The development of a shoreline oil spill R&D program for diluted bitumen on marine shorelines
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Abstract
There is a concern that an accidental spill of the Canadian oil sands diluted bitumen, condensate and/or synthetic crude could come into contact with the Canadian marine shorelines. While the dispersal and weathering processes of crude and fuel oils are relatively well known, the fate, behavior and countermeasure of dilbit spills and its components are less directly understood. There is additional uncertainty as to the fate of spilled dilbit if it were to reach any type of shoreline. Recently there have been focused oil spill R&D studies on Canadian oil sands diluted bitumen (dilbit) and its components by the Government of Canada.

The Emergencies Science and Technology Section, Environment Canada has begun a 3 year R&D program to examine several specific topics related to the environmental impact and detection of diluted bitumen on marine shorelines typical of those found in Northern British Columbia. The new knowledge derived from the R&D studies will be used to develop operational guidance tools to provide spill response personnel with technical support for decisions regarding shoreline treatment options.

This paper reports the results from the 2013 and 2014 field campaign and from the testing of new scientific instruments to detect hydrocarbons in the column water. This includes information about the characteristics of the shoreline and the potential for the penetration of the dilbit into the different shorelines types as well as a statistical overview from the aerial shoreline survey of the Douglas Channel in northern British Columbia.

1 Introduction
In Canada, there is significant resource development in the oil sands regions of Northern Alberta. The Canadian oil sands contain the world’s third-largest oil reserves after Saudi Arabia and Venezuela (Alberta Energy, 2011). The transportation of diluted bitumen (dilbit) has become an important industry for Canada and the quantities transported will be considerable in short term by pipeline, marine tanker and rail. Recently, the first oil sands bitumen tanker left the Port of Sorel in Quebec, Canada, last September for the Gulf of Mexico and another one left in October for the Europe (CBC, 2014). In order to transport bitumen by pipeline, industry needs to add diluents like condensate and/or synthetic crude to reduce the viscosity to allow it to flow (Environment Canada, 2013). Concurrent with this development, there is a concern that an accidental spill of oil sands diluted bitumen and its component could come into contact with marine shorelines, freshwater lakes and river shorelines. Over the past three decades studies on the fate, behaviour and weathering processes of crude and fuel oils have greatly improved the collective knowledge and understanding of a potential oil spill, there have not been any major focused oil spill studies on oil sands diluted bitumen and its components. To address these knowledge gaps and concerns raised by these uncertainties, the Government of Canada announced the World Class Tanker Safety System on March 18, 2013. Along with a number of tanker safety measures under this program, the Minister of Natural Resources, announced that the government will conduct scientific research on non-conventional petroleum products, such as diluted bitumen, to enhance the understanding of these substances and how they behave when spilled in the marine environment (Transport Canada, 2013). Between 2013 and 2016, the Emergencies Science and Technology Section (ESTS), will assess baseline environmental scientific information on selected Northern British Columbia shorelines as well as study the fate, behaviour and cleanup of the non-conventional dilbit products on different types of shorelines and under various conditions. The objective is to deliver both operational guidance and scientific information that is legally defensible and credible to provide spill response teams with more informed technical support for decisions regarding shoreline treatment options. As an initial step in these shoreline studies, the first two years were used to study the local environment of Northern British
Columbia in order to address knowledge gaps related to the geology, the geomorphology as well as the baseline chemical data in the sediment. This paper will focus on the geology and the geomorphology data, while the chemical data will be covered in the Hollebone et al (2015) paper presented at Interspill 2015. Field campaigns were necessary to access many sites and to evaluate the sensitivity of the environment in the Northern of British Columbia. The results of the field campaigns are currently being used in a concurrent laboratory meso-scale study on the fate and behavior of the dilbit in different simulated shoreline substrates representative of the real environment.

2 Study Sites

This shoreline research study sites have and will continue to focus on the Northern Regions of British Columbia (BC) (Figure 1). The Douglas Channel is one of the principal inlets in the BC coast. From the Hecate Strait, there are about 140 km of waterways along the Douglas Channel. This represents one of the potential corridors that could be used by tankers to transport the diluted bitumen and condensate (Environment Canada, 2013). This is currently a busy shipping artery with Rio Tinto Alcan already established in Kitimat along with proposed liquefied natural gas (LNG) projects and a port where construction is already underway. The Douglas Channel and surrounding area are rich in biodiversity. The map in Figure 2 illustrates part of the channel along with the associated sensitivity resources. This map was created with the geographical information system known as the Environmental Emergencies Mapping System (EEMAP). The data represents the sensitive resources that need to be protected during an oil spill.

