NORTHWEST TERRITORIES WATER BOARD

NUNAPPA SIVUNIUKPAIT IMMAKUN

PROTOCOL FOR THE MONITORING OF DRILLING-WASTE DISPOSAL SUMPS

Inuvialuit Settlement Region
Northwest Territories

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FOREWORD

Under the *Northwest Territories Waters Act* the Northwest Territories Water Board is charged with the responsibility for licensing water use and waste disposal in the Inuvialuit Settlement Region of the Northwest Territories. Industrial waste discharges have the potential to impact environmental quality, and are thus, of concern to the Board. Public concern regarding the disposal of drilling wastes to in-ground sumps in permafrost terrain has prompted the consideration of post-closure monitoring requirements. The Board has developed a protocol to guide proponents with the collection of environmental information at closed sumps. This information is necessary to evaluate contemporary design, construction and abandonment practices and to evaluate the environmental impacts of drilling waste disposal to sumps. Collection of environmental information in a standardized format will facilitate data analysis and the development of information upon which to evaluate and improve disposal practices.

The Board would like to recognize the efforts of Dr. Steven Kokelj and Mr. Robert Jenkins of the Water Resources Division of Indian and Northern Affairs Canada in the drafting of this protocol. The Board would like to acknowledge the valuable contributions made by Dr. Larry Dyke, Geological Survey of Canada and Mr. Bruce Smith, BGC Engineering. In addition, comments received from the Board's Technical Advisory Committee (TAC) improved this protocol. Advice and assistance was forthcoming from the Federal departments of Environment, Fisheries and Oceans, and Indian and Northern Affairs, and from the Territorial government's departments of Environment and Natural Resources and Health and Social Services. The Inuvialuit Land Administration, National Energy Board, and Industry also provided invaluable expertise which was used during the creation of this protocol.

Gordon Wray
Chairman
N.W.T. Water Board

BACKGROUND AND RATIONALE

Oil and gas exploration and development programs in the Inuvialuit Settlement Region require that a water licence be issued by the Northwest Territories Water Board. During exploratory or production drilling for oil and gas, wastes generated during drilling are typically disposed of in a sump, which is a large pit excavated into the permafrost. In permafrost environments, sumps are used to contain drilling waste because the low permeability of frozen ground can provide an effective primary containment medium. Following completion of drilling, the sump is capped with excavated materials and left to re-vegetate. It is intended that the active layer will re-establish within the sump cap, and that the drilling wastes will remain immobile within the underlying permafrost.

Under current licence requirements defined by the Northwest Territories Water Board, a proponent is required to provide information on the construction, contents and abandonment conditions of drilling-mud sumps. Monitoring site conditions is required for a minimum period of 5 years post abandonment. The objectives of the monitoring methodology outlined in this document include:

(1) Evaluating contemporary design, construction and abandonment practises;

(2) Assessing site conditions and long-term performance of sumps; and

(3) Evaluating environmental impacts of drilling-waste disposal to sumps.

The monitoring protocol will ensure that data collected by industry is consistent and relevant to meeting monitoring objectives. A monitoring template will also facilitate the analysis and integration of data into a DIAND database.

PROTOCOL FOR SUMP MONITORING

The monitoring information required is to be organized in an Excel spreadsheet using the format provided in the Appendix. The file is available online at www.nwtwb.com. Information that must be collected prior to the start of operations is outlined with an asterisk (*).

(1) Site identification and location:

The following information is required:

i) Operator and well name;

ii) Water Licence #;

iii) National Energy Board Well Identification # (WID); and

iv) Sump coordinates (UTM and latitude and longitude).

(2) Site history and local environmental conditions:

Information on site history and local environmental conditions can provide context within which to interpret results of monitoring data. Furthermore, if at some point in time, mitigation is required, a record of site history and site conditions will be useful. The project proposal will provide relevant information on site conditions and can be integrated into the monitoring information sheet (Appendix).

i) Site background:

A) Project background*:

1. Purpose of the well drilled at the lease;
2. Provide a site survey plan showing locations of the drilling mud sump, drill rig, equipment storage areas, extent of the ice pad, location of the spoil pile and well head and access roads (if this survey plan changes during operations, provide an updated plan within the first annual report); and
3. Describe the project team showing names of key personnel with contact numbers and describe responsibilities of various parties.

