Bridge Deck Runoff: Water Quality Analysis and BMP Effectiveness

FINAL REPORT

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Robert Perkins
Yildiz Dak Hazirbaba
University of
Alaska Fairbanks
The Alaska University Transportation Center
Institute of Northern Engineering
Fairbanks, AK 99775

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LIST OF ABBREVIATIONS AND ACRONYMS

AAC	Alaska Administrative Code
ACWA	Alaska Clean Water Actions
ADEC	Alaska Department of Environmental Conservation
ADFG	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
ADT	Average Daily Traffic (Count)
ADOT	Alaska Department of Transportation (& Public Facilities)
BMP	Best Management Practice(s)
CMA	Calcium magnesium acetate
CWA	Clean Water Act
EPA	U.S. Environmental Protection Agency
FHWA	Federal Highway Administration
GPS	Global Positioning System
HSD	Hydrodynamic settling device
KA	Potassium acetate
LRFD	Load and Resistance Factor Design
MCTT	Multi-chamber treatment train
MEP	Maximum extent practical
MS4	Municipal separate storm sewer systems
NPDES	National Pollutant Discharge Elimination System
ONRW	Outstanding National Resource Waters
SAP/QAPP	Sampling and Analysis Plan/Quality Assurance Plan
SFOBB	San Francisco Oakland Bay Bridge
STIP	Statewide Transportation Improvement Plan
SFD	Stormwater filtration device
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids

EXECUTIVE SUMMARY

The Alaska Department of Transportation (ADOT) is responsible for more than 700 bridges – most span water bodies. Are these water bodies affected by stormwater runoff from ADOT bridges? What are the regulatory and economic constraints on the ADOT regarding this runoff? What actions, if any, should the ADOT take? The Alaska University Transportation Center (AUTC) of the Institute of Northern Engineering (INE) of the University of Alaska Fairbanks (UAF) performed a project, *Bridge Deck Runoff: Water Quality Analysis and BMP Effectiveness*, to answer those questions.

Best Management Practices (BMP) are mandated or recommended for certain bridges. Which BMP is best for each bridge is not defined in law, but requires selection by the ADOT after consideration of the bridge characteristics, costs and benefits of candidate BMPs, and practicalities of construction. In the body of this report are brief descriptions of many types of stormwater BMPs, including general (not road-related) BMPs, and road and highway related BMPs; there are many standard types. There are far fewer options for bridges and fewer still that will work in Alaska's cold climate. The options can also be quite different for a bridge that is in service versus a bridge that will undergo major repairs or new construction.

The project developed a database of all the state's bridges and their parameters relevant to stormwater runoff. From those parameters a numerical rating was developed for each bridge. This rating, together with certain regulatory thresholds, is used to determine if BMPs are required. Once the need for BMP at a particular bridge is established, the ADOT should keep records of the BMP application. Unless the water body is impaired by the bridge runoff – and this project did not find any bridges where that was the case – there are a wide variety of BMPs that might be applied, ranging from low cost items such as public education and review of de-icing practices, to more costly items such a street sweeping or drainage modifications.

Are BMPs Required? Yes, if the bridge is:

- In an Urbanized Area. (66 bridges in Anchorage or Fairbanks, or perhaps Mat-Su)

- In the STIP. (61 additional bridges are slated for construction in the next five years)
- A state priority. (118 additional bridges were give a priority by ADF&G, ADEC, or ADNR indicated such in the Alaska Clean Water Actions document)
- Over waters that feed Cook Inlet. (10 additional bridges in Beluga Whale habitat)

About 255 of the state's 703 bridges should be considered for BMP based on those definite criteria. For the other bridges, the priority score might indicate it should be evaluated for BMP. In that case, however, the cut off score is not defined by regulation. Using the median score, there would be an additional 10 bridges that should be considered for BMP. For the remainder, the priority score might indicate a relative ranking, but, absent bridge-specific issues, BMP is not required.

BMP types may be divided into non-structural and structural. Non-structural BMPs include: public awareness, trash prevention, deicing changes, street sweeping, and snow management. If the runoff flows to the bridge ends, or can be made to flow to the ends, the structural BMP would refer to systems off the bridge, and these BMPs would be similar to highway runoff control (for example, vegetation, swales, and rip-rap improve the quality of the discharged water). Many of these strategies do not work in the winter, of course, but with careful snow management, some can be useful. If a bridge does not flow to the ends and cannot be practically altered to do so, some thought should be given to on-bridge structural BMP, such as piping or treatment systems. Review of the typical systems to handle bridge runoff and inquiries to all the northern tier US states, as well as Canada and Norway did not identify any easy solutions that are likely to work well in Alaska's cold climate. Thus, non-structural BMPs would be indicated.

Street sweeping and de-icing changes are non-structural BMP that are worth considering. With the EPA's current emphasis on particulates, new high-efficiency street sweeping machines have been developed. These may be economical BMP in urbanized areas. "Smart technology" involving GPS and electronic sensing might make it feasible to use special de-icers on bridges, or not use them at all, depending on the circumstances. But reviewing de-icing practices with respect to bridges could be an economical BMP. If a bridge or its associated approach roads are in the current STIP, they are noted in the database. Future STIPs will certainly include bridges and thus be candidates for BMP. During the planning of these projects, the priority score can be used to rate the bridge regarding its likely contribution to contamination. Thus the priority score can aide decision-making regarding the likely benefits of any given BMP; that is, less expensive BMPs would be indicated for lower priority scores.

CHAPTER 1

1.0 INTRODUCTION

Contamination from the surfaces of roads and bridges may enter water bodies by runoff from rain and snow melt. Generally this contamination is slight, unlikely to affect the receiving waters, and not sufficient to warrant concern. Scientific studies in the Lower-48 states have shown that, in some cases, the contamination can contributed to pollution in the receiving waters (Oberts, 2003). Since it is the owner of state highways and bridges, the ADOT must consider if contamination of water bodies from roads and bridges is significant, and if it is, what should be done about it. This report considers only bridges and the roadways closely associated with them.

ADOT's responsibilities derive from two sources. The first source is the general environmental stewardship obligation of all State of Alaska agencies. While this obligation is not defined precisely, certainly not contributing significantly to pollution of the state's waters is included. The second source is the federal Clean Water Act (CWA) of 1972 and parallel state laws. Here we focus on the CWA.

The CWA governs discharges to the nation's navigable waters, which are very broadly defined. Originally only "point sources" were regulated and these via the NPDES (National Pollution Discharge Elimination System) permits. The CWA and its regulations were later revised to cover "non-point sources," such as stormwater runoff from construction sites, and many other sources. In 1990, the EPA promulgated regulations regarding stormwater from urban areas that entered the water bodies through storm sewers. Since stormwater that entered via sanitary sewers was already regulated, the new regulations were specified as "Municipal Separate Storm Sewer Systems" (MS4). The rules came in two phases. Phase I in 1990 covered storm sewer systems in municipalities of over 100,000 populations. Since these and the ADOT issues that derive from that designation are clear, we will not need to spend any time here with Phase I, which in Alaska is only Anchorage.

Phase II, extended the rule to "small" MS4s. This is a good place to define MS4. This from the EPA:

> The term MS4 does not solely refer to municipally-owned storm sewer systems, but rather is a term of art with a much broader application that can include, in addition to local jurisdictions, state departments of transportation, universities, local sewer districts, hospitals, military bases, and prisons. An MS4 also is not always just a system of underground pipes – it can include roads with drainage systems, gutters, and ditches. (EPA, 2008c)

Since that definition is very broad, the EPA further specifies the subset of those that is regulated as "*regulated* MS4s." And which are they? There are two tests to see if an MS4 is regulated. First, is it in an Urbanized Area (UA)? This is defined per the US census, which is published every 10 years. The definition used by the Census Bureau is complex and involves both total population within a municipal boundary and overall population density. However the EPA has the census bureau data on a website, so the UA locations in Alaska are easy to find (EPA, 2007). There are only two – Anchorage and Fairbanks. In addition, the next census may declare the Mat-Su Borough also is a UA.

The second method a small MS4 may be regulated is if it is "designated by the NPDES permitting authority." That raised two questions, "Who is the NPDES permitting authority in Alaska," and "why are certain MS4s designated?" "Who" is clear. It was the federal EPA, through their Region X office in Seattle. However Alaska recently received authority both from the EPA and the Alaska Legislature, to assume the program in Alaska. Thus, since late October 2009, primacy for the NPDES program rests with the state and is administered by ADEC.
Why certain MS4s would be designed by either the EPA or the ADEC is set out in the regulations and interpretations:

EPA recommended that the NPDES permitting authority use a balanced consideration of the following designation criteria on a watershed or other local basis:

- Discharge to sensitive waters;
- High population density;
- High growth or growth potential;
- Contiguity to a UA;
- Significant contributor of pollutants to waters of the United States; and
- Ineffective protection of water quality concerns by other programs (EPA, 2005b).

As of October 2009, the EPA has not designated any regulated small MS4 in Alaska. Presumably the ADEC will work to the same list. So what if a bridge or roadway is designated a "regulated MS4?" Then

Operators of regulated small MS4s are required to design their programs to:

- Reduce the discharge of pollutants to the "maximum extent practicable" (MEP);
- Protect water quality; and
- Satisfy the appropriate water quality requirements of the Clean Water Act. Implementation of the MEP standard will typically require the development and implementation of BMP (EPA 2005a).

The most likely triggers for regulated status would a discharge to water that is deemed "sensitive" or a discharge that is deemed "significant contributor of pollutants." Although that designation would take a public notification and hearing process, ADOT needs to consider if such designation is likely in the future. Since almost all Alaskan rivers have the status "drinking water quality" in the state's CWA [AS 46.03.050 18] and its water quality regulations [18 AAC 70], some analysis is needed, if there is measurable discharge. The basic policy is that of "anti-degradation" of high quality waters. If a discharge is found to degrade those waters, for non-point sources, the discharging party would need to treat the discharges using "all cost-effective and reasonable best management practices." [18 AAC 70.015.a.2.E.ii] These treatments must be approved by the ADEC as part of a "permitting, certification or approval" process [18 AAC 70.015.b]. This opens a second route of scrutiny, namely through a consistency evaluation of a project, for example a bridge approval by the Corps of Engineers, the ADEC could ask for something in their consistency review, as could the public.

Since 18 AAC 70 refers to the water body, it seems unlikely that bridge discharges to the water would cause it to exceed the standards set out in 18 AAC 70 and The Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances. The concept of "degradation" is more qualitative, but presumably it would need to measurable and somehow significant. The ADOT should examine if conditions of the roadway with respect to the water body should invoke concern. That is, is the nature of the bridge and the likely relation to the water body plausibly cause "degradation" of the water body? Later in this report, we have developed a numerical scoring system, based on road location, traffic (ADT) and other parameters, to rank bridges according to their likelihood of transferring contamination to the water.

Thus, ADOT must implement BMP in the Anchorage and Fairbanks UA, and should prepare to implement in Mat Su. In addition, some judgment should be applied regarding if a water body is likely to be designated by ADEC in the future. This is more difficult to determine directly, but inquiry at ADEC and EPA should indicate if complaints have been received that might generate some concern.

Integrated Water Quality Monitoring and Assessment Report

A further guide to sensitivity is the *Integrated Water Quality Monitoring and Assessment Report* (ADEC 2008)

> Under the federal Clean Water Act each state must develop a program to monitor and report to the EPA on the quality of its waters. This report would characterize the quality of <u>all</u> water bodies in the state and comment on those that do not meet the water quality standards. But Alaska is not Arizona: Alaska is rich in water

> quantity, water quality, and aquatic resources, with almost half of the total surface waters of the United States located within the state. Because of Alaska's size, sparse population, and its remote character, the vast majority of Alaska's water resources are in pristine condition. More than 99.9% of Alaska's waters are considered unimpaired. With more than 3 million lakes, 714,004 miles of streams and rivers, 36,000 miles of coastline, and approximately 176,863,000 acres of freshwater and tidal wetlands, less than 0.1% of Alaska's vast water resources have been identified as impaired. Historically, Alaska's water quality assessments focused on areas with known or suspected water quality impairments.

Thus some method must be used to focus attention on the water bodies that are of interest. The EPA has done that using a categorization scheme that relies on professional judgment. Part of that judgment process called for the state's three agencies that are most concerned with water: the Department of Natural Resources (ADNR), ADEC, and ADFG, to rate each water body. These ratings then combined into Alaska Clean Water Actions (ACWA) Priority Ranks. A high ranking by the three indicates that the water body may be "sensitive".

If the bridge is directly regulated BMP must be implemented. If it otherwise might be termed sensitive based on ACWA or our scoring system, BMP should be considered. Actions taken must be cost effective. Higher cost BMP would be warranted if the likelihood of contamination is high, while lower cost might be sufficient is the likelihood is low. And whatever BMP is recommended must be safe and efficient in Alaska's climate.

Thus, this report has three main sections.

- Chapter 2-6 overview BMPs – what is available and what might work in Alaska,
- Chapter 7 is a ranking of bridges in Alaska, that notes if they are regulated directly, if because of ADEC, EPA, or other issues are likely to be regulated in the future, and finally a general scoring matrix that indicates if the roadway warrants concern.

- Chapters 8 and 9 have recommendations, for the process to decide if a bridge needs to be considered for BMP and some specific BMPs that warrant consideration.

Two appendices have photos of Alaskan bridges and a third appendix has an annotated bibliography of stormwater and bridge papers.

CHAPTER 2

2.0 BASIC INFORMATION

This Chapter presents basic information regarding to runoff in general. The topics discussed are what storm water is, what the constituents and sources of highway runoff are, and how this information is related.

2.1 Stormwater in General

Urban development alters the hydrology (rate and volume) of watersheds and streams by disrupting the natural water cycle (Georgia Stormwater Manual, 2001). As development increases, new roads, shopping centers, driveways and rooftops generate more impervious surfaces, and eventually more storm water runoff.

By the passage of the federal Clean Water Act (CWA) in the 1970s, it was no longer acceptable to pollute US water resources, even for governments. At first, when implementing the provisions of the CWA, the focus was on those discharges coming from the end of a municipal or industrial wastewater pipe. The Federal Water Pollution Control Act of 1972 required a permit for all point source discharges into navigable water bodies. In 1977 the Clean Water Act extended the scope of pollution control to "non-point sources," such as stormwater. Stormwater is an all-inclusive term that refers to any of the water running off of the land's surface after a rainfall or snowmelt event (Minnesota Stormwater manual, 2005).

Stormwater runoff occurs when precipitation from rain or snowmelt flows over the ground. Impervious surfaces like driveways, sidewalks, and streets prevent stormwater runoff from naturally soaking into the ground (EPA, 2008a).

Stormwater from rain events and snowmelt must be removed from the deck of highway bridges quickly in order to protect traffic. When the bridge crosses a water body some consideration is needed regarding the effect of this runoff on water quality.

2.2 Highway Runoff in General

The National Cooperative Highway Research Program (NCHRP) produced a report, NCHRP 474, which states that because the characteristics of bridge deck runoff have not been broadly documented, the characteristics of highway runoff may be directly comparable with bridge deck runoff (NCHRP 2002). For this reason, to understand the nature of bridge deck runoff, it is helpful to take a look at the constituents and sources of highway runoffs, and its effects on the receiving water bodies.

As described in FHWA's (Federal Highway Administration) *Effects of Highway Runoff on Receiving Waters–Volume IV Procedural Guidelines for Environmental Assessments* (Dupuis and Kobringer, 1985), several parameters affect the magnitude of pollution in highway runoff. Parameters are grouped into the following general categories:

• *Traffic characteristics*—speed, volume, vehicular mix (cars/trucks), congestion factors, and state regulations controlling exhaust emissions;

• *Highway design*—pavement material, percentage impervious area, and drainage design;

• *Maintenance activities*—road cleaning, roadside mowing, herbicide spraying, road sanding/salting, and road repair;

• *Accidental spills*—sand, gravel, oils, and chemicals.

Highway runoff contains metals, such as lead, copper, and zinc; particulates, clay and silt; polycyclic and other hydrocarbons of anthropogenic origin; nutrients, and salts and road deicing chemicals. FHWA describes typical highway runoff constituents and sources in Table 1.

Metals have acute and chronic toxicity to aquatic life, and particulates are the carriers of other pollutants and sedimentation effects on aquatic habitat, nutrients can contribute to eutrophication and salts have aquatic life toxicity effect and affects drinking water supply taste.

Table 1 Highway runoff constituents and their primary sources (Dupuis and Kobringer, 1985**)**

Constituent	Primary Source
Particulates	Pavement wear, vehicles, atmosphere, maintenance
Nitrogen, phosphorus	Atmosphere, roadside fertilizer application
Lead	Leaded gasoline (automobile exhaust), tire wear (lead oxide filler material), lubricating oil and grease, bearing
Zinc	Tire wear (filler material), motor oil (stabilizing additive), grease, galvanizing.
Iron	Automobile body rust, steel highway structures (guard rails, etc.), moving engine parts
Copper	Metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides and insecticides applied by maintenance operations
Cadmium	Tire wear (filler material), insecticide application
Chromium	Metal plating, moving engine parts, brake lining wear
Nickel	Diesel fuel and gasoline (exhaust), lubricating oil, metal plating, bushing wear, brake lining wear, asphalt paving
Manganese	Moving engine parts
Bromide	Exhaust
Cyanide	Anti-cake compound (ferric ferrocyanide, Prussian blue or sodium ferrocyanide, yellow prussiate of soda) used to keep deicing salt granular

Constituent	Primary Source
Sodium, calcium	Deicing salts, grease
Chloride	Deicing salts
Sulfate	Roadway beds, fuel, deicing salts
Petroleum	Spills, leaks or blow-by of motor lubricants, antifreeze and hydraulic fluids, asphalt surface leachate
PCBs, pesticides	Spraying of highway rights-of-way, background atmospheric deposition, PCB catalyst in synthetic tires
Rubber	Tire wear
Pathogenic bacteria (indicators)	Soil, litter, bird droppings, trucks hauling livestock and stockyard waste

On the follow page, in Table 2, the U.S. EPA recommendations are provided for some of the pollutants listed in Table 1. These criteria are created with an intention to protect the vast majority of the aquatic life in the United States

Table 2 National recommended water quality criteria for priority toxic pollutants. Criteria Maximum Concentration (CMC) and Criterion Continuous Concentration **(**CCC) (EPA, 1998)

	Freshwater		**Saltwater**	
Priority Pollutant	**CMC (μg/L)**	**CCC (μg/L)**	**CMC (μg/L)**	**CCC (μg/L)**
Cadmium	2.0	.25	40	8.8
Chromium III	570	74	-	-
Chromium IV	16	11	1100	50
Copper	13	9.0	4.8	3.1
Lead	65	2.5	210	8.1
Nickel	470	52	74	8.2
Zinc	120	120	90	81

The CMC protects against short-term (acute) effects (i.e., lethality), whereas the CCC protects against long-term exposure (chronic) effects such as significant reductions in growth or reproduction (NCHRP, 2002).

