teckcominco

January 7, 2002

Nunavut Water Board
P.O. Box 119
Gjoa Haven, NU
X0E 1J0

Attention: Philippe di Pizzo, Executive Director

**Re: Polaris Mine Decommissioning and Reclamation Plan – Response to Regulator Questions**

As part of the approval process for the Polaris Mine Decommissioning and Reclamation Plan ('Closure Plan'), the Nunavut Water Board ('NWB') and the Department of Indian and Northern Affairs requested and have received comments and questions from a number of parties. Based on the information forwarded to us by the NWB, we understand the following written submissions are the only ones received and so we have directed our response to the following documents:

1. BGC Engineering Inc. ('BGC'), Holgar Hartmaier, dated October 1, 2001
2. Department of Sustainable Development ('DSD'), Paul Partridge, dated October 25, 2001
3. Environment Canada ('EC'), Lawrence Ignace, dated October 26, 2001
4. Department of Indian and Northern Affairs ('DIAND'), Michael Roy, dated October 26, 2001
5. Department of Fisheries and Oceans ('DFO'), Jordan DeGroot, dated October 26, 2001

Development of our responses has taken considerable time as we have in some cases collected additional information or referred issues to our consultants for further design work and/or expert technical comment. To facilitate review of our responses, we have taken each of the above submissions and inserted our comments directly into them. Where our responses are more detailed, they have been included as separate attachments to this letter and references to them inserted into the above submissions.

We believe that this submission adequately responds to the outstanding issues and we look forward to receiving approval of the Polaris Mine Decommissioning and Reclamation Plan from both the Nunavut Water Board and the Department of Indian and Northern Affairs in the near future.

Bruce Donald
Reclamation Manager, Environment and Corporate Affairs
Teck Cominco Ltd.

Cc: John Knapp (Polaris Mine), Carl McLean (DIAND), Michael Roy (DIAND), Paul Partridge (DSD), Lawrence Ignace (EC), Jordan DeGroot (DFO)

Attachments – see list

## LIST OF ATTACHMENTS

Attachment # 1 – Submission to Nunavut Water Board by BGC Engineering Inc. Holgar Hartmaier, dated October 1, 2001.

Attachment # 2 – Submission to Nunavut Water Board and Department of Indian and Northern Affairs Canada by Department of Sustainable Development, Paul Partridge, dated October 25, 2001.

Attachment # 3 - Submission to Nunavut Water Board by Environment Canada, Lawrence Ignace, dated October 26, 2001.

Attachment # 4 - Submission to Nunavut Water Board by Department of Indian and Northern Affairs, Michael Roy, dated October 26, 2001.

Attachment # 5 - Submission to Nunavut Water Board by Department of Fisheries and Oceans, Jordan DeGroot, dated October 26, 2001.

Attachment # 6 - Response to concerns raised regarding impoundment of contaminated soils in permafrost, Polaris Mine, Little Cornwallis Island, Nunavut. Dr. C Burn, dated December 4, 2001.

Attachment # 7 – Letter to B. Donald From Bart Koppe of Cantox Environmental regarding 'Comments on the Polaris Mine Decommissioning and Reclamation Plan, specifically related to the human health and ecological risk assessment.'

Attachment # 8 Letter to B. Donald from S. Morison of Gartner Lee Ltd. regarding 'Response to Environment Canada re Post-Closure Monitoring' dated December 21, 2001.

Attachment # 9 - Memorandum to B. Donald from Paul Erickson of AXYS Environmental Consulting Ltd. regarding 'Garrow Lake Dam – Effect of Removal on Lake Stability and Water Quality Response to Comments by DFO' dated December 14, 2001.

Attachment # 10 - Memorandum to B. Willoughby from T. Feduniak regarding 'Contaminated Soils Storage', dated December 21, 2001.

Attachment # 11 - Memorandum from B. Donald to J. DeGroot regarding 'Recommended Procedures for the Recovery and Disposal of Waste Antifreeze from the Dock Facilities' dated December 15, 2001.

Attachment # 12 - Letter to B Donald from Rick McLean regarding 'Decommissioning of the Wharf Facility in Crozier Strait, Cornwalis Island, NT Little Cornwallis Island, Northwest Territories' dated December 4, 2001.

Attachment #13 - Fax to Norm Allyn of Westmar Consulting Engineering from Jean Barthe of Tower Arctic regarding the source of the fill for the dock cells, dated November 14, 2001.

Attachment # 14 - Updated Dock & Shoreline Sections drawn by Westmar Consulting Engineers revisions dated December 7, 2001.

Attachment # 15 - Appendix H from Revision 1 of 'Decommissioning of Dock Facilities at Polaris Mine Little Cornwallis Island, Nunavut' by Westmar Consulting Engineers.