B) Site development:

1. Provide a bar chart showing the timing of major activities, and detail those with respect to the drilling mud sump (e.g.: excavation date, discharges to sump, closure of sump);
2. Describe method of preparing the lease; and
3. Describe reclamation methods.

C) Drilling operations:

1. Describe method of drilling and depth of drilling;
2. Describe problems encountered during operations, including accidental release of hydrocarbons, etc.;
3. Describe any unusual events that may have either short or long-term environmental impacts; and
4. Indicate timing and volume of materials discharged to the sump.

ii) Sump details:

A) Report the following sump construction details:

1. Date of excavation;
2. Total days that the sump is open;
3. Date of closure;
4. Dimensions of the open sump in metres (length, width, and depth);
5. Maximum, minimum and mean daily air temperatures and daily precipitation for a period of 2 weeks prior to sump closure;
6. Identify any problems encountered during construction and closure of the sump and identify any mitigation applied;
7. Volume, gravimetric water content and chemistry of drilling muds as described in Water Licence requirements (attach separate spreadsheet).
   - *Provide an estimate of the drilling waste freezing point with respect to the waste characteristics at the time of closure;*
8. Indicate the minimum vertical distance in metres from the drilling wastes (cuttings and fluids) to the native ground surface at the sump perimeter;
9. Describe the timing and method of backfilling of the sump, including the following information:
   - *duration of backfilling (days);*
   - *date of backfilling (initiation and completion);*
   - *nature of the backfill;*
   - *presence of snow in sump;*
   - *amount and timing of water additions at closure; and*
10. Describe any other site reclamation activities.

iii) Environmental setting*:

A) Surface conditions:

1. Terrain type (alluvial, upland, coastal);
2. Slope gradient of site and relative position in local topographic setting (e.g.: hilltop, valley, slope bottom);
3. Proximity to nearest water body in metres (indicate type: lake, river, stream, sea);
4. Elevation (metres above sea-level);

5. Note presence of ephemeral drainages of ponds;
6. Indicate annual frequency and average duration of flooding; and
7. Describe natural vegetation cover.

B) Soils, ground-ice, and ground thermal conditions:

1. Describe each major soil unit, including excess ice content and thaw stability in the upper 5 to 10 metres. Obtain a minimum of six discrete samples at 1 m intervals from the 0.25 m or the top mineral horizon, 1.5, 2.5, 3.5, 4.5, 5.5 m depths below ground surface. (Samples may be obtained from the top 5.5 m of a borehole). Analyze samples in the laboratory for:
   - *Volumetric water content (Volume of water vs. volume of sediment);*
   - *Moisture content (% dry weight);*
   - *Excess ice content (volume of water in excess of saturation vs. volume of sediment – expressed as a %);*
   - *Soil texture;*
   - *Organic-matter content;*
   - *Soil Salinity, pore-water conductivity, pH (report soluble ion chemistry results in mg/L and mg/kg).*
2. Obtain representative photographs of the sump sidewalls (collect during operations); and
3. Indicate ground-thermal conditions at the site (Note, additional ground-thermal requirements are outlined in Section 4.II).

C) Groundwater (may not be applicable in areas of continuous permafrost):

1. Note presence of groundwater;
2. Primary aquifers or artesian pressures; and
3. If groundwater is encountered obtain samples for evaluation of baseline groundwater chemistry.

(3) Site conditions after closure:

A brief report should describe all site conditions that are relevant to an assessment of the environmental impact of the leaseholder's activities. It is recommended that the annual monitoring visits be conducted in late summer (August or early September). It is important to maintain reasonable consistency in the timing of site visits so that inter-annual data is comparable.

i) Infrastructure and sump morphology:

A) Photographs:

1. Provide oblique air photographs of the lease, taken after restoration, during the thaw season, at an altitude of 100 m from various orientations (N, S, W, E); and

2. Photographs of relevant features identified in site description (i.e.: sump, well head, control thermistor, and any additional disturbance or infrastructure that may be present).