These U.S. EPA criteria are for guidance, and each state may have different criteria for its water quality standards. Because Alaska has diverse and rich water sources and aquatic life, it may be possible and advisable to adopt water quality criteria on a site specific basis for some values. Prior to implementing any best management practice (BMP) to manage bride deck runoff, the practitioner should review the state water quality standards directly applicable to the specific receiving water for the bridge(s) in question.

In the following Chapter, BMPs to prevent or reduce the movement of polluted runoff from the land to surface or ground water is defined.

CHAPTER 3

3.0 BEST MANAGEMENT PRACTICES (BMPs)

Here we review general BMPs for land and roadways as an introduction to the analysis of bridge deck BMPs.

Best Management Practices are defined as a practice or combination of practices determined to be an effective, practical, structural or nonstructural means of preventing or reducing the movement of sediment, nutrients, pesticides and other non-point pollutant sources from the land to surface or ground water (Hawaii BMPs, 2010).

The adoption and use of BMPs provide the mechanism to maintain the integrity of streams and water bodies. A comprehensive understanding of BMPs available is important in selecting site specific BMPs to achieve this goal. There may be more than one correct BMP for reducing or controlling potential nonpoint source pollution for each situation encountered at various sites. It is vital to decide on BMPs that are effective, practical and economical.

Although our project focus is on the runoff from bridges, we will start with basic EPA guidance about stormwater in general. In this Chapter, we will give the definitions of most commonly used BMP in managing storm water runoff from highways. We consider that in terms of BMPs, knowledge of all common practices in use in mitigating the runoff should be available to bridge engineers so that they can judge their applicability to bridge deck runoff. We present analyses more specific to bridges and bridges in cold climates in the next Chapter.

In some cases, the Environmental Protection Agency (EPA) requires the use of BMPs to reduce nonpoint source pollution. The EPA created a National Menu of Stormwater Best Management Practices in October in 2000, and updates it on a regular basis. (EPA, 2008b) This Chapter covers EPA's National Menu of Stormwater Best Management Practices very briefly for all uses.

3.1 National Menu of Stormwater Best Management Practices

According to National menu, BMPs used for stormwater management in general classified into six categories. These categories are public education, public involvement, illicit discharge and elimination, construction, post-construction, and pollution prevention/good housekeeping. Below, we paraphrase EPA's National Menu of Storm water Best Management Practices, which may especially be useful for bridge runoff applications (EPA National Menu of BMPs, 2009).

3.1.1. Public Education –BMPs to inform individuals and households about ways to reduce stormwater pollution. Developing a municipal outreach strategy, promoting the stormwater message through classroom education, educational displays, pamphlets, booklets, bill inserts, and promotional giveaways and providing education for homeowners on pest control, pet waste management, trash and debris management, and residential car washing and for businesses on pollution prevention practices are just few of the BMPs suggested by EPA.

3.1.2. Public Involvement - BMPs to involve the public in the development, implementation, and review of a stormwater management program. EPA put forward some tools for public involvement to help spread the message on preventing stormwater pollution, to take on group activities that highlight storm drain pollution, and to contribute to volunteer community actions to restore and protect local water resources. Examples are Adopt-A-Stream Programs, Reforestation Program, Storm Drain Marking, Stream Cleanup and Monitoring, and Wetland plantings.

3.1.3. Illicit Discharge Detection & Elimination- BMPs for identifying and eliminating illicit discharges and spills to storm drain systems. Because illicit discharges often include pathogens, nutrients, surfactants, and various toxic pollutants, and unlike wastewater, stormwater flows to waterways without any additional treatment, EPA emphasizes on developing BMPs that focus on detection and elimination of these illicit discharges. Examples mentioned are developing a storm sewer system map, an ordinance prohibiting illicit discharges, a plan to detect and address these illicit discharges, and an education program on the hazards associated with illicit discharges.

3.1.4. Construction – BMPs for construction site operators to address stormwater runoff from active construction sites. During construction BMPs listed are: contractor training, land grading, preserving natural vegetation, erosion control, chemical stabilization, compost blankets, dust control, geotextile, mulching, riprap, seeding, soil retention, soil roughening, temporary slope drains, temporary stream crossings, wind fences, and sand fences, runoff control, check dams, grass-lined channels, permanent slope diversions, temporary diversion dikes, sediment control, compost filter berm, compost filter socks, brush barriers, fiber rolls, filter berms, sediment basins and rock dams, sediment filters and sediment chambers, sediment traps, silt fences, vegetated buffers, good housekeeping such as concrete washout, general construction site management, and having a spill prevention and control plan. Some of the BMPs listed above will be explained if they are applicable to highway runoffs. Otherwise, detailed information about each practice can be found on the EPA website.

3.1.5. Post-construction - BMPs to address stormwater runoff after construction activities have been completed. The best way to mitigate stormwater impacts from new developments is to use practices to treat, store, and infiltrate runoff onsite before it can affect water bodies downstream. EPA recommends that practices to reduce flows and improve water quality can be achieved by BMP inspection and maintenance, ordinances for post-construction runoff, post-construction plan review, zoning. Also, for site plans, alternative turnarounds, conservation easements, development districts, eliminating curbs and gutters, green parking, green roofs, infrastructure planning, Low Impact Development (LID) and other green design strategies, narrower residential streets, open space design, protection of natural features, riparian/forested buffers are suggested BMPs. In addition, infiltration BMPs such as grassed swales, infiltration trenches, permeable interlocking concrete pavement , pervious concrete pavement, porous asphalt pavement and filtration BMPs such as rain gardens, catch basin inserts, sand and organic filters, vegetated filter strips are advised. Retention/detention dry detention ponds, in-line storage, on-lot treatment, stormwater wetland, and wet ponds.

3.1.6. Pollution Prevention/Good Housekeeping - BMPs for municipalities to address stormwater runoff from their own facilities and activities These pollution prevention BMPs includes winter road maintenance, minor road repairs and other infrastructure work, automobile fleet maintenance, landscaping and park maintenance, building maintenance, road salt application and storage. Also, pollutant removal BMPs such as parking lot and street sweeping and storm drain system cleaning are categorized as good housekeeping ones.

3.2 Highway Runoff BMPs

A list of BMPs can be generated out of EPA's National Menu of BMPs for highway runoff treatments. In general, there are four types of BMPs that need to be considered to achieve water quality goals. These are nonstructural, institutional and structural BMPs and storm water pre- and post treatment practices.
Further definitions regarding to each type is given below.

3.2.1 Non-Structural BMPs

Non-structural BMP is the first step of BMP application. They aim to prevent pollution and minimize the increase in storm water. Non-structural BMPs can be achieved through such things as education, management and development practices and can be categorized as pollution prevention, runoff volume minimization, and sediment and erosion control practices based on their function. Pollution prevention practices have their focus on water quality while runoff volume minimization practices have focus on water quantity. There are no physical structures associated with these types of BMPs. They often offer cost-efficient and alternative approaches to reducing pollutant loads. We will discuss sediment and erosion control practices in Chapter 4 as part of bridge BMPs.

3.2.1.1 Pollution Prevention

Stormwater management begins with simple methods that minimize the amount of runoff that occurs from a site and methods that prevent pollution from accumulating on the land surface and becoming available for wash-off (Minnesota Stormwater Manual, 2005). Street sweeping, litter control, catch basin cleaning, chemical management, spill prevention and clean-up, deicing and sediment control are a part of pollution preventive solutions to highway runoffs. Brief descriptions to each BMP are provided below.

3.2.1.2 Street sweeping

Significant amount of pollutants such as sediment, trash, debris, trace metals, and road salt accumulate on streets, roads, highways. They can be swept, and prevented from contributing to stormwater runoff to surface waters. Street sweeping also helps dust control and decreases the accumulation of pollutants in catch basins, which will be discussed later.

3.2.1.3 Litter Control

The removal of litter from streets and other surfaces before runoff moves these materials to surface waters is a very effective solution in terms of preventing the litter from becoming pollution.

3.2.1.4 Catch basin cleaning

A catch basin, which is also known as a storm drain inlet or curb inlet, is an opening to the storm drain system that typically includes a grate or curb inlet at street level where storm water enters the catch basin and a sump captures sediment, debris and associated pollutants. Catch basins are able to prevent trash and other floatable materials from entering the drainage system by capturing such debris by way of a hooded outlet. The outlet pipes for catch basins on combined sewers (sanitary waste and storm water in a single pipe) are also outfitted with a flapper (trap) device to prevent the backflow of any unpleasant odors from pipes. Catch basins act as pretreatment for other treatment practices by allowing larger sediments to settle in the basin sump areas (Boston Maintenance Project, 2009).

3.2.1.5 Spill prevention and Clean-up

To prevent discharge of contaminants and hazardous compounds into the storm water system, spills should be promptly cleaned up. Spills and leaks are one of the largest contributors of stormwater pollutants (California BMP Handbook, 2003). Many spills can be cleaned simply by using absorbent material, which can then be scooped up and disposed of properly. Cleanup material could be stored at ADOT maintenance facilities.

An effective plan should be created for ADOT to coordinate with agencies responsible for spill prevention and response procedures.

3.2.1.6 Salt storage and application

The application and storage of deicing materials, most commonly salts such as sodium chloride, can lead to water quality problems for surrounding areas (Koppelman, 1984, EPA, 2009). Proper storage and application for equipment and materials is important. Even though road salt is the least expensive material for the deicing, alternative road deicing products such as calcium chloride, magnesium chloride, potassium chloride, urea, calcium magnesium acetate are considered to have less adverse effects than road salt.

Salt management and chemical spill control can be local programs. Deicing with salt and chemicals is usually a direct ADOT responsibility, while spill cleanup of oil and chemical spills is usually the financial responsibility of the party that spilled, and the clean-up is supervised, usually, by the state environmental agencies. In Alaska, this is usually ADEC.

3.2.1.7 Deicing Controls

Deicers can represent a significant threat to water resources. Rock salt is the most widely used deicer. Rock salt has sodium chloride which may impact roadside vegetation. It often contains ferrous cyanide as an anticaking agent (Caraco, 1997). Other less toxic, but higher cost, salts such as calcium magnesium acetate (CMA) and potassium acetate (KA) can be used. These can melt snow at much lower temperatures, and have less environmental impact (Caraco, 1997).

Other materials can also be applied along with salt, or alone with an abrasive such as sand. Sand is typically applied with salt, and provides tractions at very low temperatures where deicers may be less effective. One disadvantage of abrasives is that they tend to increase both solids and phosphorus loading of runoff (SWRC 2003).

3.2.2 Runoff Volume Minimization

As development increases, new roads, driveways, shopping centers, and other constructions creates impervious surfaces that prevent stormwater soaking into the ground. Thus, more water runs off. Runoff minimization BMPs aim to increase pervious area so that more water infiltrates and less runoff occur. Examples are permeable pavement or “grass-crete” parking area with rock filled trench drains, adjacent vegetated slopes and vegetated filter areas.

3.2.2.1 Using Compost as a Soil Amendment

Compost is the product resulting from the controlled biological decomposition of organic materials that has been sanitized through the generation of heat and stabilized to the point that it is beneficial to plant growth (Minnesota Stormwater Manual, 2005). Compost can be used as a soil amendment. To increase infiltration, reduce runoff, improve soil porosity, increase soil moisture holding capacity (reduce water demand of lawns and landscaping), reduce erosion, absorb certain pollutants (increase cation exchange capacity), and reduce fertilizer needs.

3.2.3 Institutional BMPs

Pollutant Trading and Mitigation Banking are two institutional BMPs that might be of interest in complex projects that will emit a known amount of contaminants to a stressed water body, or take sensitive wetlands.

3.2.3.1 Pollutant Trading

Pollutant trading is a business-like way of helping to solve water quality problems by focusing on cost effective, local solutions to problems caused by pollutant discharges to surface waters. The appeal of trading emerges when pollutant sources face substantially different pollutant reduction costs. A party facing relatively high pollutant reduction costs compensates another party to achieve an equivalent, though less costly, pollutant reduction (Idaho Pollutant Trading Guidance, 2003).

3.2.3.2 Mitigation Banking

Mitigation banking entails the restoration, creation or enhancement of wetlands or streams and placing the credits generated from the restoration, creation, or enhancement into a bank for future mitigation needs. Mitigation banking is one approach to offsetting impacts under the Section 404 of the Clean Water Act (CWA) permitting process that the Districts for the United States Army Corps of Engineers (USACE) oversee. Banks allow users to cost effectively fulfill mitigation needs without developing mitigation plans for each project separately. The USACE has an inter-agency review team (IRT) that reviews instrument applications and mitigation site designs and provides input on the value of the proposed mitigation bank. It can take several months to several years to get a mitigation bank approved, depending on the type, size, and complexity of the bank (SESWA, 2010).

3.2.3 Structural BMPs

Structural BMPs can be thought of as engineering solutions to stormwater management. Structural BMPs are used to treat stormwater at the point of generation, the point of discharge, or at any point along the stormwater "treatment train."

3.2.3.1 Bioretention

It is a soil and plant based filtration device that removes pollutants through a variety of physical, biological, and chemical treatment processes. Grass buffer strips, organic or mulch layers, sand beds, ponding areas, planting soil, and plants are used for this BMP. The stormwater runoff velocity is reduced by passing over or through buffer strip and subsequently distributed evenly along a ponding area. Exfiltration of the stored water in the bioretention area planting soil into the underlying soils occurs over a period of days (BMP Database, 2008). Stormwater planters are an example of such a system.

3.2.3.2 Stormwater planter

A stormwater planter is a small, contained vegetated area that collects and treats stormwater using bioretention. Bioretention systems collect and filter stormwater through layers of mulch, soil and plant root systems, where pollutants such as bacteria, nitrogen, phosphorus, heavy metals, oil and grease are retained, degraded and absorbed. Stormwater planters typically contain native, hydrophilic flowers, grasses, shrubs and trees (CRWA, 2008).

3.2.3.3 Ponds

Stormwater ponds, retention ponds, and wet extended detention ponds are called wet ponds. These constructed basins have a permanent pool of water throughout the year or only throughout the wet season. They have a greater depth compared to constructed wetlands. They work by treating incoming stormwater runoff by settling and biological uptake. The primary removal mechanism is settling as stormwater runoff resides in this pool, but pollutant uptake, particularly of nutrients, also occurs to some degree through biological activity in the pond (BMP Database, 2008). Wet ponds are the most commonly used BMP for stormwater runoff treatment. Extended detention wet pond is the most widely used modification, where storage is provided above the permanent pool in order to detain stormwater runoff and promote settling.

3.2.3.4 Constructed Wetland

These constructed basins have a permanent pool of water throughout the year. They are similar to wet ponds, but they are in shallower and having greater vegetation coverage.

3.2.3.5 Stormwater Wetland

It is a manufactured wetland. Gravel substrate and subsurface flow of the stormwater through the root systems force the vegetation to remove nutrients and dissolved pollutants from the stormwater.

3.2.3.6 Infiltration Practices

Infiltration practices, such as infiltration trenches, remove suspended solids, particulate pollutants, coliform bacteria, organics, and some soluble forms of metals and nutrients from stormwater runoff. These practices have high pollutant removal efficiency and can also help recharge groundwater, thus helping to maintain low flows in stream systems.

Infiltration Basin

An infiltration basin is a shallow impoundment that is designed to infiltrate stormwater. Infiltration basins use the natural filtering ability of the soil to remove pollutants in stormwater runoff. Infiltration facilities store runoff until it gradually exfiltrates through the soil and eventually into the water table.

Infiltration basins can be challenging to apply on many sites, however, because of the requirement for permeability. In addition, some studies have shown relatively high failure rates compared with other management practices (California, BMP Handbook, 2003).

Infiltration Trench

An infiltration trench is a long, narrow, excavated trench backfilled with a stone aggregate, and lined with a filter fabric. Runoff is stored in the void space between the stones and infiltrates through the bottom and into the soil matrix. Infiltration trenches perform well for removal of fine sediment and associated pollutants. Pretreatment using buffer strips, swales, or detention basins is important for limiting amounts of coarse sediment entering the trench, which can clog and render the trench ineffective. The infiltration trench treats the design volume of runoff either underground or at grade. Pollutants are filtered out of the runoff as it infiltrates the surrounding soils. Infiltration trenches also provide groundwater recharge and preserve base flow in nearby streams (Alameda Stormwater Technical Guide, 2003).

Extended Detention Basin

Dry ponds, extended detention basins, detention ponds, extended detention ponds are the names used for this type of BMP.

These basins don't have permanent pools. Their outlets have been designed to detain the storm water runoff for some minimum time such as 48 hours to allow particles and associated pollutants to settle (BMP Database, 2008).

Soakaway pit/ drywell

Drywells are usually designed to a frequent (first flush) design storm and therefore lose their ability to treat runoff when their design capacity is reached (Dupage County Manual, 2008).

3.2.3.6 Filtration Practices

Media filter, sand and organic filters, grassed swales, and grass drainage channel are filtration practices discussed below.

Media Filter

Stormwater media filters are usually two chambered including a pretreatment settling basin and a filter bed filled with sand or other absorptive filtering media. As stormwater flows into the first chamber, large particles settle out, and then finer particles and other pollutants are removed as stormwater flows through the filtering media in the second chamber. There are a number of design variations including the Austin sand filter, Delaware sand filter, and multi chambered treatment train (MCTT) (BMP Database, 2008).