Attachment # 16 - Example of Blast Layout 7 metres from Dock Face by Pacific Blasting.

Attachment # 17 - Fax to B. Donald from A. Eglauer of EBA Engineering Consultants Ltd. regarding 'Response to DFO-FHM Comments, Garrow Lake Dam Decommissioning, Polaris Mine Operations, Nunavut' dated December 13, 2001.

Attachment # 18 - Memorandum to B. Donald from Peter Chapman and Cathy McPherson of EVS Environment Consultants regarding 'Removal of Garrow Lake Dam – Significance for Garrow Bay Marine Organisms' dated November 29, 2001.

## <u>Attachment # 1</u>

**Submission to Nunavut Water Board by BGC Engineering Inc.**

**Holgar Hartmaier, dated October 1, 2001**

October 1, 2001
Project #: 0308-001-03

Nunavut Water Board
P.O. Box 119
Gjoa Haven, NT
X0E 1J0

Attention: Mr. Phillipe diPizzo, Executive Director

Dear Mr. DiPizzo,

**Re: Polaris Mine- Review of Final Decommissioning and Restoration Plan**

This letter summarizes comments by BGC Engineering Inc. (BGC) with respect to the review of the four volume set of documents prepared by Gartner Lee Limited (GLL) for Cominco Ltd. (Cominco) for the decommissioning and reclamation of the Polaris Mine, dated March, 2001.

Comments were passed on verbally to Mr. John Knapp of Cominco in a technical meeting held in Resolute Bay on September 20, 2001.

**General Comments**

The overall decommissioning and reclamation plan prepared by GLL is comprehensive in scope and addresses the main areas of concern identified in the 1999 Environmental Site Assessment prepared by GLL (June 2000). In addition, specialized review by sub-consultants was undertaken in key areas such as the stability of Garrow Lake (Axys Environmental Consulting Ltd.), the removal of the Garrow Lake dam (EBA Engineering Consultants Ltd.), the options for the removal of the process barge and decommissioning of the dock (Westmar Consultants Inc.), and the geothermal stability of the landfill and underground waste disposal sites (BGC Engineering Inc.). A human health and ecological risk assessment was carried out by Cantox Environmental Inc., which derived soil quality remediation objectives.

**Specific Comments**

**Landfilling of Waste in Subsidence Zone and LRD Quarry:**

Cominco has been using the zone of subsidence above the existing mine workings (Reclamation Landfill) to dispose of obsolete heavy equipment and other materials such as dump truck boxes, sea containers, tires, wooden crates, vehicles, etc. Vehicles and other decommissioned equipment are cleaned of all oils, fuels and fluids prior to disposal. Cominco proposes that the Reclamation Landfill will not require an engineered cover design to maintain frozen conditions and intend on covering the landfill with a minimum 1.5 metre cover of locally available soil and rock.

The Little Red Dog (LRD) quarry is proposed as the landfill for the disposal of demolition waste from the mine facilities, such as concrete foundations, decommissioned pipelines and steel tanks. The design of the quarry cover will be consistent with that developed for the Operational Landfill, which comprises 1.8 m of locally available quarried shale, graded to fit the adjacent contours to prevent ponding over the quarry.

**It is recommended that Cominco establish a protocol for the placement of the waste materials and backfill in a controlled manner to eliminate the creation of voids and areas of low compaction in all areas of proposed landfill activity. To ensure long term stability of the landfill, especially the cover materials, it is important that soils cannot settle or migrate into voids or cavities within the waste, especially during the period that is required for permafrost to aggrade into the landfill. Saturation of the waste and backfill materials with water could result in the formation of ice lenses and subsequent frost jacking of waste materials above the landfill surface, leading to a progressive deterioration of the landfill surface. An engineered cover of sufficient thickness to ensure that the waste material lies well below the seasonal active zone is therefore recommended for the reclamation landfill, similar to that proposed for the LRD quarry**

Cominco has indicated that it will use the same practices as currently adopted for the Operational Landfill, which has not experienced any stability problems to date. The Board and DIAND have also requested BGC to conduct a literature review of past practices of waste disposal in permafrost, including the issues with respect to underground disposal in the mine. BGC will provide comments/guidelines based on current and precedent practice under separate cover to the Board in response to this request.

