Peace River Project Water Use Plan

Williston Dust Control Trial/Williston Dust Control Monitoring

Reference: GMSWORKS #21 / GMSMON #18


Study Period: January 1 to December 31, 2008

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EXECUTIVE SUMMARY

Tillage Experiment

Each year the draw down of the Williston Reservoir for the production of hydro electric power results in the exposure of approximately 10,000 hectares of wide flat beaches with surfaces comprised predominantly of fine-grained sediments. On exposure in the spring, these sediments are prone to deflation by wind, resulting in large dust storms. There is need to design, test, and implement a dust mitigation program to decrease atmospheric dust concentrations to acceptable levels.

The authors of this report proposed that tillage to roughen the beach by lifting silt and clay from below the soil surface would likely provide effective dust mitigation by trapping saltating soil particles. In May 2008, a field trial was initiated at Omineca Flats beach on the Williston Reservoir as part of the Dust Controls Trials project designed to assess the most effective tillage technique to reduce dust emissions and sand transport on exposed beaches.

A replicated experiment was designed to test two tillage implements, the twisted-point chisel and lister plow, to determine their effectiveness in providing durable roughness on Williston beaches. Omineca Flats Beach was selected as the site for the 2008 tillage experiment due its elevation and accessibility by road. As a relatively “high” beach, Omineca opens earlier and stays open longer than some other beaches, thus extending the length of the dust season.

Upon arrival at Omineca beach on May 13, we found the site to be unsuitable due to numerous exposed tree stumps that prevented establish a statistically valid field experiment due to lack of adequate space. With no other alternative, we modified the experiment by eliminating the required “buffer strips” between treatments.

Visual observation of tillage plots indicated that both the twisted-point chisel and lister plow were effective in trapping soil sediment. Neither implement was effective in deep sand pockets where silt and clay could not be brought to the surface. The twisted-point chisel proved to be the more durable of the two implements for Williston conditions because it has two flex points whereas the lister plow is of ridged design. Although statistically valid field data were not obtained from the tillage experiment in 2008, we did gain confidence that tillage is an effective method to control blowing dust from beaches.

The authors and BC Hydro personnel visited several Williston beaches by helicopter and crew boat in June 2008. Davis Flats North beach was selected for the 2009 tillage experiments. Only the twisted-point chisel will be used in the main tillage experiment in 2009. An additional experiment will be established in 2009 to determine whether the entire beach area needs to be tilled to control blowing dust or whether tilled and non-tilled alternating strips will be adequate. The new study is hereafter called the “spacing experiment”. Both the twisted-point chisel and lister plow will be used in the spacing experiment.

Regional Air Quality

As part of the Dust Control Monitoring Program, monitoring of regional air quality around Williston Reservoir was conducted at six locations during the 2008 dust season using Partisol
Dichotomous Aerosol Air Samplers. The locations of the monitors were Omineca, Pet Toy, Tsey Keh, High Point, Middle Creek North, and Lafferty. Five of the sites were on exposed beaches and one site (High Point) was located in a forest clearing well above the Reservoir. PM10 and PM 2.5 concentrations were measured at all sites.

In general, PM 10 and PM 2.5 concentrations were very low. In only two one-hour periods did the PM 2.5 exceed 25 μg/m³. Most sites had several one-hour average PM10 concentrations above 50 mg/m³. It is likely that only one dust event at one monitoring location would have exceeded the proposed Canada Wide Standard for PM10 if the hourly data were averaged over 24 hours. Regional air quality will continue to be monitored at the same locations in 2009, except that the Omineca site will be moved to Davis Flats North.

1.0 INTRODUCTION

Williston Reservoir in northern British Columbia was created when BC Hydro constructed Bennett Dam on the Peace River in 1968 to generate hydroelectric power. Williston Reservoir is the largest body of freshwater in British Columbia with a surface area of 1775 km² and a shoreline of 1770 km. When reservoir levels are at low pool in the spring, 10,000 ha of beach is exposed. High winds of > 20 km/h cause dust storms from exposed beaches that impacts visibility and air quality in Tsay Key village located at the northern tip of the reservoir. With funding and coordination by BC Hydro, a 3-year field research project was initiated in 2008 to: (i) evaluate the effectiveness of two tillage practices to mitigate dust from beaches (Dust Control Trials), and (ii) conduct regional dust monitoring at seven sites surrounding Williston Reservoir. The tactic for the tillage is to bring silt-clay soil from the subsurface to the surface to provide durable roughness. The monitoring program attempts to address the following:

1.1 Key Management Question

The overall management question for the Dust Control Monitoring Program is:

- What is the impact of dust mitigation treatments on aeolian dust emission from the Finlay Reach of Williston Reservoir?