Sand and organic filters

Sand filters are usually designed as two-chambered stormwater practices; the first is a settling chamber, and the second is a filter bed filled with sand or another filtering media. As stormwater flows into the first chamber, large particles settle out, and then finer particles and other pollutants are removed as stormwater flows through the filtering medium. There are several modifications of the basic sand filter design, including the surface sand filter, underground sand filter, perimeter sand filter, organic media filter, and MCTT. All of these filtering practices operate on the same basic principle. Modifications to the traditional surface sand filter were made primarily to fit sand filters into more challenging design sites (e.g., underground and perimeter filters) or to improve pollutant removal (e.g., organic media filter) (EPA, 2006).

Grassed swales

Vegetated swales are open, shallow channels with vegetation covering the side slopes and bottom that collect and slowly convey runoff flow to downstream discharge points. They are designed to treat runoff through filtering by the vegetation in the channel, filtering through a subsoil matrix, and/or infiltration into the underlying soils. Swales can be natural or manmade. They trap particulate pollutants (suspended solids and trace metals), promote infiltration, and reduce the flow velocity of stormwater runoff. Vegetated swales can serve as part of a stormwater drainage system and can replace curbs, gutters and storm sewer systems.

Grass drainage channel

This BMP provides a channel with a vegetative lining for conveyance of runoff. Drainage ditches, roadside ditches, outlets for diversions, channels at property boundaries are typical uses.

3.2.4 Supplemental Pre- and Post Treatment BMPs

These BMPs are used as a supplement to the primary treatment device. There are cases, these devices are used as the only BMP on the runoff site.

3.2.4.1 Drain Inserts

Drain inserts are manufactured filters or fabric placed in a drop inlet to remove sediment and debris. There are a multitude of inserts of various shapes and configurations, typically falling into one of three different groups: socks, boxes, and trays. The sock consists of a fabric, usually constructed of polypropylene. The fabric may be attached to a frame or the grate of the inlet holds the sock. Socks are meant for vertical (drop) inlets. Boxes are constructed of plastic or wire mesh.

3.2.4.2 Catch basins insert

A catch basin insert is any device that can be inserted into an existing catch basin to provide some level of runoff contaminant removal. The most frequent application for catch basin inserts is for reduction of sediment, oil, and grease in stormwater runoff. The most serious potential drawback to the use of some catch basin inserts is their tendency to become clogged with sediment. Most devices depend on some type of bed-filtration for treatment, and sediment quickly clogs the filter, rendering the unit ineffective. The variable nature of stormwater runoff quantity and quality makes it difficult to determine just how well the inserts work (South Carolina, Urban BMPs, 2008).

3.2.4.3 Wet vault

A wet vault is a vault with a permanent water pool, generally 3 to 5 feet deep. The vault may also have a constricted outlet that causes a temporary rise of the water level (i.e., extended detention) during each storm. This live volume generally drains within 12 to 48 hours after the end of each storm.

3.2.4.3 Floatable skimmer

Floatable skimmers are devices used to retain floating debris and oil in detention areas. The floating debris and oil eventually sink to the bottom of the detention area and becomes part of the sediment or is removed from the surface through regular maintenance. The effect of floatable skimmers on water quality will depend upon the amount and type of floating material transported by runoff. Typically, a well designed floatable skimmer can trap virtually all floating debris that reaches it. In an area with large amounts of floating leaves, trash or oil, this can provide significant water quality benefits (Weber County, Utah, BMP, 2010).

3.2.4.4 Water quality inlets

These devices are appropriate for capturing hydrocarbon spills, but provide very marginal sediment removal and are not very effective for treatment of stormwater runoff. Water quality inlets (WQIs) typically capture only the first portion of runoff for treatment and are generally used for pretreatment before discharging to other best management practices (BMPs). Some WQIs also contain screens to help retain larger or floating debris, and many of the newer designs also include a coalescing unit that helps promote oil/water separation.

3.2.4.5 Vortex Separator

Vortex separators: (alternatively, swirl concentrators) are gravity separators, and in principle are essentially wet vaults. The difference from wet vaults, however, is that the vortex separator is round, rather than rectangular, and the water moves in a centrifugal fashion before exiting. By having the water move in a circular fashion, rather than a straight line as is the case with a standard wet vault, it is possible to obtain significant removal of suspended sediments and attached pollutants with less space. Vortex separators were originally developed for combined sewer overflows (CSOs), where it is used primarily to remove coarse inorganic solids.

3.2.4.6 Buffer boxes

These devices are used in situations where traditional best management practices (BMP) like sedimentation basins cannot be installed. Buffer boxes are simple and cost-effective, reducing the amount of sediment passing through storm drains by 26 to 34 percent for fine sediment and 86 to 96 percent for coarse sediment(EPA, 2006).

CHAPTER 4

4.0 BRIDGE DECK RUNOFF MANAGEMENT

This Chapter covers bridge definition, bridge design and retrofit constraints to mitigate the runoff, and current bridge deck runoff design practices.

4.1 Bridge Definition and Constraints

According to National Bridge Inspection Standards, a bridge is a structure, including supports, erected over a depression or an obstruction, such as water, highway, or railway, and having a track or passageway for carrying traffic or other moving loads, and having an opening measured along the center of the roadway of more than 20 feet between under copings of abutments or spring lines of arches, or extreme ends of openings for multiple boxes; it may also include multiple pipes where the clear distance between openings is less than half of the smaller contiguous opening.

Even though there has been much research done about best management practices to manage highway runoff, there has been very little published about bridges. NCHRP developed a report, which makes an assessment of the impact of bridge deck runoff contaminants in receiving waters. This report, NCHRP 474, was found to be the most specific and useful source about BMPs specific to bridge deck runoffs during our research.

Of course, not every highway runoff BMP can be applied to manage bridge deck runoff because of the bridge design and retrofit constraints at the receiving water crossing. These constraints defined by NCHRP Report 474 as follows:

- There is no flexibility regarding the size of the foot print. There is no lateral right-of-way on which to build mitigation measures. Mitigation measures can be located on the bridge only at substantial cost, or storm water must be gravity-drained back to land.
- The topography slope at some bridge locations preclude design or retrofit for gravity drainage back to land.

- The additional load of storm water piping must be considered for retrofit and in new bridge design.
- The length and slope of some bridges preclude gravity drainage to land. For floating bridges, storm water cannot be routed to land without pumping assistance.
- Maintenance may be difficult, and additional safety measures may need to be considered for bridges that are retrofitted with storm water control measures.

NCHRP reported current runoff design practices for bridge deck runoff crossing waters as follows;

- Discharging runoff through multiple open scuppers directly into the receiving water
- Discharging runoff through piping down from the bridge deck directly into the receiving water without treatment.
- Conveying the storm water runoff over the surface of the bridge to one or both ends for BMP treatment or discharge.
- Conveying the storm water runoff via piping or open troughs over to one or both ends of the bridge for BMP treatment or discharge.
- Detaining and treating the storm water under the bridge deck.

4.2 Bridge Deck Runoff Applicable BMPs

In NCHRP 474, Volume 2, there is a nonstructural and structural BMP evaluation method presented for bridges. This simple evaluation process to select the BMP starts with defining the need (e.g., heavy metals concentration reduction, discharge elimination) and the constraints as the first steps. Next step is to decide on the purpose of the selection (e.g., pollutant reduction, flow reduction).

It is mentioned in the handbook that nonstructural BMPs that are potentially applicable to bridges include:

– Street sweeping,

– Inlet box/catch basin maintenance,

– Maintenance management,

– Deicing controls, and

– Traffic management (e.g., high occupancy vehicle lanes, and mass transit).

To be cost effective, it is suggested that to achieve the required benefits, first consider the mentioned nonstructural BMPs for bridges and, if not, evaluate for institutional BMPs (i.e., pollutant trading and mitigation banking). As a next step, structural BMPs should be evaluated if both nonstructural and institutional BMPs cannot provide enough of the desired water quality benefit/protection.

A critical component of the BMP analysis includes engineering evaluations related to the type of drainage and storm water conveyance needed, and the effects these systems could have on the structural design of the bridge. In selecting an appropriate BMP, required pollutant removal benefits, site constraints, maintenance constraints, and potential environmental or aesthetic enhancements need to be considered (NCHRP 2002, v2).

The next section gives more detailed information regarding to BMPs applicable to bridges. They can be categorized into two sections as nonstructural, structural.

4.2.1 Nonstructural BMPs

Nonstructural mitigation methods are cost-effective and sometimes more efficient pollutant removers. These methods can be used as source control and management methods. Street sweeping, catch basin and scupper cleaning, deck drain cleaning, deicing controls, traffic management, and management of maintenance activities are different types of BMPs that can be implemented without any structural burden on the bridge. In this category, temporary erosion and sediment control practices also included to give ideas to practitioners to how to find temporary solutions to bridge slope runoff erosion. See below for more on slope erosion.

4.2.1.1 Street Sweeping

Research conducted in the past few years has demonstrated that street sweeping can effectively reduce pollutant loads from roadways because of improvements in equipment and in sweeping methods. Besides improved mechanical sweepers, the introduction of vacuum-assisted and regenerative air sweepers (which blow air onto the pavement and immediately vacuum it back to entrain and filter out accumulated solids) has greatly increased effectiveness, particularly with fine particles. In terms of improved sweeping methods, tandem sweeping, which is mechanical sweeping followed immediately by a vacuum-assisted machine have shown remarkable increases in percent pollutant reductions (Sutherland and Jelen, 1997). In recent studies, a new type of street-sweeping machine called the Enviro Whirl (which combines a broom with a powerful vacuum in one unit) was found to be most effective, reducing total suspended solid (TSS) loading up to 90 percent for residential streets and up to 80 percent for major arterials. The actual percent reduction also depended on the number of cleanings per year, with the maximum reduction reported for weekly cleanings. Results for biweekly cleanings are about 70 percent for both residential and major arterials.

Good planning in street sweeping is critical for obtaining high removal rates.
For example, spring snowmelt is widely recognized as being critical because of the most polluted first flush snow melt. For Alaska, in the continental region, first flush snow melt occurs in the mid-spring and it is important not to miss this highly polluted runoff because of street sweeping schedule (if there is one). Thus, the sweeping schedule should not be a cast iron plan; it should be flexible enough to respond to sudden needs.
Where structural BMP implementation is not an option because of BMP load design constraints, street sweeping appears as a very good option as it is in the case of San Francisco-Oakland Bay Bridge (SFOBB). In terms of cost and pollutant removal efficiency with the bridge design considerations, high-efficiency, vacuum-type street sweeping emerged as the most effective BMP for SFOBB (NCHRP, 2002).

4.2.1.2 Catch Basin Cleaning

Storm drain catch basins should be cleaned and maintained in order to prevent debris, chemical, trash, sediment, and other pollutants from entering waterways.

There are several design options. One design option consists of a series of trays, with the top tray serving as an initial sediment trap; the underlying trays filter out pollutants.

Another design option uses filter fabric to remove pollutants from runoff (Southeast Michigan Council of Governments, SEMCOG, 2009).

The frequency and consistency of the cleaning increases the efficiency of the catch basin. Also, it is important to remove the sediment accumulated during the winter months before it is washed off by spring rains.

4.2.1.3 Scupper Cleaning

Scuppers need cleaning for traffic safety. Scuppers can be flushed with water under pressure after the accumulated runoff material in them has been properly removed. U.S. EPA recommends restricting use of scupper drains on bridges less than 400 feet in length and on bridges crossing very sensitive ecosystems. Also, it suggests that on bridges with scupper drains; provide equivalent urban runoff treatment in terms of pollutant load reduction elsewhere on the project to compensate for the loading discharged off the bridge. Bridge scuppers should be used only when necessary to maintain the spread of the gutter flow onto the traveled way (Bridge Development, University of Maryland, 2007).

4.2.1.4 Deck Drain Cleaning

Bridge drainage covers the collection and removal of waters from a bridge deck. To accomplish this function, drains are placed adjacent to curbs for collection of water which is then either dumped directly into water or is conveyed to a suitable disposal point (CALTRANS, 2009). Deck drains can be cleaned by getting flushed with water under pressure after the removal of the accumulated runoff material.

4.2.1.5 Deicing Controls

Winter deicing activities add substantially to the pollutant loading from bridge decks. Some alternative practices that can reduce the loading include using alternative deicing compounds (e.g., calcium chloride or calcium magnesium acetate), designating “low salt” areas on bridges over sensitive receiving waters, and reducing deicing applications through operator education, training, and equipment calibration. In addition, using deicers such as glycol, urea or Calcium Magnesium Acetate (CMA) reduces the corrosion of metal bridge supports that can occur when salt is used. Use of clean sand, calcium magnesium acetate (CMA) and potassium acetate (KA) are high cost salt alternatives. In addition, using deicers such as glycol, urea or Calcium Magnesium Acetate (CMA) reduces the corrosion of metal bridge supports that can occur when salt is used.

Smart deicing practices, which use GPS to distribute the amount of chemical according to needs, can be adapted to control deicing affect on the runoff.

4.2.1.6 Traffic Management

In urbanized areas, the stormwater runoff from bridge decks is regulated because the highly contaminated urbanized runoff may pollute the receiving waters. On the other hand, even though they are not regulated under law because of low incidence of such runoffs, preventive tactics should be considered to protect critical waters in rural areas for the possible spills from trucks and hazardous material haulers, especially bridges over critical waters. These spills obviously have the same or worse potential effect to adversely influence the aquatic life in the receiving waters. As urban traffic, traffic routing of these risky vehicles away from critical bridges is one tactic to follow for the protection of these waters. Another way is to limit the number of trucks on these bridges so that the incidence of accidents will decrease.

4.2.1.7 Maintenance Practices

Necessary maintenance activities such as bridge painting, substructure repair, drainage structure repair, and pavement repair or repaving on bridges can have an adverse affect on water quality in the receiving waters beneath the bridges

Bridge painting is probably the most common bridge maintenance practice and the one with potentially the greatest adverse effects on the receiving water (NCHRP, 2002). Blasting abrasives and paint chips from painting activities may fall into the receiving waters below the bridge. Surveys have indicated that up to 80 percent of the bridges repainted each year were previously painted with lead paint. These surveys have also indicated that substantial amounts of used abrasives can be lost to the environment if appropriate containment practices are not used (Young et al., 1996). Paint overspray and solvents also may be toxic to aquatic life if they reach the receiving water (Kramme, 1985).

To avoid blasting abrasives and paint chips falling into the receiving water, it is important to capture scraps, waste and paint from sanding or painting projects. Using suspended tarps or nets below the bridge to catch falling debris may become necessary to protect the receiving waters. Booms and vacuums to capture pollutants generated during bridge maintenance will also help reduce the impacts. It is also important to transport and store paint and materials in containers with secure lids, and also not to transfer, store or load paint on a bridge.

Fully enclosed containment structures are capable of recovering 85 to 90 percent of abrasive, paint particles, and dust for simple spans; however, this type of containment is not feasible for high trusses or other complex structures (Appleman, 1992).

Worker training is also helpful in reducing the impacts of bridge painting on the receiving waters. These practices would include not allowing paint to enter surface waters, hanging drip tarps to catch drippings and dropped brushes, mixing paint or other substances away from the water, having a plan for accidental spills, and using appropriate cleaning procedures (Young et al., 1996). The use of airless sprayers and the elimination of the use of solvents would greatly reduce the toxicity-related concerns associated with chemicals entering the receiving water directly (Kramme, 1985).

The costs of implementing these measures to reduce the effects of bridge painting on receiving water quality have been estimated at an additional 10 to 20 percent for containment techniques and an additional 10 to 15 percent for waste disposal (Young et al., 1996).

Bridge cleaning -Metal bridge cleaning is a significant water quality issue in some states, particularly in Washington, Tennessee, and Oregon (Dupuis et al., 1999). According to the study survey, the cleaning process produces a water solution, which generally needs to be tested and/or treated before being either discharged to the receiving water or otherwise controlled and managed off-site (NCHRP, 2002).

Recovery of wastes, containment of wastes, and training of maintenance workers to increase their awareness of potential impacts on receiving waters are techniques that can be used to decrease the impacts of bridge maintenance activities on receiving waters. Containment of blasting abrasives and paint chips can be accomplished using shrouding, total structural enclosures, and negative pressure containment systems.

By using a vacuum bag attachment at the point of surface application, placing barges below the bridges, using containment booms in the receiving water, and funneling the debris in the enclosed container to a disposal truck or storage compartment are ways to capture the blasted materials and other residue before they run into the receiving water below the bridges.

4.2.2 Structural BMPs

We divided bridge deck runoff structural BMPs off-bridge and on-bridge practices based on the location of the treatments.

4.2.2.1 Structural Off-Bridge BMPs

Structural off-bridge BMPs are temporary construction erosion and sediment control practices that prevents or reduce the movement of sediment from a site during construction through the implementation of man-made structures, land management techniques, or natural processes (Minnesota Stormwater Manual, 2005). Stormwater runoff from construction is highly regulated in Alaska. However, the reason these practices included here is to present solutions to erosion on bridge end slopes, which impacts the quality of receiving water under the bridge. Sediment and erosion control practices suggested here may be applicable to bridge end slope erosion and also, may help in sediment control. Definition of each BMP is directly quoted from Minnesota Storm Water Manual, 2005.

Vegetated Buffer Strip are also known as grassed buffer strips, vegetated filter strips, filter strips, and grassed filters. These are vegetated surfaces that are designed to treat sheet flow from adjacent surfaces.

Filter strips function by slowing runoff velocities and allowing sediment and other pollutants to settle and by providing some infiltration into underlying soils.

Filter strips were originally used as an agricultural treatment practice and have more recently evolved into an urban practice. With proper design and maintenance, filter strips can provide relatively high pollutant removal. In addition, the public views them as landscaped amenities and not as storm water infrastructure. Consequently, there is little resistance to their use.

