the treatment area.
  - Troughs are difficult and may be unsafe to access for cleanout.
  - Troughs may leak early in the lifespan of the bridge and will be impossible to reseal because of old calking and hydrocarbons adhering to surfaces prevent new sealers from bonding.
- A failsafe or backup system may be required to accommodate debris plugging or when systems are not functioning optimally.
- Small treatment catchment systems are ineffective if they become plugged or overfilled during high runoff events or bridge cleaning activities.

The above, and other items, are summarized in the Appendix 2 table to help determine whether bridge deck runoff collection and treatment is required and feasible.

APPENDIX 1
VANCOUVER ISLAND HIGHWAY PROJECT CASE STUDY PHOTOS

Photo 1. Drainage collection trough on outside of bridge parapets. Metal plates in foreground cover cleanout catch basins.

Photo 2. Bridge parapet scupper opening to collection trough requires periodic cleanout because of susceptibility to debris plugging.

Photo 3. Asphalt curb at bridge approach intercepts grade runoff prior to bridge deck and directs it through asphalt spillway to prevent embankment erosion and downstream sedimentation. Grated catch basin at end of concrete barrier also collects runoff prior to it reaching the bridge deck and sensitive watercourse.

Photo 4. Drainage collected along asphalt curb discharges through downspout pipe away from sensitive watercourse. Outlet is armoured with rock splashpad to prevent erosion.

Photo 5. Highway drainage collection pipe discharging to constructed settling pond enables sediment settling.

Photo 6. Vegetated ditchlines with constructed ditchblocks create settling cells that treat and filter road runoff prior to it reaching a watercourse.

APPENDIX 1

VANCOUVER ISLAND HIGHWAY PROJECT CASE STUDY PHOTOS CONTINUED

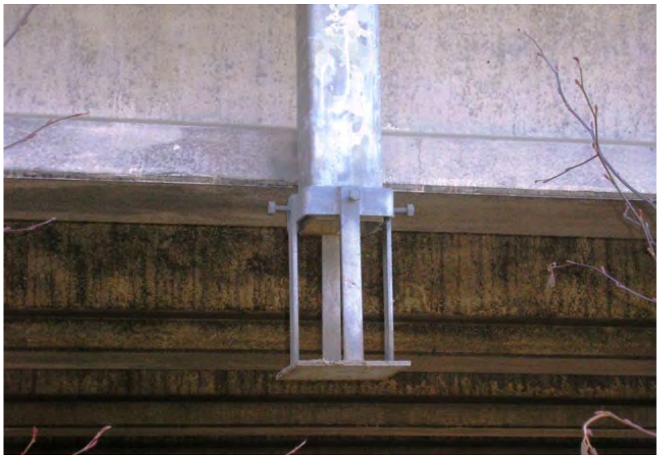

Photo 7. Spray dissipater at end of downspout dissipates discharge to avoid erosion and fill saturation.

Photo 8. Vertical collection culvert discharges to flume and then rock splashpad to avoid bridge endfill saturation and erosion.

Photo 9. Runoff through bridge expansion joint (opening through parapet shown) required installation of collection system to prevent endfill saturation and erosion.

Photo 10. Collection downpipe at outside of bridge expansion joint.

Photo 11. Construction of fish habitat ponds, in this case, immediately under a bridge, may be a cost-effective way of offsetting highway environmental impacts and enhancing habitat.

Photo 12. Constructed habitat pond underneath bridge. Additional benefits of reducing vegetation maintenance and bridge over ponds provides cover and shade for coldwater fish species.