B) Sump characteristics:

1. Dimensions of the capped sump in metres (length, width). Sump edge is considered where cap cover meets native soil;
2. Approximate thickness of sump cap above grade (If highly variable, report data from various sides of the cap);
3. Describe the nature of cap materials (texture, water content, organic content);
4. Slumping and settlement (Note evidence of erosion or settlement of cap material and/or cracking around sides of cap);
5. Note the nature of vegetation on the sump and describe the seed type applied onto the cap and any soil amendments to enhance vegetation growth.
   - *Describe nature of vegetation cover in lease areas around the sump cap and in adjacent undisturbed terrain (include photographs). Note areas with visibly stressed vegetation (include photographs if applicable);*
6. Indicate the state of soils and organic cover in areas immediately adjacent to the sump (Note if there are areas where natural organic layer has been damaged or removed);
7. Ponding (Note presence of standing water on or around sump cap. Indicate degree of ponding in area extending 50 m from sump cap in all directions and attach relevant photographs):
   - *none - 0% ponding around sump and surrounding area;*
   - *minor - <10% ponding around sump and surrounding area;*
   - *moderate - <20%, ponding around sump and surrounding area;*
   - *significant - >20%) ponding around sump and surrounding area; and*
8. Indicate if sump cap is collapsing and estimate the percentage of the cap that has collapsed.

ii) Surface water:

A) Electrical conductivity of water ponded on the lease must be evaluated. Surface water in undisturbed terrain should also be tested to provide a background condition. Indicate locations of water testing and/or sampling on a survey plan (see Section 2, A).

B) Attach photographs of areas with ponding. If there is ponding on the lease, within 50 m of the sump cap, a water sample should be collected and analyzed for routine water chemistry (conductivity, pH and major cations).

(4) Active-layer and ground temperature monitoring:

Assessment of permafrost conditions at an abandoned sump is important as frozen ground provides the primary containment medium. Active-layer and ground-temperature data monitoring (5 years) will establish a baseline for comparisons with future conditions if additional site assessments are deemed necessary.

i) Active-layer depths:

Active-layer depths must be assessed in late summer (after August) and must include the following information:

A) Survey date;

B) Control active-layer depth:

1. Collection of active-layer depths at a minimum of 8 points measured along a 35 m transect, at 5 m intervals in undisturbed terrain (preferably near control temperature cable);

C) Sump cap active-layer depth:

1. Collection of active-layer thickness at a minimum of five points on the sump cap (see Appendix for approximate locations); and

D) Sump perimeter active-layer depth:

1. Collection of active-layer thicknesses around the perimeter of the sump within 2 metres of the interface between cap materials and parent ground for a minimum of 8 points (see Appendix for approximate locations).

Active-layer thickness can be determined using a calibrated steel probe pushed into the ground to depth of refusal (note that depths may exceed 1 m). Measurement of active-layer thickness in gravel materials may not be possible. Indicate if gravel inhibits determination of active-layer thickness. Start and end points of the respective transects should be established with a GPS and recorded so that locations can be remeasured during subsequent years of monitoring.

ii) Thermal monitoring

The thermal monitoring will be conducted for a period of at least five years following sump closure. At least two cased thermistor strings are to be placed at the following locations:

A) one (1) in the center of the Sump cap; and

B) one (1) in undisturbed terrain adjacent to the lease to monitor background conditions.

Mean daily temperature readings must be recorded at a minimum of 0.25, 0.5, 0.75, 1.5, 3, 6, 9, and 12 metre depths and reported in the provided Excel spreadsheet format.

The thermistor cables are to be placed in a closed casing, so that if thermistors fail, they may be easily replaced. Furthermore, the installation must be designed to allow for manual field measurements to be taken by regulators after the licence requirements have been met. A standard 12 or 24 pin connector should be used at the top of the thermistor cable so that a switch box and multimeter can be used to obtain manual measurements after the 5 year monitoring period has expired and the data logger is removed. Details regarding the installation and connectors must be provided in the Year 1 report.

