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Bangor International Airport -Stormwater Design Services

Design Narrative

1 Introduction

1.1 Background

SMRT has been retained by the City of Bangor to undertake engineering design of improvements to the stormwater management system at Bangor International Airport. The airport is located to the west of Bangor city center, on the south side of Union Street and the west side of Interstate I-95 and comprises a land area of approximately 1,900 acres. The complex was formally a military airfield (Dow Air Force Base) and now houses a Maine Air National Guard (MEANG) Base, an Army National Guard (ANG) Base and a growing civilian airport that is owned and operated by the City of Bangor. The airport complex can be divided into two separate areas. The airfield side of the facility contains the aviation operations areas including runways, taxiways, service aprons, hangars and boarding gates. The land side of the facility comprises the access, parking, drop-off and terminal areas and also includes surrounding land owned, or previously owned by the airport.

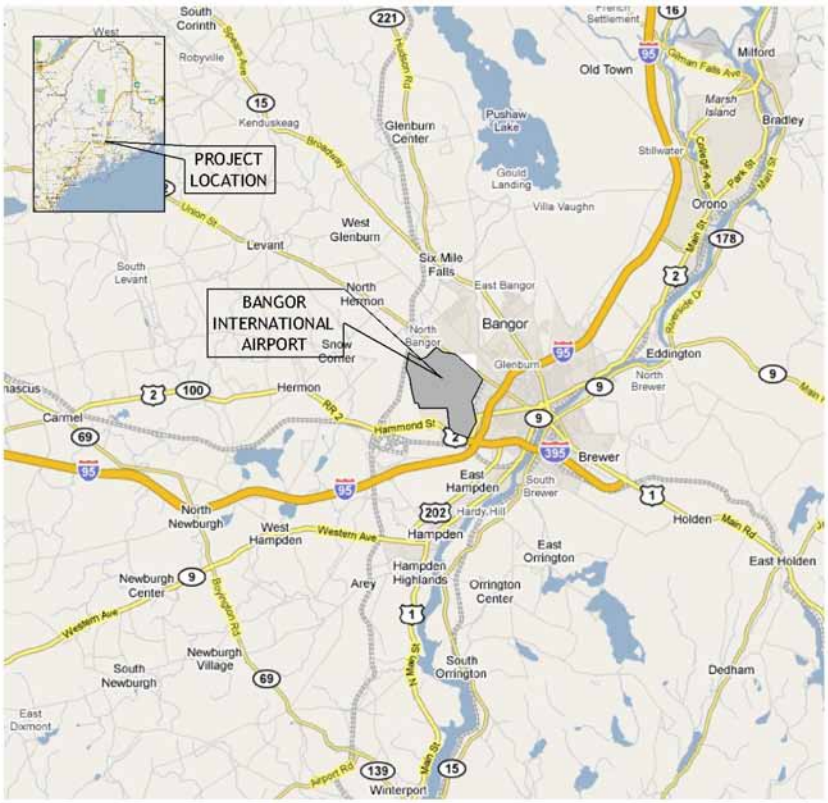


Figure 1 – Airport Location Map

The stormwater infrastructure at Bangor Airport can also be divided into two separate elements. The airfield side of the system comprises a network of inlets and subsurface pipes that collects runoff from the aircraft operations areas and discharges to the land side of the complex. On the land side of the facility the stormwater system comprises a system of linear open channels that convey runoff across the airport property towards Union Street and a large box culvert that carries the flow to the northern side of the Airport Mall. The downstream end of the Union Street culvert marks the head of Birch Stream, a small urban stream segment approximately half a mile in length that drains into Kendeskuag Stream just below the Griffin Road bridge crossing.

Water quality data gathered in a number of previous studies indicate that Birch Stream suffers from low measured dissolved oxygen levels, bank erosion due to high flow velocities, a diminished macroinvertebrate community, thermal impacts, and possibly high nutrient levels. These water quality impairments have led the State of Maine Department of Environmental Protection (MEDEP) to designate Birch Stream as an "Urban Impaired Stream". The Clean Water Act requires preparation of a TMDL (Total Maximum Daily Load) Report for all water bodies listed as impaired, or not meeting the required attainment criteria. The TMDL Study identifies key stressors that impact water quality within the watershed and recommends target reductions to these stressors that will bring the stream into conformance with the designated attainment standards. A TMDL Study was developed for Birch Stream by MEDEP and Partnership for Environmental Technology Education (PETE) in 2007. The next step in the regulatory process is the production of a Watershed Management Plan (WMP) for Birch Stream. The aim of the WMP is to describe mitigation measures within the watershed that will address the water quality impairments and bring the stream into attainment.

The Bangor International Airport complex dominates the upper reaches of the Birch Stream watershed and it is clear that improving the water quality treatment and flow regime within the airport stormwater system could potentially have a significant beneficial impact on the natural stream segment. The aim of this project is to identify and develop design solutions that will improve the efficiency and function of the airport stormwater management system and hence improve the quality and flow characteristics of the runoff released from the airport complex to Birch Stream.

1.2 Existing Airport Stormwater System

The existing stormwater system comprises an extensive network of inlets and enclosed pipes that drain to a series of broad open channels that are almost exclusively located on the land side of the facility. The channels are linked by a series of large diameter arch culverts and multiple box culverts and flow in a generally northward direction towards the Union Street culvert and into the headwaters of Birch Stream. The open channels act as large capacity conveyances and also potentially provide large volumes for treatment and detention. The original configuration of the channel system included three separate conveyances. The Domestic Canal drains the area of the main runway and taxiway and areas on the east side of the airport facility. The International Canal drains the main service aprons on the MEANG facility and adjacent to the civilian airport terminal building. The MEANG Canal drains the majority of the land side area of the MEANG facility and also accepts runoff from an area on the north side of Union Street, outside the airport property. The location of the major channel systems is shown in Figure 2 on the following page.

Insert figure 2 – Airport Stormwater System Schematic

The airport Detention Pond was constructed by damming the downstream end of the Domestic Canal, and controlling the outflow from the system with an outlet control structure. This impounded a large volume of water behind the dam and created a wet pond that is intended to provide water quality treatment through settlement of suspended solids (plug flow type basin). The wet pond is clearly under-sized for the contributing catchment area and it is unclear how much water quality treatment is provided by the structure in its current condition. However, the Detention Basin does play an important role in spill control and containment for the airport facility. Construction of the Detention Pond has created a permanent tailwater condition in the main body of the Domestic Canal, resulting in shallow standing water throughout the entire length of the structure and submerging many of the incoming drainage pipes.

The stormwater system design has been described and analyzed in a number of previous reports. The latest of these was undertaken by Edwards and Kelcey in 2007 (Bangor International Airport Stormwater Management Study Report) and summarized much of the previous data gathered in earlier studies. The report presented extensive mapping of the piped drainage system within the airfield side of the airport complex, and a summary of structural and hydraulic deficiencies within the system. It also highlighted several areas where the original drainage system has been modified and no longer performs within the original design parameters. One large flow diversion was identified that re-routes a large quantity of stormwater from the International Canal into the Detention Basin. Significant sedimentation was also observed at a number of locations, reducing system capacity for treatment and/or detention of runoff. It is clear from the report that significant gains in the efficiency of treatment and detention at the site could be made with modifications to the current stormwater system. The Edwards and Kelcey report represents a detailed summary of the available data on the existing system and makes several outline recommendations for system improvements. This document has been used as both a reference and a starting point for some of the design options explored in this study.

The catchment area contributing to the airport stormwater management system is highly impervious (approximately 33%). This inevitably leads to high peak runoff rates during storm events. It is evident from recent monitoring data that the highly impervious nature of the catchment, and the large areas of unshaded standing water within the existing open channel system cause significant thermal impacts to the downstream receiving waters. Site inspections also indicate high sediment loads, discolored water and very low dissolved oxygen levels in some areas of the stormwater system. These indicate that current treatment provisions are ineffective at some locations and fail to address some of the key stressors found in stormwater runoff from the airport complex.

1.3 Stakeholders

There are several stakeholders with a significant interest in potential modifications to the airport stormwater system. These include Bangor International Airport operations and management staff, who operate and maintain the airport facility, Maine Air National Guard and Army National Guard, who maintain operational bases within the airport facility, the City of Bangor, Penobscot County Soil and Water Conservation District, and from the regulatory community the Federal Aviation Authority, Maine Department of Environmental Protection, and the US Environmental Protection Agency (EPA). Each of the stakeholders has played an important role in reviewing and commenting on potential design options and assisting in the formation of a viable plan to improve the airport stormwater system.