There are three important First Nation communities along the Douglas Channel; specifically Gitga’at, Haisla and Gitxaala communities. All three First Nations have territory that will be involved in the studies. A large number of traditional sites and protected area exist in this region.

During the first two field campaigns, the field surveys covered different parts of the Douglas channel. In September 2013, the northeastern part of the Douglas Channel was covered by the helicopter aerial survey (Figure 3). In 2014, the southwestern part of the Douglas Channel was covered again by helicopter aerial survey (Figure 3) and also, five sites were surveyed by ground survey (Figure 4) along the northeastern part of the channel.
Figure 1 – Location of study sites: Northern British Columbia.

Figure 2 – A sample of the sensitivity mapping in the Douglas and Grenville channels.
Figure 3 – Map of the two surveys in helicopter in 2013 and 2014 in the Douglas Channel.

Figure 4 – Map of the five sites surveyed in 2014.
3 Field Campaigns

In order to fulfill the requirements that Environment Canada and the Government of Canada established in 2013 to be a World Class System, we needed to go to the field to have a better knowledge of the shoreline. There is a pre-segmentation of the shoreline that was done by the Ministry of Environment, British-Columbia, early in 90’s. As such, the objective of the aerial survey and ground survey was to update the data from the 1990s and reconfirm the pre-segmentation. The shoreline is a dynamic environment and it can undergo many changes after more than 20 years.

The methodology developed by Environment Canada for the aerial helicopter surveys is to fly at low altitude to capture shoreline video and audio commentary of the characteristics of the shorelines and also, to identify the sensitive resources along the channels. A high-definition video camera is flown at elevations of about 300 to 400 feet with a flight speed between 70 to 80 knots. The goal is to record a wide angle view of the shoreline. The video is geo-tagged using a VMS 300 video mapping system (Red Hen Systems Inc., 2003) combined with a nanoFlash recorder (Convergent Design, 2013). A detailed description of the methodology can be found in the reference by Wynja (Wynja et al, 2013).

Two surveys were done in September 2013 and in July 2014 (Figure 3). The National Environmental Emergency Center (NEEC), the National Wildlife Research Center (NWRC) and Emergency Science and Technology Section (ESTS) of Environment Canada were part of the aerial helicopter survey team.

During the second field campaign in July 2014, a team of experts carried out a ground survey on five sites in the northeastern part of the Douglas channel (Figure 4). The Port of Kitimat, Bish Cove Bay, Emsley Cove Bay, Markland Point Bay and the Delta portion of the Kitimat River were the sites. Each of those sites had different types of shoreline and different geological characteristics. The team of experts was composed of two people from the Department of Fisheries and Oceans (DFO), four people from the ESTS and one person from Canadian Wildlife Section (CWS) from Environment Canada. The logistic support and boat was contributed by Western Canada Marine Response Corporation (WCMRC) from Prince Rupert, British Columbia office. An important feature was all these researchers carried out their studies concurrently providing an inter-disciplinary result or “big picture”. The goal of the ground survey was to undertake a Pre-SCAT survey, to identify the depth of each layer of the sediment down to the water table, to evaluate the slope and to take samples of sediments on the shoreline in different intertidal zones for post survey laboratory analysis.

ESTS has also deployed the C3 fluorometer submersible instrument into the column water of the northeastern part of the Douglas Channel. It was a part of our project which is intent to develop methods and to have the necessary tools to detect hydrocarbons in the column water. The C3 test sites included the bays close to the Kitimat Port and in front of the Markland point.