Silt fences filter sediment from runoff by allowing water to pass through a geotextile fabric or by creating a pool to allow sediment to drop out of the water column. Fences constructed of wood or steel supports and either natural (e.g. burlap) or synthetic fabric stretched across an area of non–concentrated flow during site development trap and retain on–site sediment due to rainfall runoff. Silt fences are installed to protect BMPs and downstream receiving waters.

Rock or Compost Bags are filled bags that are used to filter water, control ditch grade, or to provide inlet protection.

Riprap is appropriately sized rocks that reduce the energy of fast moving flows. Riprap is used along channels and at outfalls.

Temporary Sedimentation Basins are depressions that capture runoff to slow the flow of water and allow sediment to settle out.

Filter Bags are mesh bags that capture sediment but allow water to pass through. Filter bags are installed in storm drain inlets.

Floatation Silt Curtain is a fabric fence installed in water bodies to contain sediment near the banks of the work area. They must be used in conjunction with other sediment control techniques.

Erosion control blanket is a mat made of netting layered with straw, wood, coconut or man-made fibers that prevents erosion by sheltering the soil from rainfall and runoff while holding moisture for establishing plants. Blankets are installed in channels or on slopes where mulch would not be adequate.

Fiber Logs include straw, wood, or coconut fiber logs, compost logs, and rock logs that slow water and filter sediment. Fiber logs are used for inlet protection, ditch checks, and as perimeter control where silt fence is infeasible.

Mulch is wood fibers, compost, wood chips, straw, or hay that is applied as a cover to disturbed soil. Mulch reduces erosion by absorbing energy from rainfall and runoff and provides protection and moisture for the establishment of vegetation, when properly disc anchored or spread.

4.2.2.2 Structural On-Bridge BMPs

Because of the bridge design and retrofit constraints explained in this Chapter, there are not many options in terms of structural BMPs. Simple drainage back to land is sometimes practical for relatively short bridges. The bridge deck is sloped so that the water runs to either end by gravity. From the ends, the water is treated by some method, for example, a grassy area or pond, prior to discharge to the receiving water.

Enclosed piping or open-trough drainage back to land is another practice in use, and suggested for longer bridges. The NCHRP 474 report mentions a case study that uses a series of collection trays or pans along the bridge deck that were periodically vacuum-cleaned. Also, oil water separators are given as an alternative approach that can be used in drainage treatment systems below the bridge. In the next Chapter, we discuss the applicability of some of these to cold regions.

CHAPTER 5

5.0 BMPs IN COLD CLIMATES

Snowmelt runoff and rain-on-snow events present some of the highest pollutant loading and most difficult management challenges in the course of a year in regions with cold climate (Oberts, 2003). Most BMPs to control stormwater runoff treatment are based on warm climates subject to summertime thunderstorms and other rainfall events.

Our literature review found that even though there have been a number of research projects to assess the impacts of highway storm water runoff on receiving water in cold climates, there is none specific to bridge deck runoffs.

However, cold climates can present additional challenges to the selection, design, and maintenance of stormwater treatment BMPs due to cold temperatures, deep frost lines, short growing seasons, and significant snowfall (SMRC, 2003). Identifying solutions for bridges or cold climates are certainly challenging areas. Combining the two would make it an extremely challenging task. Here is a summary not specific to bridges.

Table 3 Challenges to the Design of Runoff Management Practices in Cold Climates (Caraco and Claytor, 1997)

Climatic Condition	BMP Design Challenge
Cold Temperatures	• Pipe freezing • Permanent pool ice Covered • Reduced biological activity • Reduced oxygen levels during ice cover • Reduced settling velocities
Deep Frost Line	• Frost heaving • Reduced soil infiltration • Pipe freezing
Short Growing Season	• Short time period to establish vegetation • Different plant species appropriate to cold climates than moderate climates
Significant Snowfall	• High runoff volumes during snowmelt and rainon- snow • High pollutant loads during spring melt • Other impacts of road salt/deicers • Snow management may affect BMP storage

Finding the best management practices that are suitable for cold climates and applicable to bridges is the aim of the research.

5.1 Practices in Cold Climate States

The research involves a literature search to see what other states are doing, especially northern tier states, and cold countries, such as Canada and Norway and what BMPs exist. For this research, several DOTs contacted and questioned about their practices for bridges. Below is a summary of our finding regarding to their practices.

5. 1.1 Maine DOT

According to personal communication with Maine DOT, their Bureau of Environment is tasked with coordinating their efforts with the New Hampshire DOT. NH's recently enacted Alteration of Terrain (AoT) rules will nearly eliminate the use of scuppers to allow runoff to drop unimpeded to the river, below the bridge. Alteration of Terrain protects surface water quality by controlling soil erosion and managing, treating, and recharging stormwater runoff from development activities and an alteration of terrain permit is required whenever a project proposes to disturb more than 100,000 square feet of terrain (New Hampshire, 2008). Though, the scuppers would still be allowed to be used for large tidal river crossings, where there is a lot of mixing and a large flow.

New Hampshire the Department of Environmental Services (DES) has released a new NH Stormwater Manual. The Manual gives guidance towards how to apply the new rules, but so far the Bridge Design staff has not had to wrestle with them. The Maine DOT has been able to treat bridge runoff by letting it flow to the end of the bridge where it is picked up in catch basins. Once it is off the bridge, Highway Design is responsible for how to treat it, again, according to the new rules. The new rules seem to be requiring larger areas for treatment. Regarding bridge runoff, the DOT does have an upcoming project where they will need to use scuppers that are connected via a piping network to get the runoff to the treatment facilities designed by Highway Design. Though, the contacted DOT engineer thinks that this application will be a headache for their Maintenance forces.

5.1.2 Minnesota DOT

There have been several BMP studies in Minnesota but none that were specifically oriented towards bridge decks. Guidance in the LRFD (Load and Resistance Factor Design) Bridge Design Manual is general and recommends bridge designer coordinate with Hydraulics Unit on a case by case basis for water quality treatment options.

In general, according to LRFD bridge design manual, drainage must avoid entering state waters; bridges less than 500 feet over state waters must be designed to shed water longitudinally without deck drains, and longer required closed systems.

For most bridges, the water is conveyed to the ends of the bridge. For those few bridges where that are not possible, they use a drainage system. This could be scuppers, a closed drainage system or an open drainage system. The decision and design are done on a case by case basis.

A trapezoidal trough system is considered as an innovative solution to clogging when collecting stormwater from bridge decks used by MnDOT in a few cases. They do not have specific information on the installations though the engineers from MnDOT mentioned that it still has the same clogging problems. As for the most part, they design bridges not to need deck drainage systems by conveying water to the end of the bridge decks. So their approach is not to use them unless no other choice is left. When needed, systems are selected and designed on a case by case basis

Minnesota DOT has a stormwater manual, which includes an Issue Paper on Cold Climates does not differentiate between highway and bridge deck runoff.

Cost/benefit isn't the major factor in selecting BMP's at MnDOT. Meeting permit requirements is the most important factor, but ROW and limited maintenance budget also influence BMP selection.

In the storm water manual, there is a Chapter on cold climate impact on runoff management. It provides guidance on cold climate BMP design adaptations, developing snow management plans, implementing a management sequence, providing effective pollutant removal and runoff control in winter.

In Minnesota, the use of liquid MgCl2 spray on bridge decks has proven to be an effective way to avoid repeated NaCl application at high doses (Minnesota Stormwater Manual, 2005).

5.1.3 Washington DOT

WSDOT developed a stormwater manual to comply with Washington state law and also NPDES municipal stormwater permit regulations. WSDOT's *Highway Runoff Manual*, provides the designers with the guidelines and design criteria for selecting BMP for runoff treatment and flow control. In the manual, there is a Chapter that contains the BMP selection process and the actual design criteria for BMPs. The manual also briefly discusses special design considerations for stormwater management on bridges.

According to the information provided by the WSDOT engineer, high efficiency street sweeping is emerging as an option and some are advocating further exploration. Also, they mentioned that they are finding mixed/contradictory views regarding the performance effectiveness of such a strategy in the existing literature. In 2005, a runoff categorization study for several of the floating bridges was done.

There's also a WSDOT research effort in the early planning stages to conduct some research and development exploring the use of innovative (i.e., non-traditional) stromwater treatment BMPs for over-water fixed structures (i.e., bridges, ferry terminals, etc.). This research started in October 2008, and completed Phase 1 - the literature survey, WSDOT contacts, and a theoretical description of a new treatment system that could be placed on pier cap structures underneath bridges to be used in combination with high-efficiency street sweeping. In Phase 2, they plan on writing Sample Analysis Plans/ Quality Assurance Project Plans (SAPs/QAPPs) in anticipation of receiving federal funding to construct and test a media/trickle filter in combination with high-efficiency street sweeping.

5.1.4 Wisconsin DOT

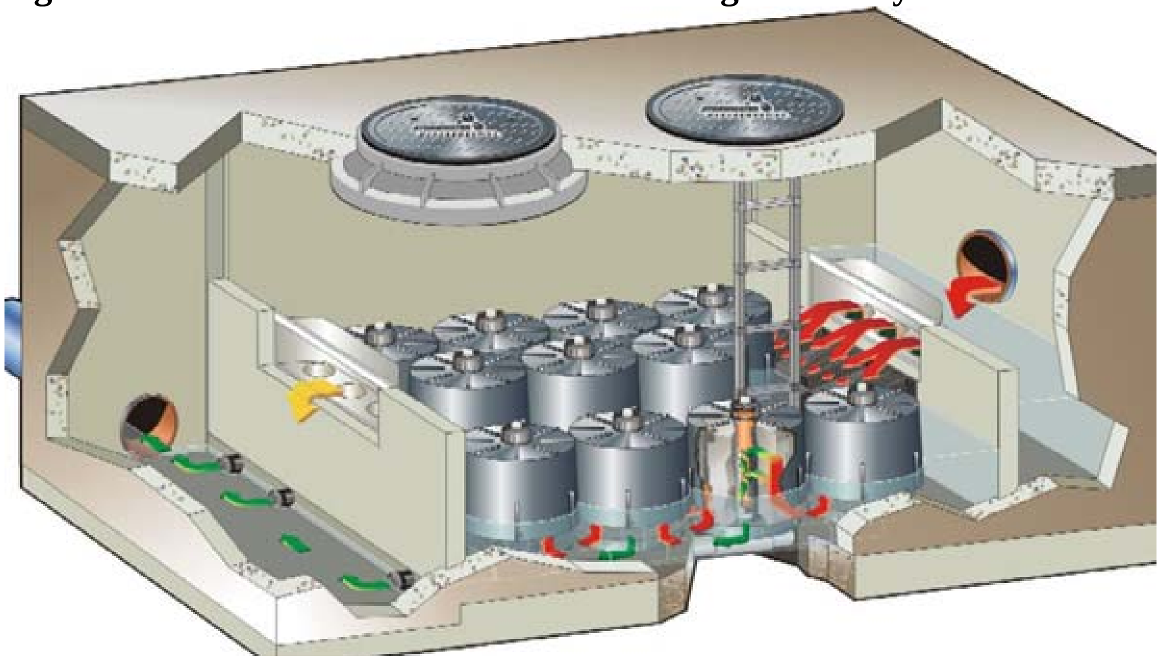
In Wisconsin, the vast majority of existing small bridges have open-rail drainage (NCHRP 2002). WisDOT currently does not have standards or design guidelines that address bridge deck runoff. Rather, they address the issue on a case-by-case basis, typically based upon the receiving water quality and/or DNR (Department of Natural Resources) or local government concerns. The treatment approach they usually use is to route the runoff from the bridge deck to the embankments, and then to filter the water as much as possible through a grass swale or other vegetative filter system. Another option available to use is generic hydrodynamic settling devices (otherwise known as catchbasins) at the end of the bridge deck. They typically prefer not to use proprietary filter systems because of the maintenance requirements.

They plan to begin working on our stormwater quality design guidelines in the WisDOT Facilities Development Manual (FDM) soon, and bridge deck runoff will be one of the issues they plan to address in it.

WisDOT also funded a study that analyzed two different treatment devices that treated runoff from a freeway.

As a part of study, the treatment efficiency of two proprietary stormwater treatment devices was tested at a freeway site in an ultra-urban part of Milwaukee. One treatment device is categorized as a hydrodynamic settling device (HSD) that removes pollutants by sedimentation and flotation. The other treatment device is categorized as a stormwater filtration device (SFD) that removes pollutants by filtration and sedimentation. Filtration is considered the primary method of treatment with sedimentation of larger particles in the pre-treatment chamber and cartridge filter bay. See Figure 1.

Figure 1. Pre-treatment chamber and cartridge filter bay



Storm water runoff from the parking lot was piped into the StormFilter (red arrows) and siphoned into a series of filter cartridges designed to remove sediment, metals, organic compounds, phosphorous and oil (WisDOT, March 2009 Brief).

The Storm Filter reduced the load of total suspended solids by 50 percent, suspended sediment by 89 percent, total phosphorous by 38 percent, dissolved copper by 16 percent, total copper by 66 percent, dissolved zinc by 20 percent, total zinc by 68 percent and chemical oxygen demand by 14 percent (WisDOT, March 2009).

Reducing stormwater contaminants with high-efficiency street sweeper has been proposed as a best management practice because of its potential cost savings over more expensive alternatives. In 2002, WisDOT had tried an old model (mechanical) street sweeper, but were unable to determine the benefits of sweeping due to a variety of quality control issues and mechanical failures. In result, the data did not sufficiently support the expected benefits. WisDOT initiated Phase II sweeping study using a high-efficiency vacuum assisted sweeper (the Whirlwind MV). Advances in sweeper technology allow the Whirlwind MV to pick up greater volumes of dirt at increased speeds (WisDOT, June

2009). The project concludes that although an exact efficiency percentage for the amount of dirt picked up has not been determined yet, the vacuum-assisted high efficiency street sweepers are definitely an improvement over older models and only these newer models appeared capable of picking up a significant percentage of finer particles.

5.2 Practices in Other States

It is typical for storm water to be conveyed over the surface to the end of the bridge deck, if the bridge is short enough, and routed to a drain inlet that leads to a discharge via grassy ditch or some sort of BMP, such as a pond. States that explicitly noted that they follow this policy were Florida, Minnesota, Oregon, Washington, Massachusetts, Delaware, Nevada, Maine, New Jersey, Utah, New Mexico, and Idaho. Other states potentially follow this policy but did not explicitly mention it. Regardless, state DOTs have identified this practice as effective and economical (NCHRP 2002).

5.3 Practices in Some Other Countries

Canada and Norway were contacted to find out about the practices that have been used to mitigating the runoff from bridges.

Jiri Marsalek (personal communication, December 31, 2009) at Environment Canada's National Water Research Institute responded to our query and regretfully mentioned that they haven't been doing much with bridge deck runoff; generally, some splash pads are installed underneath and those should distribute falling water over a larger area.

Also, based on our interview with Dr. Richard Frontier from Lavar University, bridge deck runoff is not considered as an environmental issue in Northern Quebec. Dr. Frontier, firstly mentioned that they don't have many bridges in Northern Quebec to be concerned about the runoff issues that can cause any environmental problems in the water bodies that they crosses over. Second point, he made that North Quebec is formed from little villages so it doesn't have an urbanized crowded bridges. However, he also emphasized that they don't use any deicing on the bridges. Likely vehicles such as ATVs, snow machines or cars just go slower when it comes to bridges. The water bodies pass under the bridges has species such as Smallmouth Bass, Lake Trout, Landlocked Salmon, Walleye, Rainbow Trout/Steelhead, Brown Trout, Northern Pike, Yellow Perch, Rainbow Smelt and Catfish.

Because ADT is low and also, chemicals are not used on the bridges, for now, engineers feels worry free about the likelihood of bridge deck runoffs polluting the water bodies passes under.

We also contacted Bert Van Duin (personal communication, December 10, 2009) from City of Calgary, Canada. In Canada, they try to solve the issue at the design stage with a slight incline so that it drains to either side of the stream (in case of bridge crossings of streams). In addition, runoffs from the ramps are intercepted by high capacity interceptors /catch basins before the runoff could ever make it onto the bridge deck in the first place. Also, depending on the availability of space runoff might then be routed through some devices such as an oil/grit separator or in some cases a bioretention area.

Dr. Sveinn Thorolfsson from Norwegian Technical University also contacted and he shared his studies with us. Nothing new came up, but he is working on the same topic.

CHAPTER 6

6.0 ALASKA

In this Chapter, Alaska's climate and current BMPs for bridges are discussed in detail. Also, some recommendations are presented.

6.1 Climate

Managing runoff for the safety of traffic, rain and snow melt must be conducted off the driving surface and is important for the success of that BMP used for that bridge. Thus, it is crucial to know how much and what kind of bridge deck runoff would occur and when it would occur. Because the runoff from snowmelt may require different approach in treatment than the runoff from rain, first, we analyzed the climate zones which each bridge is located so that we would know that approximately when, how much, and what kind of runoff each bridge has.

There are four general climate zones in Alaska, based on annual and monthly averages of temperature and precipitation. These are 1) an arctic zone, 2) a continental zone, 3) a maritime zone and 4) a transitional zone. Below are the definitions of each zone.

Figure 2. Alaska Climate Zones (from http://esp.cr.usgs.gov/research/alaska/figures/tafig2.gif

6.1.1 Arctic Zone

The arctic zone is characterized as a treeless plain located generally north of the Arctic Circle and north of the Brooks Range, including the cities of Barrow and Prudhoe Bay. There are two main seasons, winter and summer. The summer is very short with a transitional period in May and September. The average temperature in the winter is around -11.2°F (-24°C) and in the summer around 50°F (10°C). Winds blow almost continuously, with an average wind speed of 30 miles per hour (48.3 km/h). There is little precipitation; less than 10 inches (254 millimeters) per year, most of which is usually snow. In addition, there is a permanent layer of frozen earth or "permafrost", which in the summer thaws just enough to make bogs, swamps and lakes the primary topography. Permafrost is not defined by soil moisture content, overlying snow cover, or location; it is defined solely by soil temperature. (This and the following zone descriptions are taken from McVehill-Monett, 2006)

6.1.2 Continental Zone

The continental zone is best described as a zone with temperatures in the summer that average around 60°F (15°C) in the warmest month and mean lows in the winter near -10°F (-23.3°C), with an extreme of -45°F (-42.7°C) to -55°F (-48.3°C). Annual precipitation is generally about 20 inches with the majority falling within the summer months. In general, this zone is located south of the Brooks Range and inland. The sun does not set for more than a month in the summer. Surface winds are lighter than those in the Arctic. Overall there are only two seasons in this region as well: summer and winter.