1.4 Design Constraints

A number of important design constraints have been considered during the development of the concept design options. These include items that may not ordinarily be a limiting factor on stormwater design considerations, and include the following.

Financial Feasibility – The range of options for retrofitting and improving the airport stormwater management system is extensive and only physically limited by the space available within the confines of the airport property. However, it is recognized that the airport is essentially a municipal facility that works in partnership with two military co-habitants. The sources of funding for improvements to the stormwater system are not unlimited, and design solutions must be customized in extent and nature to those that are feasible within the financial and budgetary framework of Bangor International Airport and the City of Bangor. It is clear that priority should be given to design options that offer a favorable cost:benefit ratio and where possible designs that offer dual, or multiple benefits to the airport should be favored. These include targeting improvements to areas where maintenance, or structural deficiencies have already been identified and hence work is already needed, and designing stormwater BMPs that offer landscaping, or beautification benefits.

Development potential – The airport facility includes large areas of currently undeveloped land that could potentially provide areas for additional stormwater treatment. However, the siting of BMPs on vacant land must be managed in a way that is sensitive to future development potential in and around the airport. The presence of a major and growing aviation transportation hub has considerable potential to attract both aviation and transportation related industry that could be a significant economic benefit to the city. Therefore, where possible the design solutions offered have been limited to areas within the extents of the current stormwater management system.

Impact on airport operations – Design solutions that increase the efficiency of the stormwater management system must be carefully considered with respect to potential impacts on airport operations. Under usual design conditions stormwater conveyance and detention structures can be designed with some minimal degree of risk of ponding around inlets, or flooding during major storm events. However, where aviation operations are concerned designs must be significantly more conservative. Efficient drainage of aviation pavements is essential to safe operation of the airfield and this consideration must be given priority over other design parameters. Although this project focuses on modifications to the system on the land side of the airport facility, care must be taken to avoid excessive increases in hydraulic grades and potential backwater effects on the upstream system.

Wildlife attractants and habitat concerns – A key consideration in the safe operation of the airport is the minimization of potential wildlife attractants. Stormwater system can often offer ideal habitat areas for birds and other wildlife that can potentially impact airport operations. The Federal Aviation Authority has issued guidance on hazardous wildlife attractants near airports and this includes a section on stormwater management facilities.

Photograph 1.4.1 - Open water areas present a potential hazardous wildlife attractant

2 Project Approach

The general approach to this project has followed five basic steps. These are outlined in the original scope of work and are as follows.

2.1 Kick-off Meeting

An initial kick off meeting was held with the stakeholders to air some potential approaches to retrofitting the stormwater system and field concerns and perspectives from interested parties. The intent of the kick off meeting was to introduce the project to the key stakeholders, field questions about the scope and aims of the project, and determine the acceptability of a variety of approaches to tackling stormwater quality and quantity improvements.

2.2 Desktop Study

Following the kick off meeting a desktop study was undertaken to assess the level and suitability of the existing data on the Birch Stream Watershed and identify data gaps that will be critical to defining effective solution options. This included a desktop review of current and historical water quality data and ground survey information and conversations with representatives of the data sources. The desktop study was intended to provide a solid foundation on which to develop a coherent strategy for improving the watershed. The following tasks were undertaken in this phase of the project:

- Review of existing reports and studies;
- Review of historical plans and data from the City of Bangor Engineering Department archives;
- Analysis of the existing drainage system design and current operation including assessment of existing hydrologic and hydraulic models of the system. Refinement of the model has been undertaken to reflect information gathered in field visits and to improve the accuracy of the system representation;
- Identification and assessment of potential pollutant streams and the treatment capacity of the existing stormwater system;
- Identification of opportunities for disconnection and provision of treatment for small contributing catchment areas localized (where this can be achieved as part of an overall landscaping and beautification plan that will add value to the airport property);
- Selection and development of potential treatment BMPs for use in retrofitting the existing stormwater system;

2.3 Site Visits and Field Assessments

A number of field visits were undertaken throughout the design phases of the project. Sediment sampling was undertaken at several locations within the stormwater system to determine the constituents of the deposited material and the feasibility of dredging and disposal options. Sediment sampling results, and a brief assessment of the implications are included in Appendix 3.

Some deficiencies were found in the original aerial topography of the site and this was determined to be insufficiently accurate for design purposes at a number of locations. Supplementary information was obtained through field survey by Plisga and Day surveyors of Bangor Maine. This information was used to refine the HydroCAD ® model and develop elevations for inlet and outlet structures.

2.4 Identification of Concept Design Solutions

Using the data gathered in the desktop study and during site visits and field assessments a number of concept design solutions were developed to address the key stressors that contribute to water quality impairments in the downstream receiving waters. The focus of the design effort was towards solutions that offer favorable cost:benefit ratios, utilize areas in critical need of maintenance and/or renovation, and modifications that offer benefits to the airport facility other than simply improvement to stormwater quality. Detailed explanations of the concept design development process are given in the later sections of this report.

2.5 Development of Final Design Solutions

A stakeholder meeting was held following the issue of the draft Concept Design Report. The design solutions developed for the report were presented to the stakeholders for review and discussion. A number of constructive comments were received both on the concept design options presented and on additional BMPs that could be added to the scope of improvement works. Following review and discussion by the stakeholders the concept design solutions were further developed and new approaches were added. These are presented in this report as the final design solutions.

Every effort has been made to promote a modular, or phased design so that the BMPs can be monitored and expanded as part of an adaptive approach to management of water quality and pollutant loads in the receiving water body. Priority is again given to approaches deemed to have the lowest cost benefit ratio (provide the greatest water quality benefit for the lowest cost). This will minimize initial capital investment and allow assessment of the effectiveness of BMP installations of different types and at different locations. Post-installation monitoring of water quality and peak flows will enable further work to be directed towards the most favorable improvement techniques.

The final designs include detailed drawings of proposed BMPs including layout geometry, grading, surface profiles, sections, inlet and outlet control structures, plantings, temporary works (including diversions and stabilization methods) and outline specifications, as required to obtain pricing and develop construction documents. Each of the design solutions is accompanied by a budget construction cost estimate, and a draft implementation order and schedule has been developed.

3 Summary of Project Phases

3.1 Desktop Study

The desktop study comprised a review of existing data on the airport stormwater system from a variety of sources. The incoming data has been analyzed, refined and summarized where possible to offer a complete and accurate basis for the development of design solutions. A summary of the data review tasks completed is given below.

3.1.1 Image Files

The available image files include several hundred scanned images of historical construction and record drawings from the facility that were provided by the City of Bangor Engineering Department. The drawings are indexed and labeled enabling specific areas of interest to be easily identified for inspection. The information included in these files indicates the original design intent of the stormwater infrastructure and gives an understanding of how the design was developed and modified throughout the life of the facility. Original design and construction elevations and dimensions can be compared with recent field measurements to estimate the level of sediment accumulation and the potential impact on system capacity and operation. In some cases modifications to the original system can be compared with the original design data to assess the impact of later work on the original design parameters.

3.1.2 Flow Data

Flow data from two monitoring stations within the Birch Stream catchment area was received from the City of Bangor Engineering Department. It is understood that this data has been collected as part of an ongoing flow monitoring study that is being undertaken by CES Inc. on behalf of the City of Bangor. The flow data gives some useful information on stream base flows and the operation of the stormwater system in response to rainfall events of differing magnitudes. For at least one event it was possible to compare the flow data to the recorded rainfall depth on that date, giving data against which the HydroCAD ® hydrologic model could be assessed. Temperature data were also recorded at the monitoring stations and these clearly show the thermal impacts to Birch Stream during the summer months. The full flow data comprises a report several pages long for each month. The most pertinent data has been compressed into a concise summary that is included in Appendix 2. Details of the storm event data and comparison with the hydrologic model predictions are included in the HydroCAD® Model Report in Appendix 1.

3.1.3 Water Quality Data

Water quality data and monitoring results were obtained from previous studies of the Birch Stream catchment and ongoing monitoring efforts by MEANG, as part of their Storm Water Pollution Prevention Plan (SWPPP). The MEANG monitoring efforts focused solely on COD measurements at the monitoring stations. Some additional parameters were measured during the earlier MEDEP monitoring efforts. A summary of the water quality data obtained from the MEANG monitoring, and an extract from the 2003 MEDEP report is included in Appendix 2.