***TeckCominco Response***

- *The landfill debris will be cut into sizes and shapes that minimize voids spaces as fill material is placed over the debris.*
- *Equipment will be used to crush debris where practical to minimize voids.*
- *Debris placed into the landfill will be placed in lifts and covered with fill material prior to being covered by the next lift of debris.*
- *Portions of the landfill will be constructed during winter(s) and during those periods materials placed will already be in a frozen state.*
- *Moisture from precipitation and run-off during the summer periods of landfill construction will aid in strengthening the fill as it freezes to minimize settling of the landfill.*
- *If there are any differential movements within the landfill, any cracks or voids formed will be sealed off by downward percolation and freezing of the surface water from precipitation*
- *Landfill operators will be given a technical briefing and instructions (with checks) on the protocol that will be used for the placement of debris in the landfill as well as closure specifications for the landfill.*
- *A field supervisor will have the responsibility to ensure that the protocol(s) for placing debris as well as geotechnical specifications for the closure of the landfill are followed.*
- *Landfill operators will be required to note the type, placement and depth of debris emplacement to ensure there is an adequate record of the protocol used to place material in the landfill. Photographic documentation will be maintained.*

- *The design of the engineered cover for the landfill has the specific objective of being thick enough to ensure that the landfill remains frozen by being buried below the active layer.*
- *The landfill will be visually inspected as part of the post-closure monitoring plan to confirm geotechnical performance as specified in the Closure Plan.*

**Backfilling of Mine Portals**

Cominco is proposing to seal all entrances to the underground mining operations. The proposed method involves a 0.5 m thick bulkhead consisting of steel plate supporting a reinforced concrete wall. The concrete will be pumped into the steel bulkheads from the ground surface through holes drilled into the tunnel. A grid of reinforcing bars tied into the rock surrounding the tunnel and supported by rock bolts will stabilize the bulkhead. Backfill will be placed within the tunnel openings between the bulkhead and the portal. At the ground surface, the backfilled material will be graded to conform to the adjacent slopes.

***The sketches provided in the submitted documents do not indicate complete filling of the tunnel with backfill between the bulkhead seal and the ground surface. Presumably, the purpose of the bulkhead is to prevent the loss of backfill material down the tunnel decline. It is recommended that the final construction specifications require that the backfill be placed up to tunnel crown level to prevent long term settlement of the rock mass around the tunnel as well as the fill around the exterior face of the portal. The entire tunnel void should be completely backfilled. No design criteria were available for the bulkhead itself, and it is not clear if consideration was given to potential loads associated with water or backfill (saturated) which may be present upon completion of the closure procedures.***

The bulkhead should be constructed to conform to a certain set of design criteria and specifications, which may require approval by WCB and/or the local mine inspector.

***<u>TeckCominco Response</u>***

- *The tunnel from the collar of the portal to the bulkhead seal will be completely filled as suggested.*
- *The purpose of the bulkhead is to provide an 'engineered' seal with a known minimum strength to prevent future access to the mine. We would have proposed fill by itself as a method of sealing the openings but did not feel it would be acceptable to Regulators. As stated in the Closure Plan, the design of the seal will be submitted to the local Mines Inspector for approval prior to construction.*

**Dock Area Decommissioning and Barge Reclamation**

The decommissioning and reclamation plan assessed various options for the dock area decommissioning and barge reclamation. Cominco has indicated that the preferred option will be to dismantle the barge on-site and dispose of it into the LRD quarry. The dock area will be cleaned of contaminated soils and the sheet pile cells will be cut off underwater below low water level. The shoreline will be reinstated back to the original location, with a sloping beach, with an underwater slope of 17.5 Horizontal: 1 Vertical.

***We concur with Cominco that this is the best option from both technical and environmental standpoints.***

*Closure*

*The decommissioning and reclamation philosophy proposed by Cominco involves utilization of the existing footprint of surface and underground disturbances to get rid of the inert wastes generated during closure. In addition, surface facilities such as the dock area and Garrow Lake are being restored to their pre-mine conditions as much as possible. In disposing of the wastes on site, Cominco will reinstate the surfaces of the LRD quarry and existing reclamation landfill to a stable, drained condition, through the long term aggradation of permafrost. Hydrocarbon and metals contaminated soils will be placed deep underground within the permafrost, ensuring secure long term disposal and isolation from receiving bodies of water. No free phase liquids will be placed underground or into the surface landfills.*

*Cominco has stated that in proceeding with this work, it will be in their best interest to ensure that it is done properly from the outset, as the costs for re-mobilizing contractors to carry out follow-up work will be prohibitively expensive.*

*Assuming that Cominco will address the above comments, we have no further technical concerns with the proposed decommissioning and reclamation plan at this time.*

*We trust that this meets with your requirements at this time. If you have any questions or require additional information, please do not hesitate to contact the undersigned. Thank you.*