The Dust Control Monitoring Program was designed to provide data to measure the efficacy of the mitigation measures (including the Dust Control Trials) in the Finlay Reach.

1.2 Management Study Hypothesis

The primary hypothesis being tested in this study is that:

- Dust mitigation measures carried out pursuant to the BC Hydro/FNs Williston Dust Mitigation Program (including measures carried out as part of the Dust Control Trials) significantly reduce the emission of wind-blown dust from the Williston Reservoir drawdown zone in the Finlay Reach.

1.3 Objectives and Scope

The objectives of the monitoring program will address the management question indicated above by collecting the data necessary to draw inferences and to test the above hypothesis. In addition, the monitoring program will:
• Provide long-term data on airborne particulate matter concentrations in the upper Finlay Reach air shed; and
• Evaluate the effectiveness of dust mitigation procedures including tillage, irrigation as well as vegetation and wetland rehabilitation.

2.0 MATERIALS AND METHODS

2.1. Tillage Experiment
2.1.1 Site selection, experimental design, and treatments
   In November 2007, scaled maps of Williston Reservoir were used to determine that Omineca Beach contained adequate land area for the tillage experiment that would cover 75 hectares. Upon arrival at the site on May 13, it was discovered that Omineca Beach was unsuitable for the tillage experiment due to a large number of tree stumps that covered much of the beach area. There was not adequate room on the beach to establish the experiment as planned. Due to lack of space, we forced to forego the 100-meter-wide buffer strips between each of the treatments. In many cases, we ended up using the check treatment as the buffer strip between the twisted-point chisel and lister plow tillage treatments. This was highly unsatisfactory because the wind erosion/particulate monitoring instrumentation for the check treatment could not be obtained due to the lack of buffer strips.

   The configuration of the treatment areas consisted of five Blocks distributed from north to south along Omineca beach (Fig.1 and 2). Individual plots were 250 m long by 100 m wide. There were three treatments: (i) tillage with a twisted-point chisel implement (Fig. 3a, Fig. 4a)), (ii) tillage with lister plow implement (Fig 3b, Fig. 4b.), and (iii) a control (i.e., no tillage). A 100-m-wide buffer strip was needed between each of the three treatments, however, this was not possible due to lack of adequate beach area.
Fig. 1. Layout of the tillage experiment on Omineca beach. Each plot is 250 meters long and 100 meters wide. Figure is not to scale. Note the lack of buffer strips between all individual treatments. Buffer strips between all treatments could not be established due to lack of adequate space on the beach.
Fig. 2. Tillage experiment on Omineca beach looking north from Block E.

Fig. 3. Shanks and points of the two tillage implements used in the experiment are (a) twisted-point chisel and (b) lister plow.

Fig. 4. Roughness produced by lifting silt and/or clay soil to the soil surface with the (a) twisted-point chisel and (b) lister plow.
2.1.2 Instrumentation

In order to assess the effectiveness of the tillage treatments in reducing sand transport and dust emissions, each plot was instrumented on the northerly and southerly sides (upwind and downwind) along the dominant wind direction. On each side of the plots 3 BSNE trap arrays (Custom Products Ltd) and a single PM10 E-Sampler (Met One Ltd) were installed to measure sand and dust transport and PM10 dust concentrations.

One BSNE array and an E-Sampler were installed along the centerline of the plot (Fig. 5) taking care to ensure that E-sampler did not interfere with the sampling efficiency of the BSNE array. Two additional BSNE arrays were placed 1/4 of the distance of the plot width to either side of the central BSNE array. This spacing was implemented in order to reduce the possibility of sediment being collected in the traps that originated outside the sampling area when wind directions were not orthogonal to the plots.