Some additional water quality testing was undertaken subsequent to issue of the Concept Design Report. This testing was commissioned with the specific intent of comparing pollutant levels in the Domestic and International canal flow streams. Although by no means conclusive, the additional water quality testing suggested that dissolved oxygen and propylene glycol impacts are concentrated in the International Canal Stream and are not a significant issue in the Domestic Canal. The results of the additional testing are also included in Appendix 2 of this report.

3.1.4 Previous Studies and References

The following published studies of the airport stormwater system and the Birch Stream catchment were reviewed as part of the desktop study:

- Birch Stream Total Maximum Daily Load (TMDL) Report (Susanne Meidel, Partnership for Environmental Technology Education (PETE), Melissa Evers, Maine DEP, 09/04/2007);
- Urban Streams Nonpoint Source Assessments in Maine – Final Report – Chapter 3 Birch Stream in Bangor (PETE, Maine DEP, 2/16/2005);
- Preliminary Report on the Results of Biological Monitoring Activities Carried out on Birch Stream in Bangor, ME in Summer 2003 (Susanne Meidel, Partnership for Environmental Technology Education (PETE), Leon Tsomides, Maine DEP, 12/29/2003);
- Update Drainage Study Report for Bangor International Airport (Edwards and Kelcey, 2007);

In addition several references were reviewed for information pertinent to the treatment of deicing fluids and stormwater runoff from airport operations, and the design of stormwater management system that avoid the creation of nuisance wildlife habitat. These include:

- ESTCP Cost and Performance Report – Enhanced Biological Attenuation of Aircraft Deicing Fluid Runoff Using Constructed Wetlands (US Dept. of Defense, May 2004);
- Sub-surface flow wetlands to treat glycol-contaminated stormwater from aircraft de-icing operations, BATEA (Higgins, Dechaine, Minkel, Liner & Wallace, 2007);
- Canadian Soil Quality Guidelines for Propylene Glycol: Environmental and Human Health – Discussion Document (Canadian Council of Ministers of the Environment, 2007);
- Natural, Cost-Effective and Sustainable Alternatives for Treatment of Aircraft Deicing Fluid Waste (Castro, Davis and Erickson, 2004);
- FAA Advisory Circular – AC No. 150/5200-33A – Hazardous Wildlife Attractants on, or near Airports (July 27, 2004);
- Guidance for Developing a Stormwater Management Manual for Washington State: Mitigating Hazards Due to Wildlife Attractants at Airports (Herrera Environmental Consultants, Inc, July 12, 2007);

3.1.5 HydroCAD® Model Review

A HydroCad® model was produced for the airport stormwater system by Edwards and Kelcey in the 2007 Airport Drainage Study. The model was developed from a previous study that was used to support a State Permit Application for the airport development in 1991. It appears that some further work was done to improve the model in the Edwards and Kelcey study and verify the input data for feasibility level design assessments. In the course of this study the Edwards and Kelcey model input was checked for accuracy by comparing the data to design information from original plans and documents, field measurements and observations, and detailed topographic survey information. The model configuration was also assessed to evaluate how closely the hydraulic function of the stormwater system was represented. In general, the model was found to represent the stormwater system within the expected level of accuracy. However, a number of minor modifications and adjustments were made to the input parameters and node configurations in order to improve the accuracy of the representation, and to develop greater confidence in the simulation results so that the model can be used as a design tool moving forwards. A detailed description of the HydroCAD ® model review and adjustments made to the model parameters is included in Appendix 1.

3.1.6 Summary of Findings

The desktop study clarified many important facets of the design and operation of the current stormwater system that serves the Bangor Airport facility. The increased knowledge of the history and performance of the stormwater network has been essential to identifying key pollutant sources and stressors and to targeting Best Management Practices to areas where they will be most effective. A number of the key findings are listed below.

1. Extensive studies of water quality in Birch Stream indicate the presence of the following stressors in order of importance. Propylene Glycol, toxicants (this term is used to refer to DROs of uncertain origin, SVOCs, and high measured conductivity from unspecified sources), high peak flows, elevated water temperatures, elevated nutrient levels, presence of coliform bacteria. It should be noted that these may not all be related to the airport stormwater system.
2. It is apparent that there is adequate space within the extents of the existing stormwater system to develop BMPs that will offer more efficient and effective water quality treatment.
3. The depth of the existing underground collection infrastructure, the topography of the airport complex and the presence of ledge close to the ground surface at many locations present significant obstacles to the construction of new on-line detention and treatment structures.
4. The detention capacity within the system is under-utilized at many locations. This is evidenced by the relatively low water elevations and high flow-through rates observed in modeling of large storm events.
5. Accidental flow diversions have led to re-direction of flow from large contributing catchment areas. This has led to a significant increase in the amount of runoff directed to the main Detention Basin. The basin is no longer operating within the parameters for which it was designed.
6. There are clearly at least three major flow paths through the land side of the airport complex and these handle runoff of varying quality. Much of the runoff from de-icing aprons discharges to the International Canal System. The MEANG Ditch and the Domestic Canal system convey runoff from large impervious areas and are likely to contain more typical urban NPS pollutants.

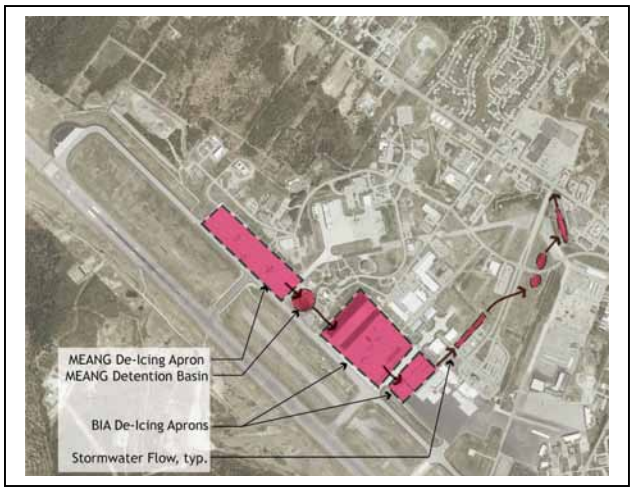


Figure 3 – Flow path of runoff from de-icing aprons

7. Subsurface flow engineered wetlands have been used successfully at many airport facilities for treatment of stormwater runoff contaminated with deicing fluids. The wetland treatment systems are significantly more effective in reducing pollutant loads when coupled with aeration.

8. The Domestic Canal system was originally designed as a flow-through channel system with a free outlet to the Union Street culvert. The primary function of the system was to efficiently convey large flows to the downstream receiving areas. Standing water within the channel and submersion of the incoming culverts was a condition created by the construction of the downstream Detention Basin.

9. The large areas of standing water within the existing stormwater system contribute to elevated summer temperatures, and hence low dissolved oxygen readings in downstream receiving waters.

10. A brief analysis of historic conditions on the airport property indicates that reducing peak flows at the head of Birch Stream to those experienced before development of the site in the early 20th century will be impractical for all large design storm events. Detention design efforts should focus on reducing current peak flows to the extent practical, particularly for the more frequent storm events (1", or less of precipitation).

11. There are a number of areas throughout the airport property where abandoned pavement structures remain in place. These areas offer significant potential for the removal, or minimization of runoff at source. The typical pavement sections shown in the Dow Air Force Base plans include 12"-19" of concrete pavement and a further 42"-50" of underdrained gravel base material. The base material itself provides a significant potential storage reservoir for runoff.

12. The City of Bangor has plans to divert some flows from the southeast corner of the Birch Stream catchment area towards Odlin Street, by installing a connecting culvert between the two drainage systems.

13. The City of Bangor Engineering Department has developed design plans to address ongoing sediment transport to the stormwater system from the City Department of Public Works (DPW) yard.

14. The main Detention Basin that serves the airport provides some degree of spill protection to Birch Stream and Kenduskeag Stream. In the event of a catastrophic oil spill event the capacity of the basin will provide containment.

15. The direction of excess runoff towards the north end of the main runway and Hermon Bog should only be considered if a free outlet can be provided that will not increase standing water at any location near the end of the runway.

16. A review of FAA directives and associated research indicates that particular attention must be paid to the design of airport stormwater systems in relation to the formation of nuisance wildlife habitat. Large tracts of open water serve as a significant attractant to waterfowl and should be avoided. Open water areas are particularly attractive when wide enough to offer security from land-based predators. Open banks and fringe areas limit potential refuge areas for predators and further enhance these areas as habitat for waterfowl.