*Respectfully submitted,*
*Per BGC Engineering Inc.*

*Holger Hartmaier, P.Eng., M.Eng.*
*Senior Geotechnical Engineer*

*HHH/sf*

## Attachment # 2

**Submission to Nunavut Water Board and Indian and Northern Affairs Canada**

**by Department of Sustainable Development**

**Paul Partridge, dated October 25, 2001**

October 25, 2001

Mr. Phillipe di Pizzo
Executive Director
Nunavut Water Board
P.O. Box 119
Gjoa Haven, NU
X0E 1J0

Mr. Carl McLean
Manager, Land Administration
Indian and Northern Affairs Canada
P.O. Box 100
Iqaluit, NU
X0A 0H0

Re: Comments on the Polaris Mine Decommissioning & Reclamation Plan

Dear Mr. Pizzo & Mr. McLean,

The Department of Sustainable Development has reviewed the proposed decommissioning and reclamation plan for the Polaris mine. In general the plan is found to be comprehensive and well thought out; however, a few points were identified that need to be addressed prior to acceptance and approval of the final plan. These points include permafrost encapsulation of waste material, hazardous materials management, and the SQRO study aspect of the plan, and are covered in more detail below.

## Permafrost Encapsulation of Waste

Concerns were raised about the plan's proposal to encapsulate contaminated soil and material in permafrost under the assumption that permafrost is impermeable. This assumption may lead to serious errors in engineering designs and will reduce the overall effectiveness of the plan. Support for this is found in recent studies indicating that permafrost is not permeable and will allow the passage of contaminants through fissures, cracks, and other air voids and water within the frozen soil matrix. Further studies conducted in Alaska seem to indicate that contaminants, particularly hydrocarbons, have the ability to degrade permafrost. For this reason we are not convinced that permafrost encapsulation will provide a long-term and environmentally acceptable solution to containing contaminants.

***TeckCominco Response***

- *Through Gartner Lee Ltd., Dr. Chris Burn was requested to respond to the above question. Dr. Burn's curriculum vitea and response is attached (Attachment #6).*
- *Mr. Partridge has forwarded the specific reports, which initiated his concerns. We requested that Dr. Burn review these documents in conjunction with the Closure Plan and subsequent information provided to him from the staff at Polaris.*
- *Dr. Burn recommends that the stope where the hydrocarbon contaminated soils are placed, have the floor wetted to ensure any voids in the rock are sealed by ice. This will be done.*
- *It is important to note that the hydrocarbon contamination that is to be stored underground **is not in the free fluid phase**. It is attached to fine soil particles and as such will not mobilize in the underground environment. Complete freezing of the contaminated soil in conjunction with an impermeable boundary of ice (as outlined above) will ensure containment. The papers referred to by Mr. Partridge deal will free flowing hydrocarbon contamination.*
- *The review by Dr. Burn also clearly shows that there is no issue of permafrost degradation at the depths that the contaminated soil will be stored in the mine.*
- *It is important to note that the hydrocarbons are encapsulated in a location remote from other mine workings. Access to the area is limited and as an additional measure of protection, the access tunnel will have a wetted earthen plug installed and allowed to freeze.*

In conjunction with the previous concern, questions have been raised as to whether BGC would be a suitable choice in assessing the competence of the proposed encapsulation method. These questions do not stem from BGC ability to do the work, but form the fact that they were solicited by Cominco, through Gartner Lee Limited, to assess the ability of the containment area to sustain permafrost conditions.

***TeckCominco Response***

- *Mr. W. Savigny of BGC participated in the development of permafrost aspects of the Closure Plan. Subsequent to the Closure Plan being submitted to the NWB, Mr. Hartmaier became associated with BGC and was contracted by the NWB to review the Closure Plan. Prior to Mr. Hartmaier submitting his comments to the NWB, TeckCominco contacted the NWB to ensure they were aware of the above facts.*
- *Dr. C. Burn was engaged to provide a second opinion on the permafrost encapsulation method proposed in the Closure Plan. His review has clearly demonstrated that this approach is technically sound and poses no risk to the environment over the short term or long term ("thousands of years")*

## Hazardous Waste Management

Comments were made about the manner in which Cominco was going to dispose of the various types of material as listed in section 5.6 of the plan. In the past there have been instances where recipients have been unable to properly look after or dispose of certain materials when they were no longer in use. The proponent is obligated to ensure that the recipient of any hazardous materials (including excess fuel) is a responsible party who is fully capable of handling the material; this includes dealing with spills and ensuring proper disposal.

Our Department would like clarification on the following points:

- The manner in which the di-electric fluids from non-PCB transformers will be disposed of.