6.1.3 Maritime Zone

Temperatures in the maritime zone usually reach 50°F to 55 °F (10°C to 12°C) for mean maximums during summer and drop to around 23°F (-5°C) for mean lows during winter. As a result of this temperate climate, seasonal change is not as obvious as in the other zones. Because of the moderating effects of the ocean, very infrequently do temperatures reach extreme highs of 70°F (21°C) and extreme lows of -22°F (-30°C). Winds are typically between 13.8 mph (22.2 km/h) and 20.7 mph (33.3 km/h). Precipitation is much greater than that of the interior or the arctic, with an average of about 40 inches per year.

6.1.4 Transitional Zone

The transitional zone includes as far west as Bristol Bay, the region around the Cook Inlet, the Chugach Mountains and as far east as the southern Copper River basin. The transitional zone follows approximately 1492 miles (2400 km) of the Alaskan Coast. Unlike the other regions, this zone is difficult to define due to the large variation in topography.

6.1.5 Summary

In this section of the Chapter, we looked into Alaska's four types of climate zones. According to our research and analysis of each type, we believe that it may be wise to handle runoff from rain differently than the runoff from snowmelt. Knowing the region where each bridge is located may help bridge engineers to understand the type of runoff created from that bridge decks. For example, in arctic zone, because there is little precipitation; less than 10 inches per year, most of which is usually snow, runoff from bridges in this region may not be as critical as the ones from the bridges in continental and maritime regions. In continental zone, annual precipitation is generally about 20 inches. In this region, it is important to consider first flush of snowmelt in the spring time. Good planning in street sweeping may solve the problem by capturing the spring melt on time before highly first flush goes into the receiving waters. In maritime zone, precipitation is much greater than that of the interior or the arctic, with an average of about 40 inches per year. Any kind of BMP may be justifiable because of the high amount of runoff from the bridge decks.

6.2 Current BMPs and Recommendations

Alaska has divided into three ADOT regions. These are Central, Northern and Southeast regions. To find out about current best management practices used for bridge deck runoffs, bridge and maintenance engineers were contacted. Communications were made via email with Southeast, and Central regions. Because of the proximity of its location, Northern region ADOT engineers were interviewed in-person about the subject.

6.2.1 Deicing Practices

To find out about current deicing practices in Alaska, bridge maintenance engineers were contacted in each region of Alaska.

In Central Region, they use sand mixed with salt (less than 5%) on all roads and bridges with one exception. The Knik River bridge has an installed spray system that uses potassium acetate. (Mike Zidek, January 23, 2010. Personal Communication. ADOT).

According to our interview with the Northern Region, Maintenance Engineer, no deicing chemicals are used in Northern Region. Snow is scraped and pushed off the bridge decks or hauled to the snow dumps whenever it is necessary. There is no certain schedule for the cleaning. (Jays Bottoms, January 5 2010. Personal Communication. ADOT, Fairbanks, AK).

In the Southeast Region, the ADOT has some roads that are “chemical routes” on which deicing is applied. The typical treatment is spray brine. They are currently considering adding a corrosion inhibitor to the brine.

6.2.2 Snow Removal BMP

In general, Alaskan bridges are plowed to remove snow. The plows push the snow to one end and beyond. The plowing operation may leave snow in regions of the bridge where there is curbing and the plow is limited by the guardrail. Once the snow is off the bridge, the relation is no different than plowing of the highway itself, except that there may be more at the ends of the bridge than other locations of the highway. A BMP is to take the snow from the end of the bridge to a snow storage facility, where it falls under the same regulations as any snow removed from roads.

6.2.3 Structural BMP for Alaska

In longer bridges, where it is not practical to run the water to the ends of the bridge, deck drains are commonly used. The deck drain typically has a short pipe under the bridge deck that leads the water away from structural elements.

Figure 3. Piping from a bridge deck drain.

These deck drains require maintenance, since if they become plugged with soil, organic material, or trash, the water load to the deck can be increased and become a safety hazard to the public during a heavy rain.

If the deck drains lead to an impaired water body, and a determination in made that the runoff should not enter the water body, a solution often applied in warm climates is to connect the drains with a piping system and lead the water to some treatment or holding system off the bridge. Even in warm climates retrofitting bridges in this manner has difficulties.

- The pipes need to be self cleaning. This requires a slope of ½ to 1%. The required drop may not be available.
- If the pipe becomes clogged, it is a difficult project to clean the pipe.
- Catch basins or other devices may be added to the system, but the space may not be available under an existing bridge.

- Other solutions, such as open troughs may work, if the space is available.
- Lift stations or such may be required.
- The dead load on the bridge is increased.

However in cold climates, a much more difficult situation arises. The piping is under the bridge deck in the shade, while the bridge deck is in the sunlight. Thus water can flow into the colder pipe, where it can freeze. In addition if the pipe is clogged at one end and frozen at the other, water can freeze and burst the pipe. If there are lift stations or other appurtenances, these can freeze as well. Appendix 2 has an inspection report of a bridge in Anchorage that has had freezing and leaking problems with a deck drain piping system.

A logical solution to this would be to heat trace the pipes and appurtenances. The ADOT has ample experience dealing with culverts that are filled with ice and various heat tracing schemes. Electric tracing did not work. The current method in the interior is to have smaller thaw pipes in the top of the culvert, which are capped each fall. Then in the spring, during breakup, maintenance crews attach steam to the thaw pipes and thaw a channel through the culvert. This requires timing to be sure the water is flowing to enlarge the hole, but before there is enough water from the upstream side to overflow the road. If the thaw pipes were broken, it is still possible to steam the entire culvert, although the related work is much greater. Relating the labor intensive effort for culvert thawing to work on a bridge, this would require special device to thaw from the top side of the bridge. To thaw from underneath would require special safety precautions and might not be practical.

In some Alaskan bridge locations, power is not available. Our research has probed other states and none seemed to have solutions to this freezing and maintenance issues.

CHAPTER 7

7.0 BRIDGE DECK RUNOFF PRIORITIZATION SCHEME

Here, we developed a prioritization scheme that will help identify which bridges should be considered for BMP. The scheme is applied to our bridges in Alaska on an Excel worksheet that accompanies this report. The scheme starts with similar scheme used in Washington, and then adds factors from the ACWA, STIP and several other Alaskan environmental parameters. The prioritization scheme can be used to indicate bridges where the impacts of bridge deck runoff on the receiving water should be considered. For example, when considering the benefits of constructing a new BMP or modifications to existing BMPs, the weight can be given to the bridges with highest prioritization score.

To calculate prioritization scores (P-score) for more than 700 ADOT owned bridges in Alaska, first, we gathered the data for all the bridges in the state, and created a database with more than 30 parameters for reference and calculated P-score by using about 20 of them.

We started with a storm water outfall prioritization system Washington DOT (WSDOT) developed, which compares the impacts of one outfall with another and makes an assessment of their overall impacts to determine cases in which retrofitting is warranted (WSDOT, 1996). We present that first, then, added special information from Alaska.

Below is the prioritization equation developed by WSDOT. Following the equation are summaries of each element of the equation.

P-Score = (A + B) + (C1 * D) + C2 + [(E1 + E2 + E3 + E4) * E5] + E6 + F.

Where:

A = Type and size of receiving water body.

B = Beneficial uses of receiving water body.

C = Pollutant loading.

D = Percentage contribution of highway runoff to watershed.

E = Cost/pollution benefit.

F = Values trade-off.

Next, we customized the prioritization score based on Alaska needs, and called it Modified P- score.

Modified P score formulation is as follows;

M P-score= P score+ P+S+T+V+W+X

Where:

P= ADFG score

S= Maximum state priority score give by ACWA

T= Traffic type

V= Salty water

W= Silty water

X= Dimension of the bridge.

To emphasize the importance of fish bearing streams, we factored DF&G score twice in calculating the Modified P, once as ADFG score and once as part of the maximum ACWA priority score.

In the following section, the scoring used for the database input method is presented. It also includes the summaries and provides an inclusive listing of the point values for each element in the prioritization equation. It is indexed by column names from the database:

- A-column characterizes the type and size of receiving water body. Parameters used as follows.

Column A- Type of Receiving Water Body	
Groundwater	10
Small stream	8
Small lake	6
Sensitive wetland	6
Large stream	5
Large lake	3
River	2
Wetlands	2
Tidelands	2

- B- Column presents a score for beneficial uses of receiving water body.

Column B- Designated Uses of Receiving Water Body Value (B)	
Drinking water standards violated (SV)	20
Drinking water prevention	18
Public health SV	16
Public health prevention	14
Fisheries SV	12
Fisheries prevention	10
Aesthetics	4
Flood protection	4

Column C- gives a score for pollutant loading, which is a measure of the potential amount of contaminants from ADOT right of way that mix with runoff and could impact surface water bodies. The loading scored based on the average daily traffic (ADT) which represents the amount of traffic that travels on all lanes on a designated portion of roadway in both directions during a 24-hour period. This information was collected from

Juneau AKDOT's recent bridge database. The ADT is given in the Column "ADT" and the score if given in Column C, per these values:

Column C- Pollutant Loading Value (C1)	
Very high (30000+ ADT)	4
High (30000-15000 ADT)	3
Medium (15000-5000 ADT)	2
Low (5000-0 ADT)	1

- Column D - Percentage contribution of highway runoff to watershed.

Element D. Percentage Contribution of Highway Runoff to Watershed Value (D)	
Less than 5%	5
2 to 5%	4
1 to 2%	3
0.5 to 1%	2
Less than 0.5%	1

- Column E1 through E6 focuses on the cost-benefit analysis of any application that can be done on the bridge. Column E1 shows right of way and scores 4 for all bridges because only ADOT owned bridges are considered for this study.

Column E1- Right-of-Way Cost Points	
DOT-owned land	4
Rural (low cost)	3
Suburban/transitional	2
Urban (high cost)	1
Prohibitive	0

Column E2 presents BMP capital cost for each bridge. Because no data available regarding to this, this column scored as 3 for all bridges.

Column E2 Best Management Practice (BMP) Capital Cost Points	
No cost	5
Low	4
Medium	3
High	2
Very high	1

- Column E3 is about the conveyance structure of the bridges. Because there is no available data available for Alaska bridges, and needs to have a field check for each bridge, impermeable (pipe or asphalt) conveyance structure were assumed for each bridge.

Column E3 Conveyance Structure Points	
Impermeable (pipe/asphalt)	4
Soil	3
Vegetation	1

Column E4 shows receiving water body characteristics. Each bridges was categorized with the water body underneath according to Alaska's Final 2008 Integrated Water Quality Monitoring and Assessment Report (Alaska Integrated Water Report, 2008). This report divides water bodies in Alaska into five categories. Below are the definitions of each category taken from that report.

Category 1: Waterbodies are placed in this category if there are data to support a determination that the water quality standards and all of the uses are attained.

Category 2: Waterbodies are placed in this category if some of the water quality standards for the designated uses are attained.

Category 3: Waterbodies are placed in Category 3 if data or information are insufficient to determine that the water quality standards for any of the designated uses are attained.

Category 4: Category 4 waters have been determined to be impaired but do not need a TMDL.

Category 5: Waterbodies are placed in Category 5 if the water quality standard(s) are not attained, i.e., the waterbody is impaired for one or more designated uses by a pollutant(s) and requires a TMDL or waterbody recovery plan to attain Alaska's water quality standards (18 AAC 70). There are 25 waterbodies identified for placement in Category 5 and Section 303(d) listed as impaired.

Column E4 Water Quality of Receiving Water Body Points	
303(d) listed- Category 5	5
305(b) listed- Category 4	5
Sensitive groundwater	5
Class B or equivalent low classification- Category 3	4
Class A or equivalent mid-level classification- Category 2	3
Class AA, marine, or equivalent high classification- Category 1	2

- E5-column was scored as 1 because in Alaska, all waters are classified as drinking water in order to protect the habitat.

Column E5 Water Quality Multiplier Points	
Discharge to marine, large lake, low classification wetland	0.5
Discharge to all other surface waters, Class I or II wetland, or sensitive groundwater system	1

E6-column shows information on construction projected for the next three years (2010-2013), was collected from ADOT website under STIP. This is based on the assumption that is less expensive to construct a retrofit BMP while construction is underway.

Column E6 Future Construction Plans Points	
Outfall [Bridge] is within the boundaries of a planned construction project	3
No projects planned in the area, the BMP would be a stand-alone project	1

Prioritization Score Column: This column shows the score found by using the parameters- A, B, C, D, E1, E2, E3, E4, E5. This method is explained in detail in the previous section.

- P- Element is the score given by DF&G to prioritize some waters over others to protect critical fish bearing resources.

Element P DF&G Priority Score	
High	5
Medium	3
Low	1

- S-Element shows the waters identified by the ACWA as high priority. Waters are nominated and scored by DF&G, DEC, and DNR state agencies, and factored into the calculation by their highest score from one of these agencies.

Element S State Priority Score	
High	5
Medium	3
Low	1

- T-Element- In this element, heavy truck traffic identified for each bridge by using traffic nature of each highway. If the bridge is exposed to heavy truck traffic, heavy truck column marked as 1/0, yes or no.

Element T Traffic Type	
Heavy truck traffic	1
No heavy trucks	0

- V-Element-To be aware of the biological environment under the bridge in general, a column described the water underneath the bridge as salty or fresh. It is scored as -1, if it is salty water and scored as 1, if it is fresh water.

Element V Salty Waters	
Fresh	1
Salty	-1

- W-Element identifies silty water goes under the bridge. We gathered the data from Juneau Department of Transportation. The column name is Silty, and depending on the siltyness of the water goes under the bridge, that column marked as silty /not silty, -1/1.

Element W Silty Waters	
Silty water	-1
Not silty water	1

- In Element X, the bridges were grouped into three sections depending on their length. If the bridge is longer than 400 ft, it is considered Long and scored as 5. If the length is between 200 and 400ft, its score is 3, and if it is less than 200 ft, it is a short bridge, and scored as 1.

Element X Dimension of the Bridge	
Long (Longer than 400 ft)	5
Medium (200 to 400 ft)	3
Short (Less than 200 ft)	1

After all the factors for each bridge/BMP retrofit are assimilated, the modified score can be calculated. The highest scores should be given first priority for retrofitting. In the next section, each entry in the database explained columnwise.

7.1 Database

The database is contained in the Excel spreadsheets accompanying this report. The worksheet with the priority scores is found on tab *P Scores.* Other worksheets have the raw data and text explanations. Each column labeled as described below.

A. Bridge number
B. Bridge name
C. Average daily traffic (ADT)
D. Type and size of receiving water body
E. Beneficial uses of receiving water body
F. Pollutant loading
G. Percentage contribution of highway runoff to watershed
H. Right-of-way Cost points
I. BMP capital cost points
J. Conveyance structure points
K. Water quality of receiving water body points
L. Water quality multiplier points
M. Future construction plans points
N. Values trade-off
O. Prioritization score
P. ADFG score (these next four items are explained below)
Q. ADEC score
R. ADNR score
S. Maximum score of ADFG, ADEC, and ADNR on the AWCA.
T. Traffic Type: In this column, heavy truck traffic identified for each bridge by using traffic nature of each highway. If the bridge is exposed to heavy truck traffic, heavy truck column marked as Y/N, yes or no.
U. Urbanized areas: By using EPA's urbanized area maps for Alaska, each bridge in these areas were identified

V. Salty Waters: To be aware of the biological environment under the bridge in general, a column described the water underneath the bridge as salty or fresh. It is Y-yes, if it is a salty water, and it is N-no, if it is a fresh water.

W. Silty Waters: Another column spared for identifying silty water goes under the bridge. We gathered the data from Juneau Department of Transportation. The column name is Silty, and depending on the siltyness of the water goes under the bridge, that column marked as Y/N.

X. Dimension: In this column, the bridges were grouped into three sections depending on their length. If the bridge is longer than 400 ft, it is considered Long and marked as L. If the length is between 200 and 400ft, it is Medium (M), and if it is less than 200 ft, it is a short bridge, and shown as S.

Y. Urban fringe

Z. Modified score

AA. Climate: We overlaid climate zone map of Alaska on Alaska bridge map provided by Juneau Department of Transportation by using Google Earth so that we identified the bridge numbers in each zone, and marked them in our database. If the bridge is in Arctic zone, in climate column, we marked as A- arctic zone. If it is in Maritime zone, it is marked as M, if it is in continental zone, it is C, and if in Transitional zone, and it is marked as T.

AB. Bridge length

AG. Facility carried the bridge

AH. Location of the bridge

AJ. Region of the bridge

AK. Main material of the bridge

The Highway Database and the Prioritization Scores are in the attached Excel File, *Bridge Deck Runoff June 2010*. On the several worksheets are a list of all the states' bridges, sorted by Modified P-score, a list of current STIP projects that involved bridges, a text explanation of the columns in the file, and the full prioritization scores.

CHAPTER 8

8.0 DECISION PROCESS

A BMP selection process is developed to help bridge engineers prioritize bridges in terms of the need for BMPs. Following check steps may help engineers to make a decision in whether a BMP should be considered for a bridge or not. Of course some bridges have "special issues." For example, the Million Dollar Bridge and the Susitna River bridges are on the National Register of Historic Places (NRHP). Such special issues, however, should be well-known to ADOT engineers working on projects related to those bridges.

8.1 Is it in Urbanized Area (UA)?

According to EPA, an urbanized area defined as a land area comprising one or more places – central place(s) – and the adjacent densely settled surrounding area- urban fringe- that together have a residential population of at least 50,000 and overall population density of at least 1000 people per square mile. EPA has developed a set of digitized maps for each urbanized area as defined by 2000 U.S. Census. All waters are regulated in UA according to new CWA regulations.