17. The presence of significant numbers of waterfowl can contribute to elevated bacteria levels in the stormwater system and downstream receiving waters (Patterns and Sources of Fecal Coliform Bacteria in Three Streams in Virginia, 1999-2000, Hyer, Moyer)

3.2 Field Investigations

3.2.1 Sediment Sampling

Sediment sampling operations were undertaken at several locations throughout the airport stormwater system in order to categorize the constituents of accumulated sediments. Target locations were selected where sediment removal is required to maintain the existing stormwater system and where new, or improved BMPs are proposed. The samples were taken by MAI Environmental on November 5th, 2008 and sent for laboratory analysis. Results of the analysis were received on November 25, 2008. At all locations high levels of Diesel Range Organics (DROs) were measured in the sediment samples and this could potentially impact disposal options and costs for dredging and removing sediments from the stormwater system. At many locations sediment removal will be required, both to maintain the function of the stormwater system and to achieve the water quality improvements needed to allow Birch Stream to meet its attainment criteria. However, should disposal of sediments become costly the rate at which this task can be achieved will inevitably be impacted. Disposal options and costs for dredged sediments will be highly dependant on the approach taken by regulatory authorities to this task. It is strongly recommended that the City of Bangor meet with staff from State of Maine Department of Environmental Protection, Bureau of Remediation and Waste Management to discuss disposal and/or re-use options well in advance of planned sediment removal operations.

3.2.2 Survey Data

Following review of the existing topographic information for the site, several areas were identified where more accurate and detailed topographic information is required to proceed with BMP design. This was anticipated in the original proposal for the project as the previous survey information was obtained by an aerial flyover. Plisga and Day surveyors visited the site to obtain detailed information in areas of concern. These focused on inlet and outlet culvert elevations that were not accurately delineated and specific areas of topography, where elevations are critical to the final design.

3.2.3 Site Visits

Site visits were undertaken on three occasions prior to development of the conceptual design solutions. The visits were intended primarily to gain familiarity with the catchment area and the operation of the airport drainage system. An inspection was also made of the natural portion of Birch Stream to observe water quality and the physical nature of the stream channel. During these visits measurements of culverts, pipes and inlets were undertaken as well as checks on topographic information and estimates of sediment depth at a number of locations. The site visits confirmed some of the findings discussed in the Desktop Study portion of this report. Details of site visits and key findings are described in the Field Reports included in Appendix 4.

3.2.4 Summary of Findings

1. Water quality in the International Canal system from the exit of the underground culvert adjacent to the terminal building and through to the main Detention Basin is universally poor. A milky color was observed in the runoff detained in the ditch and swale structures and there is a noticeable odor emanating from the standing water. In addition, large algal mats are evident at the outlet to the detention basin and in the area immediately upstream of the Union Street culvert. The water quality in this system appears noticeably impaired when compared to both the Domestic Canal system and the MEANG ditch.

Photograph – Water quality in the International Canal system is poor

Photograph – Algal mats are evident downstream of the Detention Basin

2. Sediment accumulation is a significant problem within the Canal System. There are a number of locations within the existing system where it is evident that sediment accumulation has reached a point where it is reducing the conveyance capacity of the channels. The source of sedimentation is evident at some locations where upstream pipes and structures have collapsed. Areas where sediment removal is required as an essential maintenance activity can be targeted as locations for new stormwater BMPs in order to minimize the combined cost of rehabilitating the stormwater system.

Photograph – Sediment accumulation is a significant problem in areas of the channel system

Photograph - Sediment accumulation associated with pipe collapse

3. There is no easy access to many facets of the stormwater system making routine maintenance activities almost impossible. The Domestic Canal is the best example of this with a channel depth of approximately ten feet and side slopes that are near vertical in some places. Access to this area for sediment removal and other routine maintenance is impossible without specialized equipment. Newly proposed designs must include access to BMPs to allow maintenance activities. Areas where pipe replacement is necessary to rectify structural deficiencies offer a good opportunity for the creation of access ramps to the stormwater system.

Photograph – Domestic Canal showing limited maintenance access

4. A review of the geotechnical boring logs shown on original design drawings for the Dow Air Force Base indicated that ledge is present close to the surface at many locations on the airport property. Confirmation of this can be found along the Domestic Canal channel where exposed ledge is evident in the channel side slopes. The subsurface conditions, coupled with the depth of the existing upstream collection system present a significant challenge to expansion of the existing conveyance or detention structures. However, there is little evidence of high water levels within most areas of the system.

Photograph – Exposed ledge in side wall of Domestic Canal

5. Inlet and outlet protection is not provided a most culverts within the existing stormwater system. This has the potential to lead to significant blockages and flow disruptions. The main Detention Basin outlet comprises a horizontal subsurface orifice that has significant potential for blockage and failure. Adequate inlet and outlet protection will be designed throughout the system to protect newly proposed BMPs and prevent blockage and failure of culverts and outlets.

Photograph – Culverts with no inlet protection are prone to blockage and failure

6. The MEANG ditch is located in a considerable area of "dead space" within the airport complex. There are no apparent plans for development at this location. The ditch system expands into a large, well-grown open area at the downstream end. The outlet to this system comprises twin 24" diameter culverts under Griffin Road. The outlet culverts have collapsed at both ends and several sink holes along the line of the pipes are evidence of further collapse in other sections. It is evident that the culverts will need replacement, but also that the downstream end of the ditch system offers significant potential for greater detention and treatment of runoff from contributing areas.

Photograph – The downstream end of the MEANG ditch offers potential for greater detention and treatment.

7. The channel system downstream of the International Canal and the MEANG Ditch is in generally good condition. The channel is stable, well-shaded and has a relatively steep profile that encourages rapid, but non-erosive flow and aeration. Alterations to this channel system are not recommended, with the exception of installation of protection for an aerial sewer crossing (see below). Changes to the flow regime will need to be minimized using appropriate inlet and outlet protection and erosion control BMPs.

Photograph – Channel downstream of MEANG and the International Canal

8. The aerial sewer crossing within the lower channel section described above is supported on concrete columns that are in poor condition. Much of the pipe insulation has deteriorated and there are noticeable sags in the pipe between the supports. This pipe appears to be in imminent danger in its current condition. The addition of any flow to this channel through re-direction will place greater stress on the pipe supports. A protective berm should be considered at this location.

Photograph – Aerial sewer crossing

3.3 Development of Concept Design Solutions

Using the data gathered in the desktop study and during site visits and field assessments a number of concept design solutions were developed to address the key stressors that contribute to water quality impairments in the downstream receiving waters. These are documented in previous studies and include the presence of propylene glycol, toxicants, high peak flows, elevated water temperatures, low dissolved oxygen, and elevated nutrient levels. The concept design solutions were presented at a stakeholder meeting in order to field comments and input, and then further developed into the final design solutions presented later in this report.

The conceptual designs took two approaches to water quality treatment. Source removal and localized treatment approach was adopted where practical. This included the addition of pipe inlet treatment berms, small bioretention areas on the land-side of the airport complex, and the removal of large disused pavement areas throughout the airport property. Additional downstream, centralized treatment BMPs were proposed at locations within the existing stormwater system. These were designed to treat effluent from the upstream piped system that is too deep to intercept at source.

The water quality treatment approaches in the centralized BMPs were tailored according to the key pollutants found in each individual runoff stream in the open channel drainage system. The system, as described in previous sections comprises the International Canal System, the Domestic Canal System and the MEANG Ditch System. The development of conceptual designs for each system is described below.

3.3.1 International Canal System

The International Canal System receives runoff from all primary aircraft de-icing areas at the airport and the standing water within this system shows signs of significant impairment. The **key stressors** in the International Canal runoff stream are **de-icing fluid, sediment and thermal impacts**. Both BIA and MEANG have undertaken recent capital investment programs to address the capture and treatment of runoff at the de-icing aprons. However, due to overspray, wind spreading and shedding of excess fluid from aircraft, it is impossible to capture all of the de-icing fluid used, and some inevitably appears in stormwater runoff from these areas. Specific BMPs have been designed to treat this pollutant stream, including aeration and subsurface flow wetlands. Research and recent improvements at other airports including Buffalo Niagara International Airport (treatment wetlands), London Heathrow Airport (subsurface flow treatment wetlands) and Edmonton Airport (treatment wetlands) have been used as example approaches in developing design criteria for treatment of runoff impacted by de-icing fluid contamination. The new BMPs are proposed at locations where extensive maintenance to the stormwater system is required to rectify existing deficiencies, in order to reduce the net cost of the improvements. The construction work will include sediment removal, bank stabilization and the filling of large areas of open standing water with gravel and planting soil. These methods are designed to address sedimentation, minimize future erosion, and reduce available habitat for nuisance wildlife.