In addition to the BSNE and E-Samplers, three 3-m-tall meteorological towers were located along the beach at the easterly inland edges of Blocks A, C and D to provide wind speed, wind direction, temperature, humidity and precipitation throughout the study period (Fig. 6).

Fig. 5. A BSNE array and PM10 E-Sampler located along the enter line on the upwind edge of twisted-point chisel plot.
2.2 Regional air quality

Regional air quality monitoring around Williston Reservoir was carried out at six locations using Partisol Dichotomous Aerosol Air Samplers (Model 2025). The locations of the monitors are shown in Fig. 7.

The sites were selected to provide representative dust conditions around the reservoir. Five of the sites were located on exposed beaches at relatively low elevations (Table 1). In contrast, the High Point site was located across the reservoir in a forest clearing well above the beach at 1096 m.

At each site PM10, PM 2.5, wind speed, wind direction, and temperature were measured (24-hour average). The instrumentation in the regional air monitoring program is shown in Fig. 8.
Fig. 8. Representative upwind and downwind PM10 dust concentrations for the three surface treatments.

Table 1. Coordinates and elevations of the regional dust monitoring sites

<table>
<thead>
<tr>
<th>Site</th>
<th>Longitude</th>
<th>Latitude</th>
<th>Elevation(m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsay Keh</td>
<td>124 57' 41.1&quot; W</td>
<td>56 53' 18.5&quot; N</td>
<td>672</td>
</tr>
<tr>
<td>High Point</td>
<td>124 50' 20.7&quot; W</td>
<td>56 51' 24.4&quot; N</td>
<td>1096</td>
</tr>
<tr>
<td>Middle Creek North</td>
<td>124 37' 20.9&quot; W</td>
<td>56 37' 45.9&quot; N</td>
<td>675</td>
</tr>
<tr>
<td>Pete Toy</td>
<td>124 30' 58.9&quot; W</td>
<td>56 26' 19.6&quot; N</td>
<td>674</td>
</tr>
<tr>
<td>Laffery</td>
<td>124 21' 24.7&quot; W</td>
<td>56 20' 43.7&quot; N</td>
<td>667</td>
</tr>
<tr>
<td>Ominica</td>
<td>124 10' 3.8&quot; W</td>
<td>56 6' 47.4&quot; N</td>
<td>670</td>
</tr>
</tbody>
</table>
3.0 RESULTS AND DISCUSSION

3.1 Tillage experiment
3.1.1 Tillage effectiveness

Both the twisted-point chisel and the lister plow tillage implements provided adequate surface roughness to trap eroding sediment when silt and/or clay could be brought to the soil surface (Fig. 3). Of the two implements, the lister plow appears to provide the rougher surface. Neither implement was effective in deep sand pockets. The existence of deep sand pockets was not visually apparent as some sand overlies the silt/clay layer on most of the beach area.

Both tillage implements were damaged on numerous occasions as a result of hitting tree stumps and buried roots that were not visible from the surface. The twisted-point chisel implement is equipped with a recoil spring on each shank and the shank itself has some flex (Fig. 3a). This allowed the twisted-point chisel implement to better handle beach debris with less equipment damage compared to the fixed-shank (i.e., no flex) lister plow (Fig. 3b).

Visual observations indicate that both the lister plow and twisted-point chisel implements effectively reduced sand transport during wind events by reducing the near surface wind speed because of the increased surface roughness and by the trapping of sediment in the furrows (Fig. 9). It appears that the traction requirements to pull the 8.5-meter-wide tillage implements on Williston beaches was overestimated and that crawler-type tractors are likely unnecessary. All reports from Tsay Keh tractor drivers (who tilled several hundred hectares of beach) indicate that 4WD wheel tractors with 180+ horsepower provide adequate power and traction.

![Fig. 9. Trapped sediment on the upwind edge of a twisted-point chisel plot. Trapping of sand reduces the abrasive action of the saltating sand that ejects dust into the air stream.](image)

3.1.2 Instrumentation

The BSNE samplers collected sand and coarse dust at four heights from 0.1 to 1.15 m above the surface. Total flux of sediment is computed by integrating with height the mass collected in the 4 traps. Although sediment fluxes varied greatly from storm to storm and from plot to plot, on average there was a very consistent pattern.