For our project, it means that if a bridge is located in UA of Alaska, BMP must be considered for that bridge deck runoff to protect the water quality of receiving waters. In the database, all bridges in UAs of Alaska are marked as Y, yes, and need to be considered for some kind of BMP.

If it is not in UA, then is it in STIP?

8.2 Is it in Statewide Transportation Improvement Program (STIP)?

It is less expensive to construct a retrofit BMP while other construction is underway so if the bridge is in STIP, then BMP options should be considered to handle deck runoff prior to the completion of the project. (The STIP can be found on the ADOT's website at http://www.dot.state.ak.us/stwdplng/cip_stip/index.shtml .)

8.3 What is State ACWA Score?

Under ACWA, ADNR, ADFG and ADEC have developed a water body nomination and ranking process. ADNR hydrologists provide factor-ratings for water quantity, whereas biologists in ADFG provide aquatic habitat factor ratings, and ADEC provides water quality ratings. Each water body is assigned a high, medium, or lower priority. This provides a general notion of how "sensitive" a water body is.

In the ranking process, the agencies use criteria that prioritize assessment, and corrective action needs for polluted waters and waters at risk of pollution, waters with habitat degradation, or water quantity problems. These criteria include the statutory criteria as well as severity of pollution and uses to be made of the waters, per the Clean Water Act § 303(d) (1)(A).

Most waters that are listed as impaired under Categories 5 and 4 of State of Alaska Water body category are ranked as high priority in ACWA. ACWA does not drive the listing decision though. The Integrated Report plays a role in the ACWA prioritization process.

8.4 Is the bridge is over the waters that feed Cook Inlet?

The National Marine Fisheries Service proposes to designate a critical habitat under the Endangered Species Act for the Cook Inlet Beluga whale. This would result in all discharges to upper Cook Inlet coming under scrutiny.

8.5 What is Modified Prioritization Score (PS)?

Refer to Chapter 7 for modified P-score calculation. If a bridge in this analysis gets a very high score, BMP should be considered. If it is low, there may not be any need for a BMP. Most of the bridges that have high modified P scores will require BMP consideration based on one of the four proceeding criteria, but a few may not. Here the ADOT will need to set the threshold based on the score. Aside from the threshold, the modified priority score serves as an index of importance of BMP for that bridge and allows relative rankings between bridges.

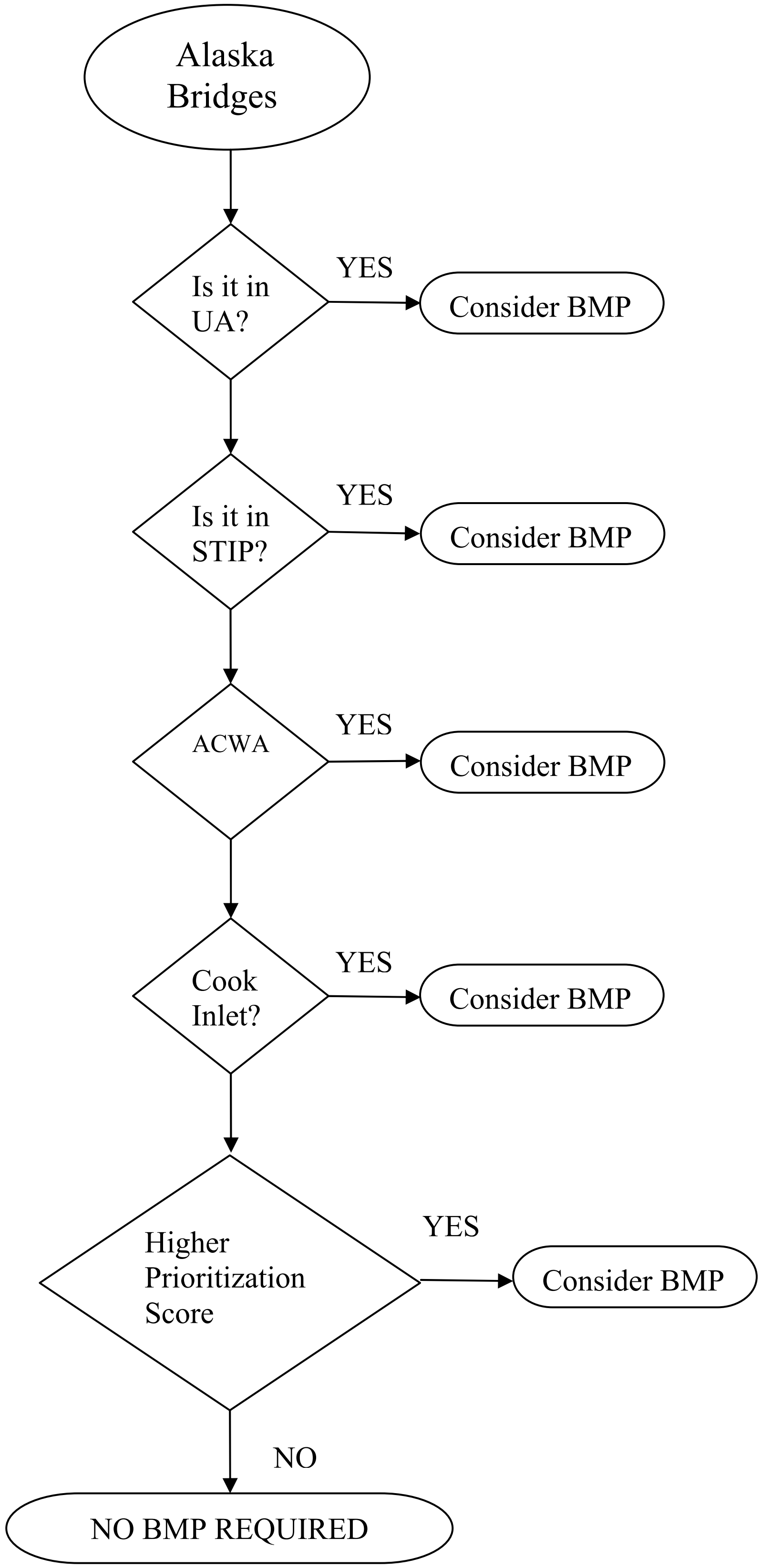
8.6 Conclusion

In summary, the steps for determining if BMP must be considered will consist of serious of threshold questions, as indicated in the flowchart, is the bridge is in UA, in STIP, or does it cross over high priority waters listed by ACWA or waters that enter the Beluga whale habitat? If so, BMP should be considered.

Additionally, a high prioritization score may still indicate that the bridge is a candidate for a BMP. However, implementing the BMP decision should be finalized following cost- effectiveness analysis. High prioritization score may justify a higher BMP for a bridge.

In the following page, the BMP selection process is flowcharted.

8.7 Bridge Selection Process Flowchart



8.8 Checklist if BMP Indicated

If a BMP is indicated at the end of the bridge BMP selection process, a check list for BMP type is presented as follows.

I. Flow into the river via drains or sides
   a. Can it be changed to flow to ends?
      i. Unlikely – major engineering/construction project
      ii. Perhaps if very short?
   b. Can it be fitted with pipes to ends or treatment?
      i. Unlikely –major project
      ii. Little evidence of success in cold regions
      iii. But give it some thought.
   c. BMP, non-structural
      i. Public awareness
      ii. Trash prevention
      iii. Deicing changes
      iv. Street sweeping
      v. Snow management
      vi. Melting

II. Flow to ends
   a. Non-structural BMP, same as I above
   b. Structural BMP
      i. Vegetation
      ii. Swales
      iii. Treatment
      iv. Other.

CHAPTER 9

9.0 FURTHER RECOMMENDATIONS

In this Chapter, we want to review two options that represent new technology coupled with some tested ideas that might be useful BMP. Street sweeping and deicing practices BMPs are not new, but should be reviewed if a BMP is needed**.** The sweeping and deicing are BMP that can be used if BMP are required without structural alternations to existing bridges- but they are not needed in all cases. Because small particulates are an item of concern of the EPA, new and more efficient street sweepers are being developed.

9.1 Street sweeping

Street sweeping is emerging as a high priority option when the constraints of bridge deck runoff design and/ or retrofit and challenges of cold climate conditions are considered. Street sweeping on a regular basis minimizes pollutant export to receiving waters. With the recent advancements in the street sweeper technology, even fine grained sediment particles that carry a substantial portion of the storm water pollutant load can be picked up.

The Massachusetts Department of Environmental Protection (DEP) reports that a better-planned schedule of street sweeping could increase the pollutant reduction substantially (1997). The Massachusetts DEP also reports that infrequent sweepings (less than 20 times per year) with conventional mechanical sweepers result in average TSS removal efficiencies no greater than 20 percent (NCHRP 2002).

In colder climates, street sweeping is used during the spring snowmelt to reduce pollutant loads from road salt and to reduce sand export to receiving waters. Seventy percent of cold climate storm water experts recommend street sweeping during the spring snowmelt as a pollution prevention measure (Caraco and Claytor, 1997). This method is applicable to bridge deck runoff.

Cost data for two cities in Michigan provides some guidance on the overall cost of a street cleaning program. Table 4 contains a review of the labor, equipment, and material costs for street cleaning for the year 1995. The average cost for street cleaning was $68 per curb mile and approximately 11 curb miles per day were swept (SWRC, 2003).

Table 4 The Cost of Street Cleaning for Two Cities in Michigan

City	Labor	Equipment	Material and Services	Total
Livonia	$23,840	$85,630	$5,210	$114,680
Plymouth Township	$18,050	$14,550	$280	$32,880

Table 5 gives another example of sweeper cost data for two types of sweepers: mechanical and vacuum-assisted. In this table, it is shown that while the purchase price of vacuum-assisted sweepers is significantly higher, the operation and maintenance costs are lower (SWRC, 2003).

Table 5 Estimated Costs for Two Types of Street Sweepers

Sweeper Type	Life (Years)	Purchase Price ($)	O&M Cost ($/curb mile)	Sources
Mechanical	5	75,000	30	Finley, 1996 SWRPC, 1991
Vacuum-assisted	8	150,000	15	Finley, 1996 Satterfield, 1991

According to Clayton study done in 1999, the optimum sweeping frequency appears to be once every week or two. More frequent sweeping operations yielded only a small increment in additional removal.

Effectiveness-New studies show that conventional mechanical broom and vacuum-assisted wet sweepers reduce nonpoint pollution by 5 to 30%; and nutrient content by 0 to 15%, but that newer dry vacuum sweepers can reduce nonpoint pollution by 35 to 80%; and nutrients by 15 to 40% for those areas that can be swept (Runoff Report, 1998).

9.2 Deicers

Use of clean sand, calcium magnesium acetate (CMA) and potassium acetate (KA) are high cost salt alternatives to rock salt.

There is no perfect solution to deice roads at a reasonable price with no impacts to the environment. However, some strategies can be applied to reduce the impact. In addition to reducing the number of lane miles salted or sanded, the amount of sand applied can be reduced by changing traditional road salting techniques, often requiring a purchase of equipment by a community. A simple modification is to use spreaders which are calibrated and adjusted with road speed, to reduce wasted salt application (SWRC, 2003).

Using a “clean” sand source, free of fine materials, can help reduce both the TSS and the phosphorus loads associated with road sanding. Phosphorus control is critical in many northern and mountainous regions, which are home to a majority of the natural lakes in the lower- 48 United States (SWRC 2003).

It may become cost efficient to use these special deicers only on bridges. It may be possible with GPS controlled equipment to have a dual system that uses the expensive treatment only on the sensitive bridges.

9.3 Close Follow-up on Bridge Retrofit/Replacement Projects

A cost effective approach to BMP requires some analysis of the benefit of the BMP, such as regulatory approvals or improvement of the environment, to the cost of the BMP. If the cost of the BMP is small, ADOT might want to install it even though they are not under pressure to do so. If the cost is large, careful analysis of the situation is warranted to find the BMP with the lowest cost that will satisfy the requirements. Thus, for new bridge construction (which is often a replacement for an exisiting bridge) or major renovations to existing bridges, and an analysis of which BMP might be installed should be done, since these might be very small costs in the overall project.

In Alaska, statewide, more than 60 projects are bridge related projects mentioned in STIP database. These are either new bridge construction, rehabilitation and/or bridge replacement projects. In this Chapter, because it is less expensive to construct a new or retrofit BMP while other construction is underway, these projects are briefly discussed to draw attention so that bridge engineers may consider finding ways to integrate BMP projects with the current ongoing projects already underway.

Bridge projects may be divided into three types. These are bridge rehabilitation projects, new bridge construction, retrofit, and bridge replacements projects.

It is important to reduce costs by identifying opportunities to combine stormwater BMP projects with construction projects such as bridge retrofits or replacement projects. Retrofitting bridges with structural storm water BMPs is technically difficult and can be very costly (NCHRP, 2002). Retrofitting can include the construction of new structural BMPs or modifications to existing BMPs. Therefore, it is important to be knowledgeable about the current and future construction plans. During our search of such plans in Statewide Transportation Improvement Plan (STIP) database, bridge retrofit, replacement and new construction projects are classified based on their regions. More detailed information about each project can be found in the STIP database.

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APPENDIX 1

A1.0 OBSERVATIONS OF INTERIOR ALASKA BRIDGES

In this Chapter, Dr. Perkins made observations in April 2010 from Robertson River Bridge, The Gerstel Bridge, Salcha River Bridge are examples for this study.

A1.1 Robertson River Bridge on the Alaska Highway

Deck drains not clogged, 1 foot curb.

Drains over land were straight pipes.

This bridge is an over-truss. Note brown stain under each drain.

Deck drains over river had a bend and discharged below the lowest truss members.

A1.2 Johnson River Bridge on the Alaska Highway

Johnson River had “New Jersey Barrier-type” sides instead of curbs and each barrier had a 1 inch gap before the next barrier and a scupper towards the center.

One of the scuppers is shown.

The outside of the scupper was flush to the concrete and drained without a pipe. There was a horizontal member below the scupper. These had holes to avoid standing water.

Note that the drainages through the expansion joints of the barrier (actually, the concrete barriers are separate pieces) hits over a support.

A1.3 The Gerstle River Bridge

The bridge is a series of through trusses.

It has deck drains that flow into a short down pipe.

Blow the pipes are some stains

However more prominent are gravel spots where, apparently, the snowplowing operation pushed some snow with gravel over the one foot high curb.

Note that this gravel may not have had salt or deicing in it, rather at this time of year, April, the black gravel melts the ice. This picture shows both the gravel in the lower left and a spot that may have come from the down pipe in the center. Both appear black or dark because of the small gravel chips that are used for traction sand. The chips are typically less than a quarter inch in longest dimension, but considerably larger than “sand.”

The upstream side of the bridge piers has a steel nose on it to break ice. There is little room to put any structure here that would be safe from ice. The downstream side has more room.

A1.4 Salcha River Bridge on the Richardson Highway

The Salcha River Bridge on the Richardson Highway is a steel beam bridge with a concrete deck. The deck drains are in a depression in the concrete.

In the photos, the depression is outlined by the gravel.

Note that there is a small "gravel fillet" between the roadway and the curb. But this is not prominent. Also, there is deck drainage through the expansion joints.

These deck drains flow through square pipes that run at about 45 degrees out and are sufficient to move the water past the lower flange of the beam. Note the old pipe in the photo is not associated with the stormwater system.

This photo shows the concrete seat of the main beams and the expansion joint drains between the concrete and the ends of the beams. Note there is a steep gravel slope from the bottom of the concrete to the water.

On all four bridges, I did not see any obviously clogged drains. This has been an unusual year with not much snow. I examined several locations with the drainage over land and did not note any issues – obvious deposits. The only evidence of the runoff is the staining from the gravel chips on the ice – which is highly visible, but unlikely to be of any environmental pollution significance.

APPENDIX 2

A2.0 Anchorage Port Access Bridge, Bridge No. 455.

Attached is a file

A2.1 Section of 2008 Fracture Critical Inspection Report.

This section of the 2008 report has information on the piping and drainage problems, including broken pipes and water damage, associated with this bridge which features a so

Photograph No. 49 – Looking at the south exterior face of the cap for pier 2A between Girders 4 and 4. Note: the drain pipe is cracked with signs of leakage present.

Photograph No. 50 – Looking at the west column for pier 2A. Note: a tree is growing adjacent to the concrete pedestal at the west column.

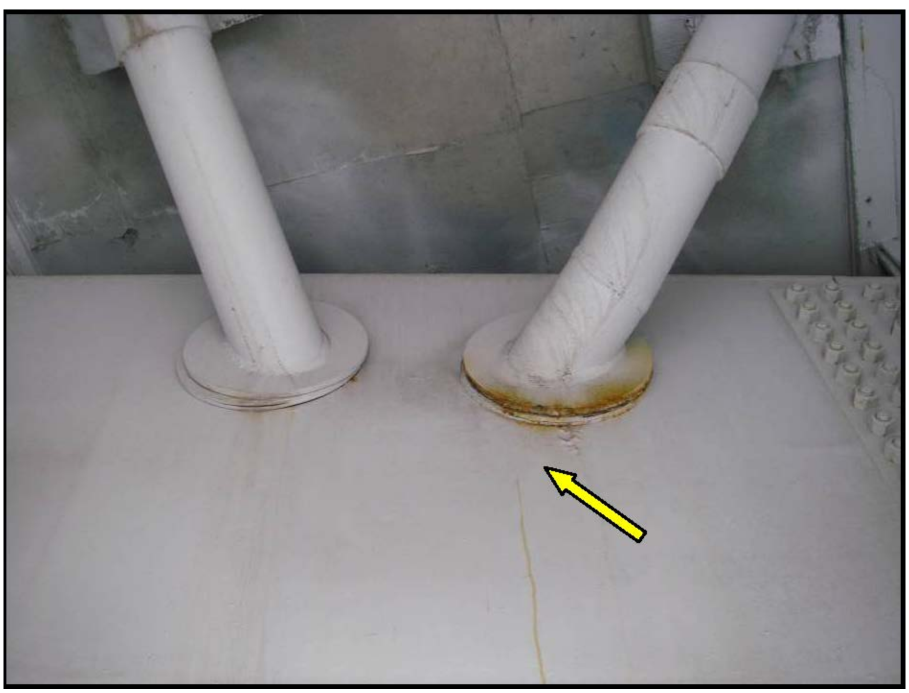
Pier 3A

Pier 3A consists of a welded box cap, 29.02 feet in length with two integral steel columns. The top of the cap is a maximum of 43 feet above the ground. The cap was accessed by using a self propelled lift. Girders 1 through 5 frame into the cap at varying degree of skew between 26 and 27°. Girder 4 does not extend past the north face of the cap. Four access hatches exist in the cap and one access hatch exists in each column. The following deficiencies were observed:

- The drain pipe has a loose gasket in the north web near Girder 5.
- The east column has 2-inches of moist debris on the bottom of the inside of the column (see Photograph No. 51).
- There is evidence of the drain pipe leaking in the east column at the location where it enters the cap. This may be leaking onto the bottom surface of the column which would cause the debris to stay moist.
- The slope is encroaching on the south face of both the east and west concrete pedestals (see Photograph No. 52).