3.3.2 Domestic Canal System

The Domestic Canal System receives runoff form the large impervious areas of the main runway and taxiway, Army National Guard apron and the DPW yard. The **key stressors** in the Domestic Canal runoff stream are **thermal impacts, sedimentation and other general urban NPS pollutants** (as evidenced by high conductivity measurements). The key aim of the proposed changes to Domestic Canal is to reduce the area of standing water within the system and to improve the flow regime in the channel. In order to do this the water level in the Detention

Basin will need to be lowered by providing a new low-flow outlet and a new, narrow base flow channel will need to be created in the Domestic Canal. The areas to either side of the base flow channel will be constructed of a stabilized soil filter material that will be planted with wetland grasses. Transverse sediment berms will be provided at intervals along the channel to isolate sediment accumulation areas. Inlet grates will be provided at downstream culverts to protect against blockage and ease the operational maintenance burden. The new configuration will minimize the open area of water, reducing thermal impacts, and hence improving dissolved oxygen levels. Filtration of runoff will also be provided as will a reduction in sediment transport to downstream areas.

3.3.3 Detention Basin

The Detention Basin was constructed at the downstream end of the Domestic Canal System effectively damming the original open channel conveyance and backing up water throughout the system. The basin currently functions as a wet pond and although it is significantly under-sized for the contributing catchment area and offers minimal water quality benefits, it does serve an important spill control function. In addition to runoff from the airport facility the Detention Basin receives runoff from several commercial businesses along Maine Avenue and Union Street. The Detention Basin water quality is poor, turbidity is high, dissolved oxygen levels are low and the large expanse of unshaded open water promotes rapid seasonal heat gain. The basin also suffers from significant sedimentation and this is approaching a level where sediment removal will be needed to maintain the function of the structure. The **key stressors** in the Detention Basin runoff stream are therefore identified as **propylene glycol, toxicants**, **thermal impacts, and sedimentation.** The proposed Detention Basin BMPs are designed to address these stressors while maintaining the spill control function of the structure. A new low flow outlet will be constructed to reduce the standing water elevation and hence the area available for thermal gain. Further reduction in the open water area can be achieved using floating wetlands, of the type the airport has installed on a trial basis. The new outlet will be provided in the form of two linear gravel outlet berms. This will enable runoff from the one-inch design storm to drain slowly from the basin over an extended period. The existing outlets (at higher elevations) will remain to control discharges from higher intensity storm events. The base flow from the Domestic Canal system will continue to drain through the basin, via a narrow channel. The area surrounding the channel will be filled with soil filter media, stabilized and planted to establish a fringe wetland that will be partially inundated during storm events. Small pockets of deeper wetland can be created within the filled areas. The wetland plantings and soil media will contribute to water quality treatment through filtration and nutrient uptake. A sediment forebay will be constructed at each of the remaining inlets to the basin using large diameter stone enveloped in a wire gabion system to localize sediment accumulation and facilitate maintenance tasks.

3.3.4 MEANG Ditch

The MEANG Ditch System receives runoff from the impervious areas of the majority of the MEANG base and some areas of general urban development along Union Street. The **key stressors** in the MEANG Ditch runoff stream are **sedimentation and general urban NPS pollutants**. The proposals for this area of the system are straightforward and concentrate on the lower end and outlet structures. The existing outlet culverts are in a state of structural collapse and require replacement. In the course of this work it makes sense to adapt the outlet to the MEANG system to maximize the efficiency of the detention provided. Water quality treatment is provided by the construction of an underdrained filter bed at the lower end of the ditch. This drains to the new outlet structure and will remove the existing standing water and reduce thermal impacts in addition to providing treatment of suspended solids through filtration.

3.3.5 Localized Treatment BMPs

In addition to the BMPs proposed within the existing stormwater system, several localized treatment BMPs were developed to provide water quality treatment close to pollutant sources (particularly large impervious areas). The **key stressors** in these areas are **toxicants (including DROs, SVOCs, metals, nutrients, sediments)** commonly found in the runoff from highly impervious, urban surfaces. The BMPs designed to reduce levels of these pollutants, and to take some of the load from the BMPs within the stormwater system include Bioretention filters adjacent to Godfrey Boulevard and Taft Street, removal of abandoned impervious and paved surfaces throughout the airport complex, and the provision of local pipe outlet filters. The work being undertaken by the City Engineering Department to add inlet filters to the catch basins within the City of Bangor DPW yard will compliment these efforts, as will the plan to re-direct a minor drainage area at the south end of Maine Avenue.

3.3.6 Impacts on Water Quantity

Due to the significant impervious area on the airport complex, existing detention volumes will need to be maintained, or improved in order to improve the existing flow regime in the downstream receiving channel. Modifications to existing flow configurations, culverts and detention outlets under the proposed conditions (post-improvements) were assessed at the Concept Design stage using hydraulic and hydrologic modeling. This allowed opportunities to improve both water quality treatment and detention efficiency within existing structures to be identified. New and modified outlets are proposed at locations where they can contribute to improved detention efficiency and reduce thermal impacts to downstream receiving waters. The HydroCAD analysis of the existing and proposed system configurations at the Concept Design Phase demonstrate that a significant reduction in peak runoff can be achieved during design storm events. The results of the analysis are summarized in the table below.

Table 3.3.6 - Summary of Peak Runoff to Birch Stream Under Design Storm Conditions

Design Storm Event	Historical Catchment Model	Existing Conditions	**Proposed Conditions**	Reduction Over Existing	Increase Over Historical
One Inch	3	55	**29**	48%	755%
Two Inch	110	352	**271**	22%	146%
2-Year (2.7in)	268	616	**537**	11%	100%
10-Year (4.1in)	693	1205	**1039**	13%	50%
25-Year (4.8in)	936	1486	**1277**	13%	36%
100-Year (5.8in)	1303	1900	**1649**	13%	27%

Note:

All storms are 24-hour duration Type III SCS Unit Hydrograph Distribution events

Runoff values are given in cfs.

The table shows that the proposed Concept Design improvements have the potential to significantly improve the flow characteristics at the outlet to Birch Stream over current conditions, particularly during storm events with less than one inch of total rainfall. These events comprise 90% of all rain events in the northeast USA.

However, the reduced peak runoff values still represent a significant increase over historical (estimated pre-development) peak runoff rates. Therefore, while it is possible to significantly improve the flow regime with these improvements, restoring the stream to historical, or natural flow conditions is not considered feasible.

3.3.7 Maintenance and Inlet and Outlet Protection

The Concept Designs include BMPs that will improve the overall function of the stormwater system and provide greater quality and quantity treatment. The designs incorporate features that will facilitate routine maintenance of the system and allow access to the stormwater infrastructure where practical. These features include new inlet and outlet protection grates at culverts that will prevent undue blockages, transverse sediment berms aimed at isolating areas of sediment accumulation through the system, and maintenance ramps that will allow vehicular access to new BMPs. These provisions will not eliminate the need for periodic maintenance and some of the more sophisticated BMPs will require regular attention to ensure that they continue to function as designed. This will inevitably raise the maintenance workload at the facility, although it is hoped that the designs presented will minimize the burden of these tasks. A draft Stormwater Maintenance Program is included in Appendix 5.

3.3.8 Concept Design Solutions

A summary of the Concept Design Solutions was presented in the Concept Design Report – Draft, issued by SMRT in November 2008. The sketches and details of BMP configurations presented at the Concept Design stage are not included in this report to save unnecessary duplication. All of the Concept Design Solutions have been further developed to form the basis of the Final Design Solutions, which are presented in Section 4. A copy of the Concept Design Report summary presentation is included in Appendix 6.

3.4 Stakeholder Comments and Feedback

Upon completion of the concept design phase of the project a Concept Design Report was issued to the stakeholders and the ideas were presented at stakeholder meetings. The feedback from these meetings was generally positive and included a number of constructive comments and ideas for further development of the BMP designs. The comments received are summarized below.