To assess the effectiveness of the three tillage treatments the ratio of upwind to downwind sediment flux were averaged for each tillage treatment for all blocks and for all wind events giving a total of 800 observations per treatment. The results indicated that the twisted chisel
treatment on average, reduced sediment transport of sand and coarse dust by 56.3% while the lister treatment reduced transport by 41.1%. In contrast the control plots showed an increase in transport mass of almost 200%.

The PM10 Dust concentrations at the up and downwind sampling locations varied considerably from plot to plot in association with changing wind speed and direction. In general, hourly PM10 concentrations were surprisingly low even during the most intense wind events. Hourly PM10 concentrations were typically well below 25 μg/m³ with the exception of seven cases when concentrations rose above 25 μg/m³ to a maximum of 427 μg/m³. These seven higher values were associated with three distinct wind events on May 16 and May 18 and May 24. In all but two cases the high concentrations were found downwind of non-tilled surfaces.

The generally low PM10 concentrations are similar to the results reported in the 2007 Morrow Environmental PM10 and PM2.5 Air Quality Report. It is important to note that the proposed Canada Wide Standard (CWS) for PM10 that is to be achieved by 2010 is based on 24-hour average concentration of 60 μg/m³. As a result, it is likely that only one of the above cases would have exceeded the proposed regulation if the hourly data were averaged over 24 hrs.

Although upwind and downwind concentrations varied considerably from plot to plot, there was a discernable decreased in hourly concentrations across the tilled sites, although no distinction could be made between the twisted-point chisel and lister treatments (Fig. 10). In contrast there were in many cases noticeable increases in PM10 concentrations downwind of the control plots.

Decreases in downwind PM10 concentrations were most pronounced at low to moderate wind speeds above threshold when the wind direction was aligned parallel to the centerline of the blocks. At higher wind speeds, concentrations became more uniform across almost all plots reflecting the strong atmospheric mixing of the dust that overshadowed the localized entrainment and/or trapping on given plots. This observation in part reflects the relatively short length of the treated plot surfaces and the associated dust emission depression that can be overshadowed by regional transport processes where regional dust originating outside the study site is transported through the sampling area. Overall, it appears that tillage is an effective method of dust control assuming that a sufficiently large area can be tilled to overcome regional transport effects.

Fig. 10. Partisol Dichotomous sampler located at the Pete Toy site.
3.2 Regional air monitoring

The PM10 and PM2.5 concentrations varied considerably from one site to another over the study period (Fig. 11), which reflects exposure, wind speed and directions as well as local sediment sources and surface moisture content. In general, PM2.5 concentrations are very low, typically <10 μg/m³, except during strong wind events. In only two one hour periods did the PM2.5 concentrations exceed 25 μg/m³; June 3 at Ominica Beach and one hour on May 26 at High Point. The low PM2.5 is likely related to the relatively low concentration of very fine particulates in the local beach sediments.

Fig. 11. PM10 and PM2.5 dust concentrations at the regional monitoring sites May-June, 2008.

The relatively high PM2.5 concentration (29 μg/m³) at High Point was unexpected, particularly because of the relatively low wind speeds and this sites sheltered location. Although somewhat speculative without additional evidence, this very fine dust in the absence of coarser
dust, suggests that the high PM2.5 may be associated with wood smoke from forest fires.

Almost all sites showed several one hour average PM10 concentrations above 50 μg/m³. The most frequent high values (>50 μg/m³) were recorded at the Pete Toy site. This is thought to result from its rather exposed location and position with regard to the dominant transporting wind speeds.

In general the lowest PM10 concentrations were found at High Point and the Tsay Keh beach sites. During the study period dust concentrations at the Tsay Keh site exceeded 50 μg/m³ on only one occasion (May 30, 2008) during a moderate wind event. The generally low PM10 and PM2.5 concentrations at Tsay Keh are similar to the results reported in the 2007 Morrow Environmental, PM10 and PM2.5 Air Quality Report.