  ***TeckCominco Response***
  - *As reported in the Closure Plan, the di-electric fluids were sampled and confirmed that they do not contain PCB's.*
  - *It will be up to the contractor selected for decommissioning to handle these fluids in one of three ways:*
    1. *Incinerate the oils as this is a permissible disposal method for mineral oils.*
    2. *Ship the oil to southern Canada as a waste product for disposal through a licenced disposal agent.*
    3. *Sell the oil with the transformers and ship it to the buyer as a product and not a waste.*

    *Details of the final decision will be provided to the NWB prior to the initiation of the disposal of transformers and/or the fluids contained in these transformers.*

- The amount of freon that is expected to be recovered from the freezer units.

  ***TeckCominco Response***
  - *There are 4 mine air refrigeration units in use. Each unit uses a maximum of 750 lbs. of R-22 freon for a up to total of 3000 lbs. if the units are fully charged. The freon will be pumped back into shipping bottles and returned to the original supplier for recycling or to an approved disposal company.*

- Whether there were any chlorinated solvents incinerated in the burning pit, and if so, an approximate amount.

  ***TeckCominco Response***
  - *There have been no chlorinated solvents incinerated in the burning pit.*

- Is there a marker indicating the fact that there is buried asbestos on site, and has the site been catalogued as such by the regulating authority.

  ***TeckCominco Response***
  - *In 1993, asbestos from our MAK generators were removed, placed into 4 – 45 gallon steel drums and under an approval from Sylvester Wong of the NWT Mines Inspection Branch, entombed in backfill deep within the mine. It was placed in 760-202 Stope located at Nad83 UTM co-ordinates 8368650 N, 558625 E, -256 m elevation.*
  - *There is no surface marker as the material is not buried near surface in the conventional manner so there is no risk of it ever being disturbed.*
  - *There are no other asbestos related issues at the mine site that require attention in the closure and reclamation of the Polaris Mine.*

## Soil Quality Remediation Objectives Study

The quality of Cantrox Environmental Inc., Human Health and Ecological Risk Assessment has generated concern about their findings. This question was raised because they consistently overlooked or dismissed rudimentary facts on wildlife such as the endangered status of the Peary Caribou, or that they made the broad assumption that muskox are just large caribou; failing to take into consideration the differences in niches, the fact that they are more sedentary then caribou, and their increased ability to forage in hard snow conditions. It appears that they failed to do more then give wildlife a superficial glance in determining the acceptable limits for the SQRO, as they fail to consider the influence of contaminants on anything but adult wildlife, which would be when wildlife is arguably the least susceptible to contaminants.

***TeckCominco Response***

- *CCME protocols provide for the use of site specific protocols to be used for sites with atypical characteristics.*
- *The assessment conducted by Cantox uses highly conservative assumptions and provides protection to both the Peary Caribou and muskox. The assessment also considers the most sensitive stages of the animal's life for determining acceptable exposures.*
- *Refer to Attachment #7 from Bart Koppe of Cantox Environmental who has provided a comprehensive response to this question.*

It is understood that the mine is located in an area of marginal habitat, and that areas where the mine contributed to significant concentrations of contaminants, as defined by the SQRO study, will be remediated. This, coupled with the fact that there were areas of high lead and zinc concentration exceeding these recommended limits prior to the mines inception, would support use of the values proposed by the study.

We trust that our comments will be of value in finalizing the plans for this project. If you have any questions or require clarification do not hesitate to get in touch with me.

Sincerely,

Paul Partridge
Coordinator, Claims Implementation & Land Use
Department of Sustainable Development, GN

CC. Earle Baddaloo - Director of Environmental Protection Service, GN

## Attachment # 3

**Submission to Nunavut Water Board by Environment Canada**

**By Lawrence Ignace, dated October 26, 2001**

Environmental Protection Branch
Qimugjuk Buidling
P.O. Box 1870
Iqaluit, NU
X0A 0H0

Oct 26, 2001

Dionne Filiatrault
Technical Advisor
Nunavut Water Board
P.O. Box 119,
Gjoa Haven, NT X0B 1J0
By Facsimile: (867) 360-6369 By email: Dionne@polarnet.ca

**RE: Review of Polaris Decommissioning and Reclamation plan**.

Environment Canada has reviewed Cominco's Decommissioning and Reclamation Plan for Polaris Mine site and offer the following comments and recommendations for your consideration.

Cominco has conducted an extensive evaluation of surface contamination and assessment of disposal options for all installations and facilities of its Polaris mine site. In general EC has not identified any major concerns with the Plan with the exception of the approached proposed for Garrow Lake.

**Garrow Lake**

Final bathymetrics of the lake should be provided to indicate the bottom profile that exists following the removal of the tailings pipeline.