Photograph No. 51 – Looking down at the interior bottom surface of the east column for pier 3A. Note: 2-inches of moist debris exists on the bottom surface.

Photograph No. 53 – Looking east inside the cap of pier 4C, in the north cell between Girders 3 and 4. Note: a slight misalignment exists between the bottom flange stiffener



plates in north cell at the splice.

Photograph No. 54 – Looking at the drain pipe between Girders 1 and 2 on the north web in

pier 4C. Note: the drain pipe is leaking at the entrance through causing blistering paint
Photograph No. 55 – Looking at the bottom surface of the interior of the west column of pier 4C. Note: standing water and moist debris; the lower flush pipe broken.

Photograph No. 56 – Looking up through the interior of the west column of pier 4C. Note: surface corrosion on the stiffening rings due to dysfunctional drainage system.

Photograph No. 57 – Looking north at the east column of pier 5. Note: water drains from the inside of the column onto the concrete pedestal.

Pier 6

Pier 6 consists of a welded box cap, 64.00 feet in length with two integral steel columns. The top of the cap is a maximum of 57 feet above the ground. The cap was accessed by using a self propelled lift. Girders 1 through 9 frame into the cap with no skew. Four access hatches exist in the cap and one access hatch exists in each column. The following deficiencies were observed:

- Signs of previous standing water exist on the cap bottom flange and webs. The previous water line is approximately 3” high. Dry debris exists on the inside of the east cell of the pier cap (see Photograph No. 58).
- Condensation exists on surfaces of the east column due to clogged drain pipe at the bottom leaving moisture in the column. Surface corrosion is forming on top of the bottom flange of pier cap due to condensation. Lower drain pipe is clogged and there is debris on the bottom surface.

Photograph No. 62 – Looking at the interior of the north cell at the east end of the cap of pier 9. Note: signs of previous standing water on the bottom flange, webs, and stiffeners.

Photograph No. 63 – Looking at the lower drain pipe in the east column of pier 9. Note: the drain pipe is clogged and standing water and wet debris exist on the bottom surface of the east column.

Photograph No. 86 – Looking south at the concrete collar of

the column of pier 18WS. Note: a 1 square foot by 1-inch deep spall exists in the concrete collar under the drain.

Pier 19WS

Pier 19WS consists of a welded box cap, 28.53 feet in length with a single integral steel columns. The top of the cap is a maximum of 25 feet above the ground. The cap was accessed by using a self propelled lift. Girders 1 through 4 frame into the cap at varying degree of skew between 18 and 20°. Three access hatches exist in the cap and one access hatch exists in the column. The following deficiencies were observed:

- 1/2-inch deep ponding water exists between Girders 1 and 2 in the north cell. This is causing peeling paint and surface corrosion on interior face of the cap bottom flange and the bottom 3 inches of the longitudinal stiffeners and cap webs between Girders 1 and 2. Wet debris exists on cap bottom flange between Girders 1 and 2. Surface corrosion exists on the interior of the cap bottom flange splice plate between Girders 1 and 2 (see Photograph No. 87).

One missing bolt exists in the cap top flange splice plate between Girders 1 and 2 in the south cell (see Photograph No. 88).

APPENDIX 3 Annotated Bibliography

The following are publications that we reviewed and have written a short abstract and notes about their relevancy to bridge deck runoff.

Allan, Craig J.; Evett, Jack B.; Saunders, William L.; Wu, Jy S. "Characterization and Pollutant Loading Estimation for Highway Runoff." Journal of Environmental Engineering, Vol. 124, No. 7, July 1998.

Abstract:

Three highway segments typical of urban, semi-urban, and rural settings in the Piedmont region of North Carolina were monitored to characterize the respective runoff constituent's concentrations and pollutant discharge or export loadings. Runoff from the impervious bridge deck (Site I) carried total suspended solids (TSSs) concentrations and loadings that are relatively higher than typical urban highways, whereas nitrogen and phosphorus loadings are similar to agricultural runoff. Site II included a pervious roadside shoulder with traffic volume equal to that of Site I. Site III was a non-urban highway having lower traffic counts and imperviousness due to the presence of a roadside median. The existing roadside shoulder and median appeared to attain at least 10-20% hydrologic attenuation of peak runoff discharges, more than 60% reduction of event mean concentration of TSSs, and attenuation of the first-flush concentrations for most pollutant constituents. Bulk precipitation data collected at the bridge deck site indicated that 20% of TSS loadings, 70-90% of nitrogen loadings, and 10-50% of other constituent exports from the roadway corridors might have originated from atmospheric deposition during dry and wet weather conditions. The long-term highway pollutant loadings have been derived to provide a basis for comparing highway runoff with other categories of non point sources (NPSs).

Notes:

According to this report, the TSS and loadings from the bridge deck site were larger than those that would typically be expected from highway runoff. The report indicates that the road shoulder and median present at the other sites were most likely responsible for the reduced TSS and loadings found (591).

Avelleneda, Pedro; Ballestero, Thomas P.; Briggs, Joshua; Houle, James. J; Roseen, Robert M.; Wildey, Robert. An Examination of Cold Climate Performance of Low Impact Development Stormwater BMPs in A Northern Climate. Durham, NH: University of New Hampshire, 2006

Abstract:

Between 2004 and 2006 a range of six Low Impact Development (LID) designs were tested and monitored over 11 storm events for cold climate performance including filter media frost penetration and resulting hydrographs, seasonal variations on contaminant removal efficiency, and attenuation of chloride pulses associated with melt events. LID systems evaluated include 2 types of bioretention systems, a surface sand filter, a gravel wetland, a tree filter, and porous asphalt. The LID performance data will be contrasted with conventional structural BMPs (swales, retention ponds), and some select manufactured stormwater systems. Winter monitoring includes both rainfall runoff data and diurnal melt events. Contaminant event mean concentration (EMC), and performance efficiency were evaluated for storms with varying rainfall runoff characteristics. Runoff constituent analyses included total suspended solids (TSS), diesel range organics (DRO), nitrate (NO3), and zinc (Zn). Several water quality parameters (temperature, dissolved oxygen, pH, conductivity) were monitored as real-time data. Performance evaluations indicate that LID designs have a high level of functionality during winter months and that frozen filter media appears not be a concern. Trends in chloride attenuation are complex.

Notes:

This article provides information related to LID BMPs in northern climates. The LID's tested were: 2 bioretention systems, a surface sand filter, a gravel wetland, a tree filter, and a porous asphalt (2). According to the results, the LIDs continue to operate efficiently during the winter months, although chloride contamination becomes a significant issue (11). The climate of the study area is defined as coastal, cool temperate forest. The annual precipitation is approximately 48", and the average low temperature in January is -9°C (4). While this does not compare to the majority of Alaska's climate, it may be appropriate for the southeast and southcentral coastal regions.

Barnes, David; Carlson, Robert F.; Gould, Stephanie. "Stormwater Management Model Development for Fairbanks Alaska," 11th International Conference on Cold Regions Engineering, Anchorage, Alaska. Reston, VA: American Society of Civil Engineers, 2002

Abstract:

This joint government-university stormwater management development project will eventually aid in compliance with Phase II National Pollution Discharge Elimination System (NPDES) requirements. The project is enabling the inventory and initial modeling and investigation of management techniques for the stormwater drainage system of the interior Alaskan city of Fairbanks.

The City of Fairbanks is the lead agency and end user of this project and is primarily coordinating, mapping, and inventorying their stormwater system. The Civil and Environmental Engineering Department at the University of Alaska, Fairbanks (UAF) is using the information gathered by the City to model the system. The hydraulic model created will be a comprehensive tool required for understanding the system and is a necessary foundation for continued development of a stormwater management program. Data is also being collected for eventual support of a water quality component to the model. Ancillary to this data collection, jet truck cleaning, the primary means of system maintenance is being investigates for its potential as a water quality management technique.

Notes:

This article outlines the initial efforts of the City of Fairbanks in gaining compliance with Phase II NPDES regulations. This article may be used to develop an understanding of the stormwater management plan currently used by the City of Fairbanks and the Fairbanks North Star Borough, although it should be supplemented with more recent information.

Barret, Michael E.; Jackson, Andrew; Kramer, Tim; Malina, Joseph F. Jr. Characterization of Stormwater Runoff from a Bridge Deck and Approach

Highway and Effects on Receiving Water Quality. Austin, TX: Center for Transportation Research at The University of Texas at Austin, 2006

Abstract:

Nonpoint source pollution represents one of the largest environmental problems currently facing water quality professionals. A fraction of this pollution is conveyed to receiving waters by stormwater drainage from highways. Some highway runoff is treated by structural or non-structural systems (best management practices/[BMPs]) or is diverted to municipal treatment systems depending on locale. However, much highway runoff and almost all bridge deck runoff enter receiving streams without treatment. Highway runoff may contain suspended solids, metals, oil and grease, fecal coliform, and oxygen demanding organics. Highway runoff characteristics have been reported in some detail over the years; however, limited data on the characteristics of runoff from bridge decks are available. The objectives of this study are:

• Characterization of bridge deck and approach highway stormwater runoff in three different geographical areas of Texas,
• A statistical comparison of the water quality characteristics of stormwater runoff from the bridge surface and the approach highway at each site, and
• An assessment of the impacts of the runoff on the quality of the receiving water at each site.

Notes:

This report contains an excellent summary of previous research conducted on sources of highway contaminants, factors affecting highway runoff, existing studies on bridge runoff characterization, and effects of highway runoff on receiving waters and biota. The results of the research conducted indicates that no adverse impacts occurred during testing due to the bridge deck runoff at all three sites (31). The report concludes:

> "Highway runoff data could be used as a conservative proxy for bridge deck runoff for the constituents monitored in this study, if site-specific bridge deck runoff data were unavailable (31)."

Bhattarai, Rishi Raj; Esalmi, Mehran; Griffin, D.M. Jr.; Shretha, Sashi. Determination and Treatment of Substances in Runoff in a Controlled Highway System (Cross Lake). Baton Rouge, LA: Louisiana Transportation Research Center, 2003

Abstract:

Because bridges usually span bodies of water, quantifying and controlling non-point pollutant flux from them will take on added significance as federal regulations begin to address non-point contamination of the environment. The objectives of this study were to examine the quality and quantity of the non-point contamination coming from the Cross Lake Bridge and to examine the effectiveness of a detention pond (holding pond) in removing contaminants from the runoff. These objectives were accomplished by installing sampler/flow meters at the basin inlet and outlet to quantify the volume of runoff and mass of conventional contaminants (COD, TSS, nutrients, hydrocarbons) entering and leaving the basin. The runoff flow rate into and out of the basin was logged at periodic intervals and discrete samples were collected across flow hydrographs entering and leaving the basin. Using this data, the basin efficiency in removing pollutants from runoff could be estimated. Study results show that runoff from the bridge contains pollutant concentrations similar to those found in domestic wastewater. However, the Cross Lake holding pond removed 100 percent of total petroleum hydrocarbons, 82 percent of oil and grease, and 85 percent of the total suspended solids entering the pond. Removal percentages for other contaminants were smaller and exhibited greater variation. Analysis of pond sediments and the overlying water column showed that the majority of the metals in the runoff were concentrated in (sorbed onto) the sediments. Partitioning coefficients on the order of several thousand were measured. Holding ponds are relatively simple, low-maintenance systems that could be employed as a best management practice (BMP) at a number of DOTD facilities and be a major factor

in reducing non-point contamination at existing DOTD facilities such as district offices and maintenance yards. Holding ponds appear to be a simple and relatively inexpensive way of complying with upcoming federal and state mandates regarding export of non-point contamination from DOTD facilities; however, such facilities must be cleaned on a regular basis to remain functional.

Notes:

The results of this study show that detention ponds are a very efficient and cost effective method for removing petroleum hydrocarbons, oil and grease, and total suspended solids. It was found that most of the metals in the runoff were located within the sediments that were removed by the detention pond (59).

Bingham, Ralph L.; El-Agroudy, Amr A.; Neal, Harry V. Characterization of the Potential Impact of Stormwater Runoff from Highways on the Neighboring Water Bodies Case Study: Tamiami Trail Project. Orlando, FL: PBS&J, 2002

Abstract:

Florida's rapid growth and urbanization generated vast amounts of land clearing resulting in the creation of impervious surfaces which increased flooding and water quality degradation. Stormwater runoff contributed sediment, nutrients and heavy metals to these waters. Earlier research attributes 80 to 95% of heavy metal (mainly lead, zinc, and copper) contributions to our waters to be from highways and parking lots. In recent years, pollutant concentrations in stormwater runoff from highways have been significantly reduced due to the stricter environmental regulations implemented to protect the natural habitat and to enhance environmental conditions in rural/urban areas. This paper presents a predictive model of heavy metal concentrations in stormwater runoff from highways based on the most recent available data in Florida. The model was then used to evaluate contaminant concentrations from the runoff of the Tamiami Trail / US 41 as a case study. Predicted results of pollutant concentrations from the Tamiami Trail are compared to a) existing trace metal levels in-situ and; b) Class III Fresh Water Criteria to evaluate the need of a water treatment facility for the project area. The results of the investigation suggest that pollutant levels in stormwater runoff from the Tamiami Trail will have little effect on the quality of the water and the surrounding aquatic habitat in the Tamiami Canal.

Notes:

Based on the model developed it was predicted that the runoff from the highway project would have little effect on the quality of the receiving waters and the surrounding aquatic habitat as far ahead as 2020 (234). Based on this prediction the authors recommend that no current action should be taken to treat the stormwater. According to the authors, "It would not appear prudent to provide stormwater treatment for existing conditions which do not violate standards or future conditions which predictably meet standards, at the expense of measurable, physical impacts to wildlife and wetlands supported and protected by National Park covenants (234)."

Brownlee, B; Lawal, S.; Larkin G.A.; Mayer, T.; Marsalek, J. "Heavy Metals and PAHs in Stormwater Runoff from the Skyway Bridge, Burlington, Ontario.," Water Quality Research Journal, Vol. 23, Issue No. 4, Burlington, Ontario: National Water Resource Institute, Environment Canada, 1997

Abstract:

Samples of stormwater runoff from the Skyway Bridge in Burlington, Ontario, were analyzed for five heavy metals (Zn, Pb, Ni, Cu, and Cd) and 14 polycyclic aromatic hydrocarbons (PAHs) in dissolved and particulate-bound phases. Among the metals studied, the highest mean event-mean concentrations in whole-water samples were found for Zn, Cu, and Pb (0.337, 0.136, 0.072 $mg*L^{-1}$). These data compared well with those in the literature. Pb concentrations had to be compared to the most recent data reflecting the use of unleaded gasoline. Zn, Ni, and Cu in the dissolved phase accounted for 35 to 45% of concentrations in whole-water samples. Mean PAH event-mean concentrations in whole-water samples ranged from 0.015 to 0.5 $\mu g*L^{-1}$ for individual compounds.

Dissolved phase PAHs represents less than 11% of whole-water concentrations. Mean concentrations of ZN, Cu and Pb (997,314, 402 $\mu g*L^{-1}$) in runoff sediment were rather high and indicated that this sediment was "grossly polluted" according to the (Ontario) Ministry of Environment and Energy guide lines for sediment quality. Metal concentrations in the <45µm size fraction were greater than in whole-sediment samples, but with respect to metal loads, this enrichment was insignificant since this fraction represented less than 1% of the total mass of solids. The runoff chemistry indicates that uncontrolled discharges of highway (bridge) runoff could significantly impact receiving water quality and may require remediation by appropriate stormwater best management practices.

Caraco, Deb; Claytor, Richard. Storm Water BMP Design Supplement for Cold Climates. Elliot City, MD: Center for Watershed Protection, 1997

Introduction:

Designing stormwater best management practices (BMPs) that are effective at removing pollutants, acceptable to the public and affordable is not easy in any climate. Cold climates present additional challenges that make some traditional BMP designs less effective or unusable. Based on information gathered in a nationwide survey of cold climate BMP experts, stormwater challenges are evaluated and recommendations are made for BMP use in cold regions (9).

Some of the challenges of cold climates, such as freezing temperatures and high runoff during snowmelt events, influence the effectiveness of traditional stormwater designs. This document describes modifications to traditional stormwater designs to make them more effective in these environments.

Notes:

This report is an excellent reference for issues related to stormwater BMPs in cold regions. The report also provides some basic suggestions to solve to these problems, as well as several management methods for sand and deicer use to reduce their presence in stormwater runoff (8-1).