4.0 PLANS FOR 2009 TILLAGE EXPERIMENTS

• Several potential sites for the 2009 tillage experiments were visited by crew boat and helicopter in June 2008. Everything considered, the authors and BC Hydro personnel agreed that Davis Flat North beach is the best choice for the 2009 tillage experiments. Although Davis is a “lower” beach, it is relatively free of stumps and is large enough to easily contain the experiments proposed for 2009. The Tsay Keh tilled this beach in 2008 and reported that tillage was effective (i.e. there were relatively few deep sand pockets). This was our observation as well when we visited the beach on June 11, 2008; although by that time about half of Davis Beach was already flooded.

• At our meeting in Guelph in October 2008, the group decided to initiate a new tillage experiment to determine whether tilling the entire beach area is required for effective dust control or rather if alternative tilled and non-tilled strips may prove effective. This new experiment is referred to as the “spacing experiment”.

• As both tillage implements have proven to be effective in roughening the soil surface, the group decided in our October 2008 meeting at Guelph to use only one implement, the twisted-point chisel, for the main tillage experiment in 2009. The number of replicates will be increased from 5 to 6 to help take into account reduced number of statistical degrees of freedom due to having only two treatments (twisted-point chisel and control) in 2009. Plot length will be increased to 300 meters and width (including buffers) will remain at 100 meters. Total land area required for the main tillage experiment is 120 hectares (see Appendix 2).

• Both the twisted-point chisel and lister plow implements will be used in the spacing experiment. The non-tilled area between 8.5-meter-wide tilled strips will be 8.5, 17, and 25.5 meters wide (i.e. 1x, 2x, and 3x the width of tillage implements. Plot length with be 150 meters. The spacing experiment will be located just west of the main tillage experiment (see Appendix 2).

• The front bracket on individual shank assemblies on the twisted-point chisel is made of thin folded metal that is not strong enough for the implement. Due to this weakness, tractor drivers in 2008 had to stop and tighten the bracket assembly every hour or so. The manufacturer (Roll-o-Cone) needs to provide stronger front brackets. If these cannot be provided by Roll-o-Cone,
strong and effective front brackets can be easily and inexpensively produced using half-inch channel iron. This problem is easy to fix.

• BSNE and E-Sampler instrumentation required for the main tillage trial in 2009 is less than needed in 2008 because the number of individual plots (including buffers) will be 24 instead of 30.

• Data to be obtained in 2009 (that were not obtained in 2008) will include: (i) measurement of soil aggregate size distribution in the immediate vicinity of BSNE samplers using a rotary soil sieve, (ii) soil oriented and random roughness as affected by tillage using the chain method in the immediate vicinity of BSNE samplers, and (iii) soil sediment deposition in tilled areas following individual dust storms using GPS mapping software.

• It is imperative that data on soil aggregate stability, soil roughness, and soil sediment movement as affected by tillage be correlated with BSNE and E-Sampler data to “tell the complete story” on wind erosion and air quality in the tillage experiments.

• The three scientists involved in these experiments envision a number of multiple-author academic journal articles that will document the effectiveness of tillage practices on wind erosion and air quality on Williston Reservoir beaches. Graduate students from the University of Guelph and Washington State University will remain on site throughout the dust season to collect data.

5.0 SUMMARY COMMENTS

BC Hydro personnel did an excellent job coordinating the many logistical arrangements for the 2008 dust season. The camp setup at Omineca was incredibly good, especially given the remote location. Although we were handed some setbacks in 2008, we also learned some valuable lessons. Chief among these is our belief that roughening the surface of Williston beaches with tillage will provide effective control of blowing dust.

Attachments
Appendix 1. Research implementation plan for the Omineca Flats tillage experiment and regional dust monitoring project. Written on November 15, 2007, Vancouver, BC.

Appendix 2. Proposed plot layout for main tillage experiment (east side) and tillage spacing experiment on Davis Flats North beach in 2009.
Appendix 1

Research Implementation Plan for the Omineca Flats Tillage Experiment and Regional Dust Monitoring Project

Donald W. Fryrear, Custom Products, Big Spring, Texas
William G. Nickling, University of Guelph
William F. Schillinger, Washington State University

November 15, 2007

Overview

• Omineca Flats Beach to be accessed from April 25 – May 10, 2008.

• The priority is the establishment of the tillage experiment on Omineca Flats Beach followed by the instillation of the regional dust monitoring network.