4 Results

Pre-SCAT survey

The first result of this study is the segmentation of the shoreline. The entire Douglas channel shoreline and the islands were processed and currently have been separated into segments. This includes a description of the substrate, description of the form of the shoreline and other characteristics. The segmentation began at the upper-tidal zone. The initial step was to divide the coast into working units called segments within which the shoreline character was relatively homogeneous in terms of physical features and sediment type (Owens, 2000). This segmentation is the first tool used by the Responsible Party and the SCAT team during an oil spill to evaluate the contamination of the shoreline and to help for the cleanup. The Figure 3 displays the entire segmentation and the helicopter. Those results were integrated in a GIS Web Mapping system by NWRC, named: Kitimat planning tool. Environment Canada oil spill experts are able to see the segmentation, the classification of the type of shoreline for each segment and their information, the pictures of each segment and also the video. Information is available through Environment Canada for preparedness and response activities. As mentioned earlier, the
segmentation helps to know what kind of substrates is found in the Douglas Channel and to choose the type of shoreline the ground survey team would visit. Kitimat Port, Bish Cove, Emsley Point, Markland Point and the Kitimat River Delta were surveyed. Our data showed that each site has different types of shoreline with different substrates including the following: mixed sediment beach, sand beach, sand flat, boulder beach, marsh and rock cliff with biological features. Samples of each substrate were collected and analyzed to define the grain size at each site. The analysis was done by the ISMER laboratory at the "Université du Québec à Rimouski". The Figure 5 shows the results of each sample.

Figure 5 – Percentages of gravel (> 2mm), sand (63-2000 µm), silt (2-63 µm) and clay (< 2 µm).

The results show that there is a large quantity of fine sediment in the beach. Even when there is boulder beach the data shows there is fine sediment under the boulders. Another element is the biological feature on the surface of the substrates. In the lower intertidal zone, fine sediment is covered by vegetation such as eelgrass or aquatic plants. Also, *fucus sp.*, barnacles and mussels are presents in large quantity on boulder (Figure 6). Almost all the rock cliff is covered by bioband (Figure 7), which is an observed coastal species assemblage with characteristic colors and across-shore elevation (Coastal and Ocean Resources, 2005). On this picture, the black band is *vericaria sp.*, the white band is barnacles and
the green band is *fucus sp.* All those data will be important for the next experiment to calculate the penetration but also the retention of the dilbit in the substrate.

Figure 6 – Example of *fucus sp.*, barnacles and mussels on a boulder.

Figure 7 – Example of biobands on rock cliff.

All this data will help for the final phase of the project which is a meso-scale laboratory study to assess the penetration and retention of the dilbit on or in different substrates. This next step will take real sample from the field and test the penetration and the retention of the dilbit in laboratory. The goal will be to measure the penetration and to compare with a well-known hydrocarbon. The Cold Lake Blend (CLB) and the Access Western Blend (AWB) are the two dilbits that will be used. We will also test Bunker C and IFO 180 in the same time. The viscosity of the bunker C is comparative with CLB and the viscosity of the IFO 180 with AWB. The private research company named Coastal and Oceans Resources Inc. will develop the methodology with Environment Canada and the studies will be carried out at their research facility on Vancouver Island, British-Columbia.

**C3 submersible fluorometer**

During the field campaign in July 2014, a second objective was to deploy the new C3™ submersible fluorometer (http://www.turnerdesigns.com/products/submersible-fluorometer/c3-submersible-fluorometer) from a vessel and try for the first time using this tool in a real environment. The C3 is a tool that can be used during an oil spill to monitor the contamination on a shoreline as well as in the water column. The first deployment was done at the northeast section of the Douglas Channel, close
to the Kitimat port. The team on the vessel evaluated the angle of the C3, the depth of the C3 in the water, the tow speed of the vessel and if the sensor can detect and record data. Figure 8 shows the deployment of the C3 over the vessel by a crane in the water.

![Figure 8 – Deployment of the C3\textsuperscript{TM} submersible fluorometer in the Douglas Channel.](image)

The results of this first step with the C3 were encouraging and since this time, ESTS in partnership with NWRC developed new software to join a map with the data with the track of the vessel. The next trial will be to test the new software in the field and to try again new angle and speed. WCMRC in British Columbia was the partner to supply logistics and the vessel.

5 Conclusion

A series of field studies have been undertaken. The information has provided baseline data on the type, characteristics and chemical composition of shorelines in Northern British Columbia. As well, the information is being incorporated into meso-scale laboratory experiments that address knowledge gaps on the penetration and adhesion of dilbit on a simulated shoreline environment typical of this area of British Columbia. In the event of an oil spill, the results of this research will be critical to oil spill response decision-makers to understand the fate and behavior of dilbit on shorelines and to help to determine the endpoints of a shoreline cleanup.

6 References


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