Christopher, James E.; Harper, Harvey H.; Wanielista, Martin P.; Yousef, Yousef A. "Management of Drainage Systems from Highway Bridges for Pollution Control," Transportation Research Record 896, 1983

Abstract:
Pollutants associated with runoff water from highway bridges were characterized and quantified. These pollutants are directly discharged through scupper drains to adjacent water bodies and floodplains or detained in ponds before being released to lakes and streams. Selected heavy metals, such as lead, zinc, copper, chromium, iron, nickel, and cadmium, were of particular concern because of their potential enrichment in biota. Results show significant differences in heavy metal concentrations between water samples from bridge runoff and adjacent streams. Heavy metals tend to concentrate in bottom sediments, floodplains, and adjacent soils. For example, bottom sediment samples from Lake Ivanhoe, north of Orlando, Florida, collected beneath bridges with scupper drains showed significantly higher concentrations of heavy metals than did samples collected beneath bridges without scupper drains. In addition, concentrations of heavy metals in the sediments of detention ponds receiving bridge drainage were higher than concentrations in sediments from adjacent lakes. It appears that management and careful design consideration of highway bridge drainage systems could result in significant reduction of the amount of pollutants released to adjacent water bodies.

Notes:
This is another classic study cited by most authors. The study was completed in 1983. The research focuses mainly on the concentration of heavy metals, and found that most heavy metals were found in the bottom sediments (54). The report provides an interesting example of how construction fill requirements led to the creation of three detention ponds under the Maitland Boulevard Overpass (52). This indicates that simple coordination between the design and construction agencies can lead to bridge deck runoff solutions.

Davis, Allen P.; Flint, Kelly R. "Pollutant Mass Flushing Characterization of Highway Stormwater Runoff from an Ultra-Urban Area," Journal of Environmental Engineering, Vol. 133, No. 6, June 1, 2007.

Abstract:

Water quality of highway stormwater runoff from an ultra-urban area was characterized by determining the event mean concentration (EMC) for several pollutants and by evaluating pollutant flushing. Thirty-two storm events were monitored between June 2002 and October 2003. Mean EMCs in mg/L were 0.035, 0.11, 0.22, 1.18, 420, 3.4, 0.14, 1.0, and 0.56 for Cd, Cu, Pb, Zn, total suspended solids (TSS), total Kjeldahl nitrogen (TKN), NO_2–N, NO_3–N, and TP. First flush as defined by flushing of 50% of the total pollutant mass load in the first 25% of the event runoff volume occurred in 33% of the storm events for NO_2^-, 27% for TP, 22% for NO_3^- and TKN, 21% for Cu, 17% for TSS, 14% for Zn, and 13% for Pb. Median values for the mass flushed in the first 25% of runoff volume were greater than the mass flushed in any 25% portion beyond the first for all pollutants. The mass in later 25% volume portions were greater than in the first 25% volume in at least 17% of the events for all pollutants, indicating that a significant amount of the pollutant load can be contained in later portions of the runoff volume. Nonetheless, management of the first 1.3 mm (1/2 in.) of runoff was able to capture 81–86% of the total pollutant mass.

Dupuis, Thomas V. Assessing the Impacts of Bridge Deck Runoff Contaminants in Receiving Waters, Volume 1: Final Report. Washington D.C.: Transportation Research Board, 2002

Notes:

This is the first volume of results from a study complete by NCHRP to address the impacts of bridge deck runoff contaminants. The results of the literature review, survey of highway agencies, and the results of two thorough biological studies are presented (1). The literature review section provides listings of pertinent research and the state the research was conducted in, a summary of previous FHWA studies, and previous NCHRP studies. The findings of the literature review are also summarized by topic (source and type of pollutants, pollution accumulation in sediments, biological impacts, etc.). The summary at the end of this section identifies key gaps in published literature, including: availability of literature and ease of use by bridge designers, the lack of studies directly related to bridge deck runoff impacts, and little if any studies focused on the impact from bridge maintenance and spills (46).

The survey of state and provincial highway agencies revealed that bridge deck runoff is "becoming more prominent and difficult to address in many states" (46). Few northern region states indicated that structural mitigation systems were being used or developed (23-25). Washington appears to be taking the most progressive stance on bridge deck runoff mitigation. States that are addressing bridge deck runoff are most often doing so because pressure from state or federal environmental agencies (26). The survey also indicated that regulatory decisions were based on a general feeling that bridge deck runoff must be harmful rather than a site specific investigation (26).

Dupuis, Thomas V. Assessing the Impacts of Bridge Deck Runoff Contaminants in Receiving Waters, Volume 2: Practitioner's Handbook. Washington D.C.: Transportation Research Board, 2002

Notes:
This is the second volume produced by the NCHRP's research on bridge deck runoff. This volume is intended to serve as a guide for professionals to help develop a strategy for identifying problem bridges, design experiments to analyze the quality of the runoff, and to implement proper mitigation efforts. Each chapter helps the user identify and address site specific problems. Tables are used to guide the workflow Also, nineteen different methods for analyzing bridge deck runoff are provided. This volume should serve as the starting point to develop a strategy specific to Alaska's bridges.

Grapentine, Lee; Marsalek, Jiri; Rochfort, Quintin. Assessing Urban Stormwater Toxicity: Methodology Evolution from Point Observations to Longitudinal

Profiling. Burlington, Ontario: Water Science and Technology Branch, Environment Canada, 2008

Abstract:

The quality of aquatic habitat in a stormwater management facility located in Toronto, Ontario, was assessed by examining ecotoxicological responses of benthic invertebrates exposed to sediment and water from this system. Besides residential stormwater, the facility receives highway runoff contaminated with trace metals, polycyclic aromatic hydrocarbons (PAHs), and road salt. The combined flow passes through two extended detention ponds (in series) and a vegetated outlet channel. Toxicity of surficial sediment collected from 14 longitudinally arrayed locations was assessed based on 10 acute and chronic endpoints from laboratory tests with four benthic organisms. Greatest overall toxicity was observed in sediment from sites in the upstream pond, where mortality to amphipods and mayflies reached up to 100%. Downstream pond sediment was less toxic on average than the upstream pond sediment, but not the outlet channel sediment where untreated stormwater discharges provided additional sources of contamination. Macroinvertebrate communities in sediment cores were depauperate and dominated by oligochaetes and chironomids, with minimum densities and diversity at the deeper central pond sites. While sediment toxicity was associated with high concentrations of trace metals and high molecular weight PAHs, benthic community impoverishment appeared related to high water column salinity.

Guo, James C. Y. "Sand Recovery for Highway Drainage Designs," Journal of Irrigation and Drainage Engineering, Vol 125, No. 6, November/December, 1999.

Abstract:

Roadway sanding is a common practice in cold regions because sand increases the roadway friction when mixing with snow. However, after snow melt, sand imposes potential hazards to traffic. Recovery of sand from highways has become an increasing concern not only for the reason of traffic safety, but also for being nonpoint pollution sources to nearby wetlands and streams. In this study, a snow storage element is

introduced to the renascence project of a mountainous highway that is running through an environmentally sensitive forest area in Colorado. Recovery of winter sanding material from the highway is design to be a joint effort of surface runoff and sweeping machines. As a tradeoff exists between sand recovery and the size of a snow storage area, this study also presents a maximization methodology by which the size of the snow storage area can be determined by the diminishing return of sand recovery.

Irwin, G.A.; McKenzie Donald J. Water-Quality Assessment of Stormwater Runoff from a Heavily Used Urban Highway Bridge in Miami, Florida. Tallahassee, FL: U.S. Geological Survey, 1983

Abstract:

Runoff from a 1.43-acre bridge section of Interstate 95 in Miami, Florida, was monitored during five storms to estimate loads of selected water-quality parameters washed from this heavily traveled roadway. The monitoring was conducted periodically from November 1979 to May 1981 in cooperation with Florida Department of Transportation for the specific purpose of quantifying the concentrations and loads of selected water-quality parameters in urban-roadway runoff which may have an adverse impact on State surface waters.

Automated instrumentation was used during each of the five storms to collect periodic samples of bridge runoff and to measure continuously the storm discharge from the bridge surface and the local rainfall. For most target parameters, 6 to 11 samples were collected for analysis during each event. Results of these analyses generally indicated that the parameter concentrations in the stormwater runoff and the parameter load magnitudes were quite variable among the five storms, although both were similar to the levels reported for numerous other roadway sites. Storm intensity influenced the rate of loading, but parameter concentration was the dominant variable controlling the overall magnitude of loading.

Although only a limited number of runoff events were sampled, the data were used to estimate the following average, discharge-weighted parameter loads per storm per acre of bridge surface: 28 pounds (total solids), 7.1 pounds (suspended solids), 12.8 pounds (total volatile solids) 4.6 pounds (suspended volatile solids), 4.7 (total organic carbon), 11 pounds (chemical oxygen demand), 0.27 pounds (total nitrogen), 0.06 pounds (total lead), and 0.03 pounds (total zinc). Results of a very limited sampling of loading and 10 percent of the suspended solids loading originated from material that was transported directly to the bridge surface by precipitation. Further, a cursory assessment suggested that the total number of antecedent dry days and traffic volume were not conspicuously related to either runoff concentrations or loads.

Notes:

This is one of several studies completed during the 1970's and 1980's, when storm water was first becoming a concern. It is cited by nearly every work reviewed for this literature review. The major findings of the report are given in the last paragraph of the abstract. It has been noted that this study does not represent a good cross section of the majority of the United States due to Florida's unique setting and the age of the study (Barrett 11).

Minnesota Stormwater Management Design Manual
Authors: Emmons & Olivier Resources, Center for Watershed Protection, 2006.

Abstract:

The Center worked with Minnesota-based Emmons & Olivier Resources, a large committee of state regulators, and other stakeholders to craft the Minnesota Stormwater Manual, the most comprehensive one in the Upper Midwest to date. This manual provides an updated discussion of cold climate issues as they influence design of stormwater practices, like the challenge of high snowfall, springtime snowmelt, and Minnesota's thousands of sensitive lakes, trout streams, and wetlands that merit special protection. The related issue papers, also from this site, introduced new stormwater concepts to the state, such as unified sizing criteria, special receiving water performance standards, and stormwater credits.

Notes:

This manual has been used as a reference for our report, and it is great study about snowmelt hydrology, stormwater practices in cold regions.

Nwaneshiudu, Oke. Assessing Effects of Highway Bridge Deck Runoff on Nearby Receiving Waters in Coastal Margins Using Remote Monitoring Techniques. Texas A&M University, 2004

Abstract:

Most of the pollution found in highway runoff is both directly and indirectly contributed by vehicles such as cars and trucks. The constituents that contribute the majority of the pollution, such as metals, chemical oxygen demand, oil and grease, are generally deposited on the highways. These can become very harmful and detrimental to human health when they come in contact with our water system. The connecting tie between these harmful highway-made pollution and our water system, which includes our ground waters and surface waters, is rainfall. The main objective of this runoff study was to characterize and assess the quantity and quality of the storm water runoff of a bridge deck that discharged into a receiving water body. The bridge deck and the creek were located in the coastal margin region in the southeast area of Texas on the border of Harris and Galveston counties. Flow-activated water samplers and flow-measuring devices were installed to quantitatively determine the rate of flow of the bridge deck and determine different pollutant loading by sampling the receiving water body (Clear Creek). The collected samples were analyzed for total suspended solids, toxic metals, and other relevant constituents of concerns. The results illustrated that the runoff from the bridge deck exhibited low total suspended solids concentrations (which were highest in the creek). However, other metal constituents like the zinc and cooper concentration were high and above standards. The phosphate concentrations in the creek were the highest and exceeded EPA standards. Several nitrate concentrations were also noticeably above EPA standards.

Notes:

The findings of this report indicate that the bridge deck runoff contained low TSS and VSS concentrations, but some of the metal concentrations (especially zinc) exceeded EPA standards. The study creek phosphate levels exceeded the EPA standards while the bridge deck runoff concentration of phosphates was low (52).

Oberts, G. 2003. "Cold climate BMPs: Solving the management puzzle." ***Water Sci. Technol.,*** **48_9_, 21–32.**

Abstract:

Snowmelt runoff and rain-on-snow events present some of the highest pollutant loading and most difficult management challenges in the course of a year in regions with cold climate. Frozen conduits, thick ice layers, low biological activity, altered chemistry, and saturated or frozen ground conditions all work against effective treatment of melt runoff. Understanding the source, evolution and transition that occurs within a melt event and defining the management objectives for specific receiving waters will help focus the search for effective management techniques. Solving the management puzzle means putting together a strategy for both soluble and solids-associated water pollutants.

Notes:

This report is an excellent reference for issues related to stormwater BMPs in cold regions. The report also provides some basic understanding of snowmelt hydrology.

Oberts, G. 2003. Keynote Address:"Stormwater Management in Cold Climates-Planning, Design and Implementation", Portalnd, Maine, November3-5, 2003.

Abstract:

Tremendous strides have been made since the first international conference in Narvik, Norway in 1990 dedicated completely to the understanding and management of snowmelt in urban areas, to Maine in 2003. But with every discovery comes the need to know more. The advent of sophisticated computers and software that can predict the sun's

effect on a snowpack, the chemical data to finally know what that snowpack will yield to a receiving water, and the behavior of that water as a slug of heavily polluted meltwater enters are all recent advances in the science. But knowing these things merely whets the appetite to delve further. Drawing from participation in the series of conferences and workshops beginning with Narvik, and from experience in the field, observations will be made on what we have learned and how it applies to everyday practical application in cold climate regions. Accompanying this will be the identification of the many information needs that still exist for both theoretical and practical aspects, including: accurate modeling of the spatial mechanics of melt generation within an urban area and the runoff it generates; better definition of the nature, partitioning and fate of pollutants as they move from snowpack into and through receiving waters (recipients); improved chemical handling and the impact of chemicals on surface and ground water; the effectiveness of MTPs (meltwater treatment practices) and how they differ from STPs (stormwater treatment practices); the potential impact of climate change; and technical transfer of information to a limited world audience. The very positive result of identifying these needs is that today someone is working on every one of these elements and new collaborative efforts are under way among those interested in cold climate hydrology and water quality. We have moved past the problem recognition stage and are on the verge of truly understanding how meltwater generation and runoff can be anticipated and managed. This keynote address will set the stage for the conference, which focuses on lessons learned and practical applications for the future.

Thorolfsson, Sveinn T. "Specific Problems in Urban Drainage in Cold Climate." Urban Drainage Modeling; Proceedings of the specialty symposium held in conjunction with the World Water and Environmental Resources Congress, May, 2001.

This paper presents the specific problems in urban drainage in cold climate. The climate affects the urban drainage by changing the urban hydrological cycle and it becomes more complex in cold weather than in warm-weather. In cold climate the low temperatures and the snowfall causes several problems to the urban drainage systems. The urban runoff is affected by: 1) frozen ground surfaces, 2) frost penetration into the ground, 3) snow on ground, 4) rain-on-snow, 5) snowdrift, 6) natural and man-made snow redistribution and 7) snow removal. Additional problems are caused by frost penetration, frost heaving, freezing in pipes, ice on ground surfaces, clogging of gutters and inlets, icing in manholes and in storm sewers, ice in open watercourses, such as urban creeks and rivers, ponds and lakes, etc.

There are also changes in the transport of urban runoff and stormwater pollutants, the operation of runoff control facilities and sewage treatment plants. Snow may be stored on the catchment and produce runoff during warmer weather. Frozen ground thaws slowly and high runoff rates may occur when rain falls on frozen ground. In maritime cold climate subsequent melting and freezing periods often give significant runoff periods. Other problems are due to flooding, combined sewer overflows (CSO) and overloading of wastewater treatment plants. Pollutants may be accumulated in the snow in streets. When the last 10-20% most polluted part of the accumulated snowmelts and enters the sewer system, a shock load of pollutants may occur. The sewer system is filled up from previous inflow and a part of the concentrated pollutants may be discharge in overflows to local recipients. The wastewater conveyed to the treatment plants is discharged in overflows to local recipients. The wastewater conveyed to the treatment plants is cold, 2-5°C, due to high inflow/infiltration in rain-on-snow and melting periods. Problems to the urban surface runoff are caused by the snow redistribution on sidewalks etc or temporary surface water storage because of clogged inlets.

In cold climate areas the planning and designing procedures for urban drainage often do not consider the presence of the snow and even not the operation and maintenance procedures and guidelines. A great need for further research and development in urban drainage is therefore needed, followed up by a relevant training and education, including preparation of appropriate educational materials. Such work is going on at the Department of Hydraulics and Environmental Engineering, NTNU.

Notes:

This article provides some basic examples of problems related to urban drainage in cold regions (freezing of pipes, frost heave, peak flow rates due to snow melt, etc.), but does not contain much information directly related to non-point discharge elimination.

Wilson, Dean. Highway 520 Bridge Storm Water Runoff Study. Seattle, WA: King County Water and Land Resources Division, 2005

Introduction:

The Highway 520 Bridge Storm Water Runoff Study is a data collection effort that is part of the Sammamish-Washington Analysis and Modeling Program (SWAMP). SWAMP is a water quality and quantity monitoring modeling project that was initiated in 2000 to support a variety of potential water resource decisions for the majority of the Greater Lake Washington watershed. The continued expansion of urban and suburban development and associated hydrological changes affecting flow and degrading riparian habitat arguably make this watershed on the most highly altered on the West Coast (Kerwin, 2001). SWAMP provides a comprehensive evaluation of current and future water quality conditions in the study area.

Watershed modeling is an integral part of the SWAMP program. During development of the SWAMP work plan it was determined that water quality loadings from a limited access highway were needed for watershed model calibration in the Lake Washington watershed. Consequently, the primary purpose of this project is to assess the quality and quantity of storm water runoff from the 520 Bridge and to estimate contaminant loadings to Lake Washington.

The 520 Bridge was chosen for several reasons, including:

- Contaminant loadings from the bridge to the lake have not been directly measured.
- Contaminant sources to the road surface are assumed to be limited almost exclusively to those associated with vehicle traffic; few other potential contaminant sources are likely present on the bridge deck to confound results.

- Results will also be used to better understand the contaminant characteristics of bridge runoff to Lake Washington.
- Results will be used to calibrate/validate watershed models developed in the Lake Washington watershed (1).

Notes:

The author indicates that the observed zinc concentrations were higher than previously reported concentrations for other limited access highways. This anomaly was investigated with additional testing of the 520 Floating Bridge and two other floating bridges. It was determined that the elevated zinc levels were caused by the failure of the inner coating on the bridge downspouts, which caused leaching of zinc into the runoff (20). Also, it is mentioned that bird droppings likely elevated concentrations of ammonia and fecal coliform (21).