- Concept Design Solution Number 2 - Detail of riprap inflow slope to new International Canal Outlet should be amended to show protection on the downstream side of the slope. (City Engineering)
- Concept Design Solution Number 9 - Pre-treatment should be added to the Subsurface Flow Wetland BMP to improve design life. (City Engineering)
- Concept Design Solution Number 7 - Detention Basin outlet should be modified to provide equivalent spill protection volume to existing condition. (City Engineering)
- Concept Design Solution Number 4 - Loam specification will have to be carefully worded to allow drainage to base gravel at areas of pavement removal. (City Engineering)
- Concept Design Solution Number 8 - The site adjacent to the downstream end of the MEANG Ditch on Griffin Road is a potential development site. The proposed design should be modified to allow this to remain a viable site. (City Economic Development)
- Concept Design Solution Number 5 - Further options should be presented at the Domestic Canal to better address toxic pollutants and elevated nutrients. (Maine DEP)
- Can oil spill detection alarms be added in the system to give early warning of pollution problems and minimize expensive cleanup requirements? (BIA)
- Is it possible to use solar/renewable power for the aeration systems? (BIA)
- The open ditch alongside the Helipad is a significant safety concern due to waterfowl attraction. Birds take off and land across the main runway. Several attempts have been made to keep birds away from this area, but all have failed. Suggest this area be enclosed, or drained. (BIA)

- The Detention Basin spill function must remain to prevent downstream pollution during potential catastrophic spill events. (BIA)
- Concern over maintenance burden that will result from the new BMPs. (BIA)
- Cost sharing formula should be developed for improvements in areas where outside parties contribute to stormwater runoff. (BIA)
- Concept Design Solution Number 1 should be top priority as it provides the first place to treat stormwater off the combined ANG and BIA ramps. (MEANG)
- Concept Design Solution Number 4 should occur before Solution Number 3. (MEANG)
- Concept Design Solution Number 7 is potentially complex and costly, but probably a good long-term project. (MEANG)
- Concept Design Solution Number 8 – MEANG is currently seeking ownership of the easterly portion of the site shown for Number 8. If acquired by MEANG some potential sole federal funding may be available for this project. (MEANG)
- Concept Design Solution Number 9 should be given a high priority. (MEANG)
- Concept Design Solution Number 10 is a good project but should identify point sources from UCB, ARNG, DPW, etc. (MEANG)

4 Design Solutions

4.1 Final Design Solutions and Budget Cost Estimates

Following presentation of the concept design solutions to the stakeholder group the verbal and written review comments summarized in the previous section of this report were used to develop final designs for the airport stormwater quality improvement strategy. The final solutions presented in this section are intended to form the basis for construction plans and documents for each of the improvements, or to offer sufficient guidance criteria for implementation under a design/build type arrangement. Many of the strategies are designed to be simple to implement and could be undertaken by the City Public Works Department with assistance from volunteer workforce programs where appropriate. Engineering guidance and oversight is recommended during implementation of the more complex BMPs such as the Subsurface Flow Wetlands, Bioretention cells and revisions to the major inlet and outlet structures.

Sufficient forward planning must be undertaken prior to implementing the final design solutions. Some of these must be constructed in sequence to avoid potentially detrimental side effects, such as increased flooding, or potential contamination of newly installed structures. Other solutions can be implemented independent of other work, and in a timeframe that suits budgetary and other constraints. Prioritization and implementation of the design solutions is discussed in the following section of this report. As is the case with construction within any active stormwater system, work should be tailored to seasons where storm events are least frequent and construction should be phased in a manner such that the system continues to serve the primary function of effectively draining the airfield and surrounding property without significant interruption. Where significant levels of nutrients are found within waterways, several studies have shown that sediment removal is most effective during the winter months. This should be considered particularly when phasing the work on the Domestic Canal and the Detention Basin.

Each design solution is accompanied by a budget cost estimate for the work. These estimates have been developed for recent pricing obtained for similar work, construction estimate publications, and in some cases extrapolations based on general experience. **Vaughn Thibodeau and Sons**, a General Contractor with headquarters in Bangor has assisted SMRT, Inc. in providing current, local pricing for a number of the construction materials used in the cost estimates. It should be noted that the one highly variable item that is common to many of the improvement schemes is the excavation and removal of existing sediments. Elevated levels of Diesel Range Organics (DROs) have been found in sediments at some locations within the stormwater system. Although the reported levels are not considered hazardous, the presence of contaminants in sediments can escalate the costs of removal and disposal. The disposal options for this material will vary greatly depending on actual measured levels of DROs (and any other contaminants) in the excavated material and the approach taken by regulatory authorities to the most appropriate methods of treatment and removal. The cost estimates have assumed that clean material will be encountered outside the existing stormwater system and that a premium will be paid for removal of sediments at locations where elevated DROs were found. The estimated premium that has been used is intended to be a realistic assessment of removal costs if the material can be blended and re-used, but may not cover the cost of more expensive disposal options. As stated in Section 3.2.1 of this report it is strongly recommended that City of Bangor staff meet with staff from Maine DEP, Bureau of Remediation and Waste Management at the earliest opportunity to discuss options for this material, so that more refined disposal costing can be obtained.

It should be noted that the Design Solutions on the following pages are not presented in a specific order of priority, or suggested implementation order. Implementation and Prioritization are covered in Section 5 of this report.

4.2 Additional Recommended Improvements

In addition to the solution options described in the previous section of this report, there are several additional measures that could be implemented to protect, or improve the watershed moving forward. Some of these may be considered in current and future watershed management planning efforts, or may be integrated into future master planning for the airport and surrounding area.

4.2.1 Aerial Sewer Crossing

During execution of the Stormwater Services project an aerial sewer crossing was observed at one of the major stormwater channels. The aerial sewer crossing is located within the lower channel section adjacent to the Telcom Drive development on Union Street, just west of the intersection with Godfrey Boulevard. The sewer pipe is supported on concrete columns that are in poor condition. Much of the pipe insulation has deteriorated and there are noticeable sags in the pipe between the supports. A collapse of the aerial sewer at this location would present a significant threat to downstream surface water quality. It is recommended that an engineering solution should be developed to improve and protect the sewer at this location. The solution could take the form of repairs to the support columns, pipe replacement or repair, sleeving, or construction of a transverse berm and culverts across the existing channel.

4.2.2 Oil Spill Monitoring and Detection Systems

Bangor International Airport is a full service domestic and international airport and serves both civilian and military aviation operations, including maintenance and fuelling. The nature of the facility operations present a risk for spills and leaks of fuels and oils. Spill Containment, Control and Countermeasures Plans (SPCC Plans) have been developed to minimize the risk of spills entering the stormwater system. However, given the historic use of the site and the level of investment in the stormwater system proposed in this report, it would be prudent to consider investment in a spill detection and monitoring system.

The Slick Sleuth™ optical spill, detection, monitoring and alarm system provides a comprehensive solution to early spill detection and hence allows rapid response to spill incidents that will enable swift isolation of impacted areas and minimize impacts to downstream infrastructure and receiving waters. The system is designed to optically detect the presence of sheens from above the water surface and can be deployed at a single location, or in a networked array. Options include solar powered remote units and reporting via radio, cellular, or satellite telemetry. More information on this system is available at www.SlickSleuth.com.

4.2.3 Road Condition Monitoring Systems

Several recent developments have been made in the field of electronic pavement condition monitoring. The implementation of these systems can lead to a dramatic reduction in salt and grit usage on road surfaces. Monitoring devices can either be vehicle, or roadside mounted to give real time data on road surface conditions. An **Advanced Road-Weather Information System (ARWIS)** deployed in Ontario resulted in salt use reductions of up to 29%. This type of source control will lead to a long-term reduction in road maintenance costs and could have a significant beneficial impact on surface water quality, reducing both the impacts of salt pollution and the sediment loading.

4.2.4 Street Sweeping and Catch Basin Maintenance

Enhanced seasonal street sweeping and the regular inspection and maintenance of catch basin sumps can also have a significant beneficial impact on surface water quality. The State of

Pennsylvania Stormwater BMP Manual estimates that removal rates of up to 85% TSS and P can be achieved with suitable implementation of street sweeping.