***TeckCominco Response***

- *Final bathymetrics will be conducted after the disposal of tailings into the lake has been completed to ensure there is a complete record of the bottom profile.*

The lowering of Garrow Lake to its natural levels has been occurring over the last two years with its final release planned for 2002. This will lower the lake level by approximately 2.5 meters which results in a approximately 30% reduction to the thickness for the mixolimnion layer (surface layer). This will also expose a new wetted shoreline of Garrow Lake which could lead to the introduction of sediments to the surface waters. This could impact the water quality of Garrow Lake for future release.

***TeckCominco Response***

- *Lowering of Garrow Lake to pre-impoundment levels will re-expose a previously exposed shoreline. The original shoreline has been exposed to long term surface wind and wave erosion. The potential for increased turbidity associated with wave action was greater during the period of impoundment where increasing the elevation of the lake submerged new shoreline that had never been previously exposed to wave action.*
- *As the shoreline is being gradually re-exposed, time for the draining and re-establishment of the shoreline is occurring. This change in water level is being monitored regularly by on-site Polaris mine staff. In 2001 the lake was not lowered beyond the minimum elevation obtained in 2000. As a result there will be an extra year to lower the lake to its original elevation relative to the schedule*

*proposed in the Closure Plan. This will also ensure that the shoreline of Garrow Lake is gradually being re-established to allow for stability (e.g. re-introduction of permafrost) and continual monitoring during this initial phase of the Closure Plan (e.g. 2002-2004).*

- *Our monitoring plan (Attachment #8) has been revised to include the measurement of TSS of the surface layer of the lake to document on-going turbidity during and after lowering of the lake. The monitoring program also includes visual observations for stability of the lakeshore.*

It is also assumed in this plan that discharge from Garrow Lake will conform to the existing licence limits. Environment Canada recommends that, once "natural" discharge is allowed from Garrow Lake, the water quality should reflect, as near as possible, the natural background levels that existed before mining.

***<u>TeckCominco Response</u>***

- *In summary, within nine years it is predicted that the surface water quality of Garrow Lake will return to < 0.1 ppm Zn.*
- *Paul Erickson of AXYS Environmental Consulting Ltd. has been modeling the behaviour of Garrow Lake as a tailings facility throughout the life of the Polaris Mine (e.g. 20 years of data). On an annual basis, the Surveillance Network Program ('SNP') data has been forwarded to Mr. Erickson and he has reviewed the data in relation to the model.*
- *Included in the Closure Plan are graphs forecasting the water quality changes (Volume 2, Report # 3) through to 2005. In response to the reviewer's question, TeckCominco requested that Paul Erickson review this issue in more detail and extend the model's forecast through until 2010. In support of this, Polaris staff forwarded Paul the most recent SNP data collected in 2001. Paul's response to the issue of discharge water quality considers the latest data and his comments are included as Attachment #9.*
- *There is extensive data collected over the past 20 years of operating Garrow Lake as a tailings impoundment area supporting the conclusions of Mr. Erickson. TeckCominco feels that this provides adequate comfort and is reasonable for the prediction of water quality objectives that are part of the Closure Plan.*

The Garrow Lake report (volume 2 supporting documentation), used a model to predict the stability of the halocline and expected metal concentrations in the mixoliminion (surface layer). This model used data up to and including 1999, however it must be recognized that Garrow Lake is undergoing some immediate and large changes due to draw down (since 2000). Since this model is being used to predict into the future, these changes must be taken into consideration. In addition, if the Garrow lake dam is taken apart before these predictions can be verified, it poses a concern for long term water quality and downstream impacts.

***<u>TeckCominco Response</u>***

- *TeckCominco disagrees with the statement that the lake is undergoing 'large' changes due to draw down. The surface layer of the lake is being gradually returned to its original elevation. With the cessation of tailings deposition in the lake in 2002, the physical and chemical conditions of the surface layer of the lake will gradually change through natural processes to reflect **pre-mining conditions.** The behaviour modeling described above has been verified through an on site SNP. The modeling and sampling conducted over the past 20 years clearly demonstrated that the long term stability of Garrow Lake will not be impacted by the lowering of water level.*
- *Environment Canada has not provided a scientific basis for their concern. Providing this would allow the TeckCominco an opportunity to respond more specifically to this concern.*
- *The reviewer states that as the model is being used to predict into the future, the current changes must be taken into account. On an annual basis, Mr. Erickson receives updated data and reviews the performance of the lake relative to the forecasted performance from the model. The water quality forecast provided by Paul Erickson of AXYS Environmental Consulting Ltd. in Attachment #9 has been updated to include the 2001 SNP data to ensure the latest data is considered as part of this response.*