APPENDIX 2

BRIDGE RUNOFF COLLECTION AND TREATMENT REFERENCE MATRIX

ITEM		COMMENTS
1.0 ENVIRONMENTAL		
1.1	Overall environmental mitigation plan	Bridge drainage should be considered and evaluated in the context with all potential environmental mitigation to develop an overall cost-
1.2	Sensitivity of receiving water and downstream habitat	Habitats very sensitive to runoff impacts may require a higher level of environmental mitigation compared to those without sensitive uses or those able to assimilate direct runoff.
1.3	Environmental requirements	Potential bridge runoff environmental compliance with legislation is through results-based targets and environmental Best Management Practices.
1.4	Green options	Green treatments like vegetative covers, including seeding, plantings and bioengineering, may provide a softer approach but may only be feasible under certain conditions.
2.0 DESIGN AND OPERATIONAL		
2.1	Public Safety	Primary concern is ensuring a safe roadway, and avoiding water ponding and ice formation on bridge decks.
2.2	Longevity	New bridges are designed for a 75-year service life. If treatment and collection systems are used, they should be designed to last long-term, ideally the lifetime of the bridge.
2.3	Bridge drainage downspouts	Downspouts are the typical bridge drainage structure. Downspouts should be designed so that the discharges do not cause erosion, fill saturation or structural problems. Generally, the more open and shorter the downspout, the better it is at conveying water with less maintenance.
2.4	Bridge geometrics, grades and lengths	Runoff collection systems are only functional with adequate grades (~2.5-3%), crossfall or superelevation, and when bridge span lengths are not excessive.
2.5	Climatic conditions (weather)	Climate conditions influence the usefulness and efficacy of collection and treatment systems. Collection systems are largely non-functional during sub-freezing conditions and heavy snowloads.
2.6	Runoff Debris and Plugging	Debris accumulations restrict or plug the drainage structure and appurtenance, which may result in the structure not functioning properly. Oversized drainage structures, such as double instead of single grates, upsized catchment structures or settling areas (catch basins, ponds), and open structures where possible (e.g., flumes preferred over culverts), will help mitigate this.
2.7	Site-specific design	Individual sites may require a specific treatment because a single collection and treatment type system is not possible to cover the myriad of applications and variables including a range of climactic conditions, differing road uses and varying types and application rates of winter abrasives.
2.8	Runoff discharge location	Drainage outlets should be located to prevent erosion or endfill saturation.
2.9	Ground conditions affect treatment options	Drainage may be treated via catch basins, settling basins/ponds, vegetated swales, ditchlines or other vegetated filter strips. Site conditions influence whether some of these options are practical. For example, areas of rock do not inhibit construction of settling ponds.
2.10	Partial collection and treatment of runoff prior to bridge	Bridges may not accommodate full collection of drainage, but collection on part of the structure may be possible, such as at the corners. Collecting runoff on the grade, prior to the bridge deck, is desirable to keep the bridge runoff to a minimum, alleviate some of the environmental drainage concerns, reduce bridge maintenance, and reduce water ponding hazards for vehicle traffic.
2.11	Parapet scuppers draining over bridge deck	Concerns exist that drainage through scuppers may cause degradation to the underside of deck overhangs.

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BRIDGE RUNOFF COLLECTION AND TREATMENT REFERENCE MATRIX

ITEM		COMMENTS
2.12	Collection system	If runoff collection is required, directing the water along the parapet is probably less costly, easier to maintain and longer lasting than parapets with scuppers opening to collection troughs alongside the deck. A possible concern with parapet scuppers may be corrosion of reinforcing in the bridge deck, piers or other components from salt laden water flowing through the scupper and overflowing or leaking through the trough. Collection via open structures generally requires less maintenance relative to enclosed structures. Increased joints and elbows on drainage appliances increases maintenance and cleaning requirements. Flumes should be adequately sized, with adequate grade to enhance self-flushing, accessible for inspections and maintenance, anchored, and not of excessive length.
2.13	Bridge components sensitive to runoff	Runoff should not be directed toward abutments, pier bearings, piers, expansion joints, or stringers sensitive to runoff, including dissolved substances like de-icing salts.
2.14	Treatment options	Runoff may be directed toward catch basins, settling areas (sediment ponds), or vegetated areas prior to discharge to a downstream receiving water. Surrounding terrain and property considerations will affect treatment options
2.15	Shoulder width	Bridge shoulders should be wide enough to accommodate runoff flows and debris.
2.16	Runoff collection interception	As much runoff as possible should be intercepted prior to the bridge (e.g., by diverting drainage at the bridge approach to paved flumes).
2.17	Failsafe/relief	Design and contingencies should accommodate drainage structures not operating as designed at 100% efficacy (e.g., because of plugging, vandalism or other damage). Upsizing or providing additional drainage structures will provide some relief and act as a failsafe.
2.18	Erosion avoidance and grade protection	Protection of road embankments and bridge endfills is required to avoid erosion and prevent sedimentation. This may be done by various methods, including splashpads, flumes, enclosed piping, and vegetative stabilization. Excessive water should not be directed toward endfills. This not only reduces erosion, but also avoids fill saturation and settling, undesirable freeze-thaw and frost heave.
2.19	Collection troughs attached to bridges	Experience on VIHP is that troughs are susceptible to debris collection and plugging, and are difficult to clean. There are concerns with longevity (e.g., caulking breakdown causing leakage and resealing difficulties) and high cost.
2.20	Retrofits have been required on drainage collection systems that resulted in operational problems.	Retrofits and remedial earthworks (rebuilding endfill) include collection flumes and piping.
2.21	Cleaning activities, such as bridge washing, may overload the catch basin resulting in a discharge of non-desirable materials into receiving habitats.	Use material collection systems with larger storage, such as more/larger catch basins, and/or sediment collection ponds.
2.22	Plugging of grates and scuppers	Properly size drainage appurtenances
2.23	Bridge washing	Bridge washing activities may create the largest pulse of accumulated sediments and debris off of bridge decks. BMPs exist to address bridge washing and maintenance.
2.24	Durability, function and maintenance	Collection and treatment systems that do not function well, or require high levels of maintenance such as clean-out, are more likely to be ignored resulting in limited value and/or environmental problems. A more practical approach is to consider mitigation for the relatively few cases where they may operate well, and look at the overall environmental mitigation plan.
	3.0 MISCELLANEOUS	
3.1	Drainage collection may be required because of circumstances other than environmental	Drainage collection may be required for circumstances driven by other issues, such as safety. For example, discharge from overpasses directly to traffic underneath is unacceptable.