• It is critical that the tillage implements, tractors, and accessories selected and ordered ASAP. Fryrear, Schillinger, and a BC Hydro representative with purchasing authority need to be involved.

• Sampling instrumentation (360 BSNE samplers with 90 towers, 36 DustTraks, 6 Parisol Dicotomus samplers, 1 meteorological station) need to be ordered ASAP.

• Other equipment need includes: 1 living trailer, 1 lab trailer, a 30-ft-long crew boat, 2 John Deere Gators, 2 laptop computers, satellite phone, 5000 watt generator, drying oven, 2 precision laboratory balances (0.01 gram to 1000 gram), half-ton 4-wheel drive pickup, 1-ton shop truck equipped for field repair (i.e., welder, cutting torch, air compressor, tools, winch).

• 150 gallons of diesel for tractors and 400 gallons gasoline for Gators and the generator.

• Miscellaneous supplies such as soil sampling probes, 1200 sampling tins, 2 measurement wheels, zip-lock bags, computer flash drives, digital camera, and different-colored plot flags.

• Keep open communication channels among project scientists, Tsay Key village, and BC Hydro personnel on project progress. Field trips and/or field days by people from Tsay Key and BC Hydro to the Omineca experiment site is encouraged, especially when project scientists are present.

Experimental Design

• Tillage treatments are twisted point chisel at 1-m shank spacing, lister plow with adjustable shank spacing, and a control.
• Experimental design is a randomized complete block with 5 replications. Each plot is 250 m long x 100 m wide laid out north-south perpendicular with the dominant wind direction. There will be 100-m buffer strips between all treatments.

• Characterize the surface in 25 x 25 m grid by: probing to 30 cm to find the depth silt-clay and the texture of the surface.

• BSNE samplers will be located on the upwind and downwind boundary of each plot at 65, 125, and 185 m. Four BSNE samplers will be mounted with logarithmic spacing from the near surface to a height of 1.5 m.

• At the 125-m BSNE location (both upwind and downwind), a DustTrak aerosol monitor will be placed.

• Surface roughness after tillage will be assessed using the chain method after each major rain or wind event along the east-west transact between BSNE samplers.

• Three meteorological towers with 4 NRG anemometers (0.5-to 2-m height), wind vane (2-m height), temperature, humidity, barometric pressure sensor, and DustTrack aerosol monitor (2-m height) will be located adjacent to the tillage experiment.

**Regional Air Monitoring Protocol**

• Sites are: Omineca Flats, Corless Bay, Tsay Key Beach, Van Somer Point, Middle Creek South, and one other non-beach control site.

• Instruments will be downloaded at all sites preferably at one-week intervals. Transportation to the sites will by crew boat.

• Instrumentation at each site will include: single RM Young wind anemometer (speed and direction), data logger (CR 1000), partisol dictomus sampler (+2025 model) with 10 um and 2.5 um cuts. One twenty-four hour composite sample will be measure each day with filter retrieval done daily. These will be powered by a solar array, wind generator, and batteries. Rainfall, temperature, and relative humidity will also be measured hourly.

• Instrumentation will be installed ASAP in the spring at relatively high locations on the beach and removed before high pool at the end of the dust season. Equipment will be shipped to the University of Guelph at the end each season for cleaning, repair, and calibration.

**Personnel**

• Season-long employees will be a research technician supervisor, two research assistants, and a Tsay Key research intern / boat master. Two or more of the seasonal employees will be responsible for subsequent data reduction, analysis, and instrument calibration for the remainder of each summer.
• The three PI’s (Bills) and an implement specialist / mechanic will be at Omineca Flats for 7-10 days beginning as early as April 25, 2008 to supervise establishment and instrumentation of the tillage experiment and the regional air monitoring sites. Fryrear and Schillinger will return in early to mid June to evaluate the effectiveness of the tillage regimes and protocol for field measurements and data collection. Nickling will travel to the sites near the time of high pool to supervise final data retrieval and removal and shipment of electronic instrumentation to the University Guelph.
Appendix 2

Proposed plot layout for tillage experiments in 2009. The main tillage experiment is on the right. The tillage spacing experiment is to the left.