EC recommends that the dam remain in place and that Cominco be allowed to discharge (via siphons) from Garrow Lake in order to reach and maintain the original lake level. A new water licence could be established with set licence limits to reflect that mining has stopped and no effluent is being placed in the lake. In addition to this, an appropriate monitoring program must be established to verify the predictions of the model, as well as, the overall water quality within the lake in all layers. At a minimum, this program should operate for 5 years after the lake has returned to natural lake levels with an evaluation occurring each year, preferably during the open water season. A winter evaluation could be added to the monitoring program to allow for a better understanding of the dynamics of the lake. Following each year and at the end of the five years of monitoring, an assessment should be conducted to verify the lake's stability and whether or not it is conforming to the model predictions. The next steps for Garrow Lake would depend on this five year assessment.

### ***TeckCominco Response***

- *TeckCominco strongly disagrees with the comment that the dam should remain in place for a 5 year period following returning the lake to its original elevation. The reviewer has not identified a technical rational for the concern, yet the consequences of the Water Board agreeing to the reviewer's recommendations are costly and logistically impractical for TeckCominco. The basis for TeckCominco's comments are as follows:*
  - a) *TeckCominco has already been sampling the water quality of Garrow Lake for 20 years and has invested in a comprehensive model that has been regularly updated. This provides TeckCominco with a high degree of certainty in regards to predictions in terms of water quality objectives and the behaviour of Garrow Lake upon closure of the Polaris Mine. The environmental risk associated with the mixing of Garrow Lake due to storm events during the potential open water seasons is extremely low (see below). It appears that Environment Canada has not considered this with the above comments.*
  - b) *The only mechanism that can physically cause the Zn levels in the surface layer of Garrow Lake to increase after disposal of tailing ceases in 2002 is a major wind storm event that occurs during the short period of time when the lake may be ice free. As discussed in the report titled 'Garrow Lake Dam, Effect of Removal on Lake Stability and Outflow Water Quality'(Report #3, Volume 2 of 4 of the Polaris Decommissioning and Reclamation Plan), it would take a wind speed of 105 km for 2.5 hours to cause mixing of the upper 1 meter of the halocline with the surface layer. Wind speed in Resolute from 1961-1990 has never reached this velocity for more than 1 hour (Note – the report in the Closure Plan has an error in Figure 4. The vertical axis labeled 'Duration' should be in days, not hours). If the top metre of the halocline were to mix with the surface layer, then the 'new' surface layer would be thicker by1 metre and, subsequent wind events would have to be even more severe to cause any additional mixing of the surface layer with the now deeper halocline.*
  - c) *In addition to the information included in the Closure Plan, TeckCominco requested that Paul Erickson of AXYS Environmental Consulting Ltd. update the information in the Garrow Lake water quality model and comment further on the water quality issues (Attachment #9).*
    - *In order to assess the effects of this unlikely event (105 km/hr wind for 2.5 hours), Paul Erickson calculated that if the top metre of the halocline did mix with the surface water in 2004, the resulting concentration of Zn in the surface layer would increase by 0.015 ppm. This would result in the surface layer of Garrow Lake having a Zn concentration of 0.26 ppm. This is approximately 50% of the current licence limit for Zn (0.5 ppm). If this mixing occurred subsequent to 2004, then the resulting Zn concentrations in the surface layer would be even lower (i.e. 2004 represents the worst case).*
    - *In 2004, if there was mixing of the top two metres of the halocline with the surface layer (would require a wind for 8 hours constantly sustained at 105 km/hr), the resulting Zn concentrations in the surface layer would increase by 0.07 ppm to 0.31 ppm. This is still approximately 38% below the current licence limit for Zn. If this were to occur subsequent to 2004, then the Zn concentrations would be even lower.*
    - *In both of the above cases, the resulting water quality remains within current licence limits, within the current Metal Mining Liquid Effluent Regulations and within proposed updated Metal Mining Effluent regulations.*
  - d) *The cost of leaving the dam in is substantial. It is also impractical from a logistics perspective. Leaving the dam in place after the island is abandoned would require personnel returning to the island each discharge season, establishing a camp and remaining on the island to operate the siphon system. This would be required on an annual basis until the decision is made to remove the dam. At that time, substantial heavy earth moving equipment, crews, a large camp and fuel storage facilities would need to be re-established on the island. Roads would either need to left*

*intact after mine closure or need to be re-activated to transport fill removed from the dam to the designated disposal area in Little Red Dog quarry.*

e) *The Closure Plan proposes that Garrow Lake dam be decommissioned by partially removing the dam. This in itself is a contingency. If conditions were to occur that required containment of the lake surface waters, it would be possible to reconstruct the dam, as approximately 70% of the material would still remain in place.*