(5) Electromagnetic surveys (EM31; EM38) and soil sampling:

Ground conductivity surveys indicate the spatial distribution of conductive materials (anions, cations, metals, etc.) at an abandoned well-site. Changes in the distribution of conductive materials may indicate lateral migration of saline drilling fluids and problems with sump integrity. If the EM survey indicates elevated conductivity levels in areas other than the sump, the active-layer soils must be sampled and analyzed for geochemistry to determine the origin of the anomaly.

i) Electromagnetic Surveys

The electromagnetic surveys are to be performed during the thaw season using both an EM31 and EM38. The EM31 has a depth of penetration of 5m and the EM38 a depth of penetration of 1.5 m. Surveys must be performed by foot on a 10 m grid covering the entire sump cap and an area 50 m from the sump edge in all directions. Areas of elevated conductivity associated with saline drilling materials are to be fully delineated, even if they exceed the area of the survey defined above.

ii) Soils

In Year 1 of monitoring, 3 discrete soil samples from the surface, middle and bottom of the active layer must be obtained from a control area. If in Year 1, or in any subsequent years, the EM survey indicates conductivity anomalies adjacent to or away from the sump, active-layer soil samples must be obtained from the area of elevated conductivity and analysed for routine chemistry. If hydrocarbon contamination is suspected that the samples should be analyzed appropriately. Analysis of water soluble soil materials must include reference to methods. Analysis of samples should include:

A) Volumetric water content (Volume of water vs. volume of sediment);

B) Moisture content (% dry weight);

C) Soil texture;

D) Organic-matter content; and

E) Soil Salinity, pore-water conductivity, pH (report soluble ion chemistry results in mg/L and mg/kg).

(6) Interpretation of environmental data:

In addition to providing monitoring data in the template format shown in the Appendix, the proponent should provide a brief, defensible interpretation of the data collected during the prescribed monitoring program. This interpretation should include, but is not limited to, the following:

i) Discussion:

Explain the importance and relevance of the data collected;

B) Describe any discrepancies or deficiencies in the monitoring data;

C) Describe any unusual environmental conditions encountered;

D) Describe any environmental concerns identified during onsite activities; and

E) Identify and describe contamination identified onsite and assess its potential environmental impact. Describe the possible source of such contamination.

ii) Conclusions:

A) Summarize major conclusions from data interpretation; and

B) Identify and quantify any potential risks to either health and/or the environment as a result of activity at the site.

iii) Recommendations:

A) Provide recommendations for additional monitoring at the site;

B) Describe any remediation work that should be performed to mitigate environmental risk or unacceptable environmental conditions at the site; and

C) Provide recommendations for construction and operating procedures that may reduce the risk of environmental impact in the future.

iv) References:

A) Provide all references used during the interpretation of environmental data.

(7) Reporting and integration into electronic database:

Information that is required prior to the start of operations (Sections 2.I.A and 2.III) should be included within the original Water Licence application to the NWTWB. All the requested information in the monitoring protocol, including information submitted prior to the start of operations, should be provided to the Northwest Territories Water Board on December 1st of the year following sump closure and every year thereafter for the duration of the monitoring program as outlined in the Water Licence. Reports are to be provided in electronic format acceptable to the Board, as well as one bound copy and one unbound copy suitable for duplication. To facilitate integration of data into the database, the Excel template should be used to submit the recorded data (Appendix).

APPENDIX

1. SITE IDENTIFICATION AND LOCATION	
Well number and operator	
National Energy Board ID	
Water Licence #	
Lat./UTM	
Long./UTM	

2. SITE HISTORY AND LOCAL ENVIRONMENTAL CONDITIONS			
i) Site Background			
A. Project background			
1. Purpose of well drilled at the lease			
2. Site survey plan. Location of sump, drill rig, equipment storage area, extent of ice pad, location of spoil pile, wellhead and access road. (*Attach map*)			
3. Project team	Name	Responsibilities	Contact Information
B. Site development			
1. Bar chart showing time line of all major activities (*detail those with respect to the drilling mud sump, i.e.. Excavation date, discharges to sump, closure of sump*)			
2. Method of preparing the lease			
3. Reclamation methods			
C. Drilling operations			
1. Method and depth of drilling			
2. Problems encountered during operations			
3. Unusual/unexpected events that may have short or long-term environmental impacts			
4. Indicate timing and volume of materials discharged to the sump			