4.2.5 Asset Management Planning

Asset management planning (AMP) techniques can be used to efficiently direct maintenance resources to repair and replace infrastructure components before chronic conditions develop. This can lead to significant savings in overtime costs for emergency repairs and prevents deterioration of other connected system components. Typical stages in AMP implementation include mapping infrastructure and developing a database of component age and condition. Following compilation of this data a targeted plan for system upgrades can be developed and implemented. Such a plan could be developed for components of the airport stormwater and/or other utilities systems. This would allow a more proactive approach to be taken to system maintenance, rehabilitation and upgrades.

4.2.6 Airport Master Planning

The development of a Master Plan for future airport development would allow an integrated approach to stormwater management to be considered. This could include areas to be set aside for future stormwater treatment BMPs, reductions in existing pavement coverage to compensate for future development, realistic sizing of access roadway, parking and other infrastructure. It could also serve as a guide for the incorporation of Low Impact Development (LID) techniques to future development within the airport facility. These could include the use of pervious pavements for new development, or rehabilitation projects.

4.2.7 Formalization of Drainage Easements and Watershed Approaches

There are currently a number of commercial and institutional developments that contribute runoff directly to the airport stormwater system. It is our understanding that Bangor International Airport and/or the City of Bangor currently has no formal agreements to accept runoff from these entities. The solution recommendations identified in this report will entail a significant investment in the airport stormwater system. Given this, it would appear that the City should have some level of control over discharges into the stormwater system from other entities. Where these entities contribute to pollutant loads within the stormwater system, cost-sharing options should be investigated. Cost sharing could take the form of a stormwater utility for the catchment. A further stage of this type of approach could include the formation of a Watershed Protection District within the City Zoning Ordinance. This would allow the development of specific stormwater management regulations for new and re-development projects that contribute runoff to Birch Stream.

5 Prioritization and Implementation of Design Solutions

5.1 Prioritization

The design solutions presented in the previous section of this report represent a broad range of options aimed at improving the water quality treatment provided within the airport stormwater system. The project is part of a broader effort to improve the water quality and flow regime of discharges to the headwaters of Birch Stream such that the watercourse can meet State and federally mandated water quality attainment criteria. The implementation schedule for the improvements should therefore give priority to solutions that offer the greatest water quality benefit to the downstream watercourse.

Historic water quality assessment reports and the TMDL Study Report for Birch Stream appear to concur that the key stressors within the watershed and their level of importance are as follows.

- High Importance — Propylene glycol, toxic contaminants;
- Medium Importance — High peak flows, elevated water temperature, elevated nutrient levels.

Laboratory testing data and field observations indicate that it is chiefly the International Canal runoff stream that suffers from the presence of propylene glycol de-icing fluid, high measured BOD and consequent low dissolved oxygen levels (as well as the presence of elevated levels of other pollutants). Treating runoff from this runoff stream is therefore considered a high priority.

A number of the design solutions targeting this area will need to be implemented sequentially in order to avoid re-work, potential damage to newly installed BMPs and to avoid the potential for detriment impacts such as reduced hydraulic capacity and increased flood levels. The recommended order for improvements at this location is as follows:

1. Design Solution Number 3 – Re-grade International Canal;
2. Design Solution Number 2 – International Canal Outlet Structure;
3. Design Solution Number 1 – International Canal Aeration System;
4. Design Solution Number 9a – Swale Outlet Pipe Diversion;
5. Design Solution Number 9b – Subsurface Flow Wetland Cells.

It is important that 9a (outlet pipe diversion) is implemented before 9b so that rising water levels in the Detention Basin cannot create a backwater effect that will surcharge the new SSF Wetland cells. The SSF Wetland cells will need to be installed from the upstream end down to avoid sedimentation/contamination of installed cells.

Following the work in the International Canal the Detention Basin improvements will need to be implemented. This will enable the standing water elevation in the Domestic Canal system to be lowered and the work at this location to follow. The recommended order for improvements at this location is as follows:

1. Design Solution Number 7 – Detention Basin;
2. Design Solution 5a – Domestic Canal Improvements Phase I;
3. Design Solution 12a/12b – Helipad Ditch Improvements;
4. Design Solution 5b (if necessary) – Domestic Canal Improvements Phase II (Modular Wetland).

In addition to the aforementioned improvements that need to occur in a specified order, there are a number of Design Solutions that can be implemented independent of other work. These solutions are aimed at reducing the general non-point source pollutant load from impervious areas across the airport facility and the greater system catchment area and are as follows:

1. Design Solution 4 – Remove Existing Pavement. This can be undertaken in a phased manner with the phases to be determined by the availability of resources and financing.
2. Design Solution 6 – Godfrey Boulevard Bioretention. This work can also be constructed in phases, if desired. The Bioretention strips drain to two existing inlets and each portion of the work can be undertaken independently of the other.
3. Design Solution 8 – MEANG Ditch Improvements. The schedule for this work is not constrained by the need to complete other tasks and it should be afforded a high priority due to the structural condition of the existing outlet pipes from the ditch system.
4. Design Solution 10 – Taft Bioretention. This land is currently vacant and work could potentially begin after pre-construction subsurface investigation.
5. Design Solution 11 – Pipe Inlet Filter. These BMPs can be constructed at any time.

5.2 Implementation

The water quality treatment BMPs presented in this report are designed to form the basis of construction documents, or provide sufficient information to undertake construction under a design/build, or a supervised target cost/schedule of rates type arrangement. This flexible type of approach is recommended for work of this nature, as some of the construction parameters have not been fully investigated. As a result, some of the design solutions may need to be adapted to field conditions encountered during construction, and the quantities used to price the work may need to be revised accordingly. Perhaps the best example of this is the excavation, or dredging of existing sediments from the stormwater system. The estimated quantities for sediment removal are based on site observations and supplementary information from previous studies. The actual quantities of sediment encountered during execution of the work may differ significantly from the assumptions made. In addition, the nature and extent of any contamination present in the sediments has only been investigated to the extent needed to determine if contaminants can be expected in the course of the work. Further investigation at this stage is not considered viable and may cause undue disturbance to currently stable areas of the site. Should extensive contamination be uncovered during execution of the work, this could mandate a re-think of viable design approaches at these locations and/or raise the cost of material excavation and disposal.

Flexible approaches to implementation of the proposed designs will require proactive construction management and field supervision to control costs and ensure effective outcomes that meet both the design intent and owner expectations. It is recommended that qualified engineering supervision staff should be utilized throughout the construction work at the facility.

A number of the solution options are well-suited to the use of in-house labor and could be undertaken either partly, or wholly by the City Department of Public Works, if the resources are available. In addition, the latter stages of a number of the projects would be well-suited to the use of volunteer work groups. These groups would need to be well directed and supervised by City staff, but could potentially provide a viable alternative to paid contractors particularly for soil placement, hand grading and planting. Safety and liability concerns may limit the use of volunteer labor at earlier phases of some projects (excavation, dredging, work in active flow channels).

5.3 Performance Expectations

The solution BMPs area designed to address pollutant loading in current runoff from the facility. Many of the recommended stormwater management BMPs have a proven track record of pollutant removal and can be expected to achieve significant water quality improvements if installed in accordance with the designs. It should be expected that incremental water quality benefits will be realized throughout a phased approach to implementation of the improvements. However, it should be noted that the Bangor International Airport Facility has been the site of military and civilian airfield operations for over 80 years. During that period it is probable that there have been numerous documented and undocumented pollution incidents that could have impacted soils, sediments and subsurface deposits in the area of the facility. The facility has some recent history of spills and leaks from ambiguous sources and these may be related to historical activities at the site. Further evidence of historical impacts is available through the presence of elevated levels of Diesel Range Organics (DROs) in sediment samples taken from the stormwater management system. It is possible that, during construction of the proposed works historically impacted soils and sediments could be disturbed. The re-suspension of such materials could result in temporary and localized water quality impacts. These impacts can be expected to diminish as the newly disturbed areas are stabilized and begin to perform their design function, and with adequate construction controls the impacts to the receiving waters should be minimal.

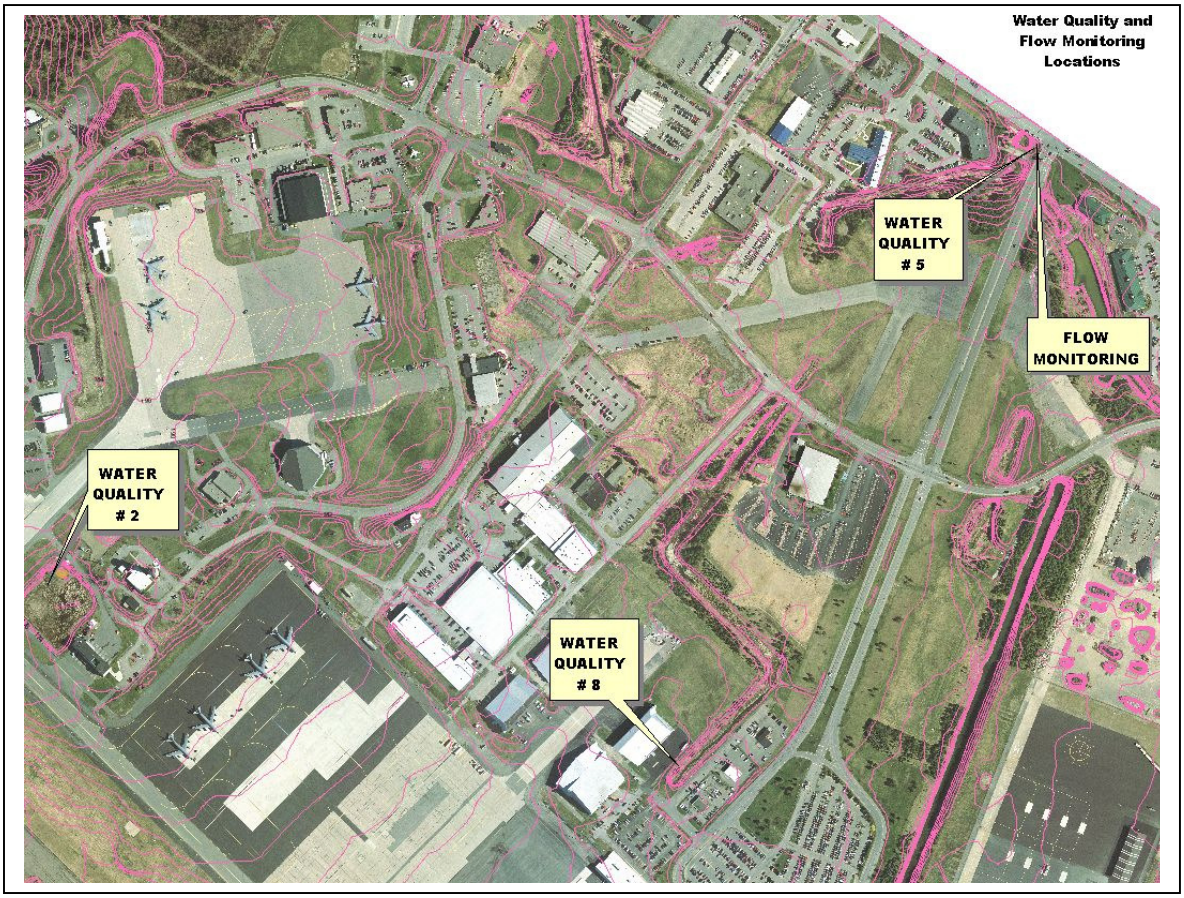
Several water quality parameters are currently measured at the Union Street culvert and at other locations within the airport stormwater system. Continuation of this testing regimen will give valuable data for comparing pre-implementation and post-implementation water quality for each of the BMP installations. The data gathered will be used to assess the pollutant removal performance of the installed BMPs and indicate the best approaches for future implementation. It is hoped that the results of the future water quality monitoring will show a steady improvement in dissolved oxygen, reductions in glycol, nutrient, toxicant and thermal pollution levels at the downstream end of the airport stormwater system. This will demonstrate progress towards achivement of the water quality goals in the Birch Stream catchment area.

The Bangor International Airport facility dominates the upper reaches of the Birch Stream watershed. However, it should be recognized that the airport is not the only source of urban pollution to the headwaters of the stream, and significant improvements to water quality will require additional work in other areas of the Birch Stream catchment. The history of poor water quality in Birch Stream over a period of decades rather than years will likely have caused a build up of residual pollutants in the sediments associated with the natural watercourse. It would therefore, be unrealistic to expect the ecology of the stream to recover rapidly, even after significant improvements to the contributing water quality. The natural processes of sediment re-suspension, transport and replacement will gradually reduce the levels of residual pollutants in the watercourse and lead to a steady improvement in water quality. These incremental improvements should be measurable through continued assessment of water quality, water quantity and biological activity in Birch Stream over years to come.

In summary, implementation of the design solutions described in this report can be expected to produce a measurable improvement in water quality at the downstream end of the airport stormwater system. The proposed improvements are designed to be incorporated into a wider strategic watershed management effort that will lead to the recovery of Birch Stream and the attainment of “Class B” water quality criteria, as required by State and Federal regulations.

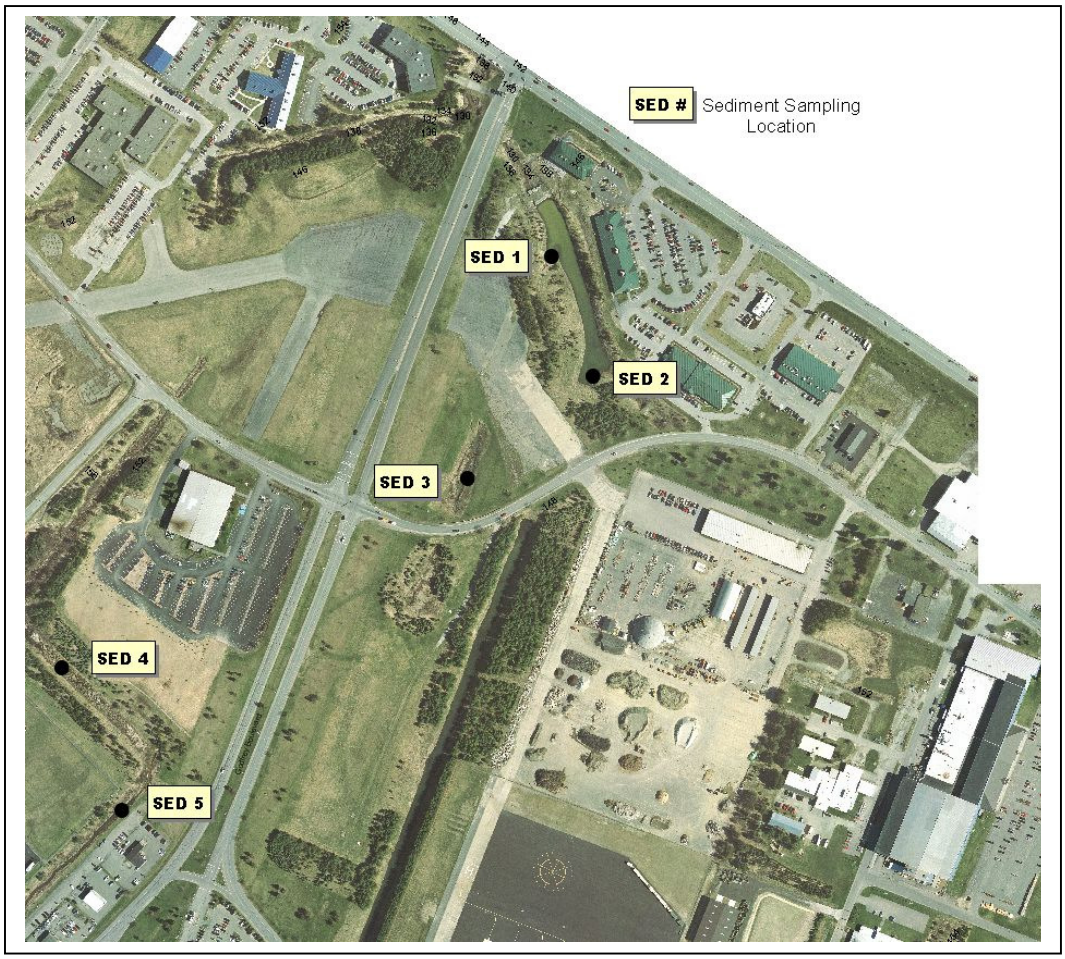
Appendix 1 – HydroCAD® Model Report

Appendix 2 – Water Quality and Flow Monitoring Data Summaries



Appendix 2 – Supplementary Water Quality Analysis – December 2008

Appendix 3 – Sediment Sampling Results



Appendix 4 – Field Reports and Meeting Minutes

Appendix 5 – Stormwater Maintenance Schedule

Appendix 6 – Concept Design Report Presentation

Appendix 7 – Aeration and Oil Detection Product Information