ii) Sump Details - Sump construction and contents	
1. Date of excavation	
2. Total days open	
3. Date of closure	
4. Sump dimensions	
5. Maximum, minimum and mean daily temperatures and precipitation (*Attach data sheet*)	
6. Problems encountered and mitigation applied	
7. Description of drilling mud as per Water Licence requirements (*Attach data sheet*)	
8. Minimum vertical distance (m) from wastes to native ground at sump perimeter	
9. Describe the timing and method of backfill	
10. Other reclamation activities	
iii) Environmental Setting	
A. Surface conditions	
1.Terrain type (*alluvial, upland, coastal*)	
2. Slope gradient and topographic setting	
3. Proximity to nearest water body in meters (*indicate type: lake, river, stream, sea*)	
4. Note the presents of ephemeral drainage ponds	
5. Indicate annual frequency and average duration of flooding	
6. Natural vegetation cover	
B. Soils and ground-ice conditions	
1. Describe each major soil unit in upper 5 to 10 m, include excess ice content and thaw stability (*Attach data sheet (excel)*)	
2. Photographs (*attach folder with digital photographs*)	
C. Groundwater (*may not be applicable in areas of continuous permafrost*)	
1. Note the presence of groundwater	
2. Primary aquifers or artesian pressures	
3. If groundwater is encountered - obtain samples for baseline groundwater chemistry	

3. SITE CONDITIONS AFTER CLOSURE

i) Infrastructure and sump morphology

A. Photographs (*attach folder with photographs*)

Photo #	Description (*include reference to site map*)

B. Sump characteristics

1. Dimension of sump (m) (*length & width*)	2. Height of cap above grade (m)	3. Nature of cap material	4. Note slumping or settlement of cap material

5. Nature of vegetation (*% cover; shrubs/grasses; canopy height*)	6. Indicate state of soil in areas immediately adjacent to sump	7. Ponding on lease (*none, minor, moderate, significant*)	8. Percentage of sump cap that has collapsed (*if applicable*)
(*Attach excel sheet if necessary*)			

ii) Surface water

	1. Electrical conductivity/salinity (*pond*) (ds/cm)	Water chemistry (*Attach excel data sheet*)
Pond 1		
Pond 2		
Pond 3		
Pond 4		

*Note: include photographs and indicate sampling locations on base map

4. ACTIVE-LAYER AND GROUND TEMPERATURE MONITORING

i) Active-layer depths

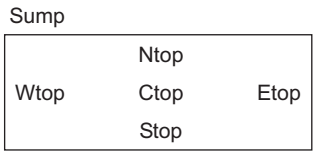
A. Survey date:

B. Control

ID	Thaw depth (cm)
1. C1 - 0 m	
2. C2 - 5 m	
3. C3 - 10 m	
4. C4	
5. C5	
6. C6	
7. C7	
8. C8	

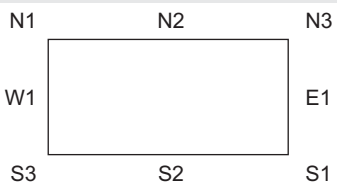
C. Sump cap

1. North top	
2. East top	
3. South top	
4. West top	
5. Centre top	



D. Sump perimeter

1. N1	
2. N3	
3. N3	
4. E1	
5. S1	
6. S2	
7. S3	
8. W1	



ii) Thermal monitoring(Attach separate excel spreadsheet with temperature data)

	Temp.	Temp.	Temp.	Temp.	Temp.	Temp.	Temp.	Temp.
Thermistor depth (m)	0.25	0.5	0.75	1.5	3	6	9	12
Date								
Date								
Date								
Date								

5. ELECTROMAGNETIC SURVEY AND SOIL SAMPLING

i) Surveys (Please include map of survey results and indicate locations where active-layer and water samples were obtained)

Water soluble materials in soils (*salinity package*)	

ii) Soils

Control soils (*Results reported in g/kg and mg/L*)

Depth of sample		Results	
Surface (*Attach excel sheet*)			
Middle of active layer			
Base of active-layer			

Disturbed area (*if necessary*)

Depth of sample		Results	
Surface (*Attach excel sheet*)			
Middle of active layer			
Base of active-layer			

If hydrocarbon contamination is suspected, samples should be collected and analyzed appropriately

6. INTERPRETATION OF ENVIRONMENTAL DATA

Information requested in this section should be in report format