– *If monitoring results identify a significant departure from the predicted water quality over two successive sampling periods, TeckCominco will discuss with the Water Board and through it, to other regulatory agencies, the course of action that may be necessary. If there is concern for the water quality exceeding the applicable standards, then one of the options that will be considered is the re-construction of the dam for the purpose of temporarily preventing discharge while a solution is implemented.*

– *The reviewer proposes a winter component to the monitoring program to 'better understand the dynamics of the lake'. As identified above TeckCominco has invested considerable resources to develop a model and to collect data (including winter) over the past 20 years. TeckCominco believes that there is a good understanding of the lake dynamics after this extensive period of monitoring.*

– *The reviewer recommends that 5 years of monitoring occur after the lake has been returned to its original level. A comprehensive monitoring program is proposed in the Closure Plan for Garrow Lake prior to and after it has been returned to its original level in 2004. Monitoring is proposed until 2011. Details of the parameters to be sampled, sample locations and timing of the monitoring program are detailed in Attachment #8. The Closure Plan proposes regular reporting of the results. In 2011, a final review of the data collected will be done and a determination made whether the site (including Garrow Lake) is stable and performing as predicted.*

– *After the site has been abandoned in 2004, the monitoring plan (Phase 2) proposes sampling of the lake during the spring while the ice is still safe to work on. During the summer it is often not possible to access the lake monitoring station due to ice flows. The monitoring plan does propose to monitor wind speeds during the potential open water season. If a wind event occurs that has sufficient energy to potentially mix the upper metre of the halocline, then additional sampling of the lake will be attempted before it freezes up.*

No definitive information was provided within Polaris's Decommissioning plan that demonstrated the current health of the aquatic biota within the lake. EC recommends that an assessment/status of the biota for Garrow Lake specifically within the mixolimnion (surface layer) be carried out. Special attention should be paid to the *Myoxocephalus quadricornis* (Four Horned Sculpin) a listed species of concern with the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

***TeckCominco Response***

– *With respect to the request for a post-decommissioning assessment of the presence of aquatic biota in the surface layers of Garrow Lake, TeckCominco does not agree that this should be required for the following reasons:*
  – *Garrow Lake was designated as a 'Tailings Impoundment Area' pursuant to Subsection 5(2) of The Metal Mining Liquid Effluent Regulations' under the Fisheries Act by the Minister of Fisheries and Oceans in 1981.*
  – *During the application period for the current Water Licence, DFO had requested studies to relate the relevance of data on metal concentrations in the water to those concentrations in fish and macro-invertebrates. The Water Licence granted did not require these studies either to support the application or as a condition of the Licence.*
  – *New Metal Mining Effluent Regulations have been gazetted and it is expected that they will come into effect in 2002. Under the proposed legislation, Garrow Lake is specifically named as a tailings impoundment area. It is one of 5 lakes in Canada with this designation. Under the proposed regulations, which will be administered by Environment Canada, there will be the requirement to conduct Environmental Effects Monitoring ('EEM'). It is important to note that under the regulations, the required location for the EEM is downstream of the discharge point of Garrow Lake and not within the lake itself.*

– *If Environment Canada or DFO wishes to conduct an assessment program of aquatic biota within Garrow Lake, TeckCominco would be prepared to provide logistical support for the work while there are facilities on the island.*

**Further Comments:**

**Contaminated Soils**

The disposal option for the underground storage of contaminated soils is an acceptable approach. However a detailed account of volumes, types of contaminated material, exact location/s and details regarding the geology of the placement area should be provided. The portals and other accesses to the mine will be sealed but there was no mention in the plan where the contaminated soils will be placed. EC recommends that the contaminated soils be sealed into place to further encapsulate the contaminated material. This would ensure that if, for any reason there is a change, such as climate change causing the loss of permafrost to this depth, the material would not have a direct route to the surface.

***<u>TeckCominco Response</u>***

- *To confirm and refine the volumes of contaminated soils, Gartner Lee Ltd. developed contour plans complete with cross sections utilizing sampling data. This was done in the area of the barge/product storage and dock areas, as these were the most complex areas containing the majority of the contaminated soils. If soils contain both hydrocarbons and metals, the material is categorized as hydrocarbon contaminated for the purpose of selecting the disposal location within the mine. There are 29,200 cu.m. of hydrocarbon containing soils to be removed and encapsulated in the mine workings. There is an additional 61,750 cu.m. of metals contaminated soils identified for removal and burial in the mine.*
- *The staff at Polaris have reviewed the volumes of materials to be stored underground and identified the storage locations in the mine for these materials. A memorandum complete with two drawings identifying the locations are attached (Attachment #10).*
- *The hydrocarbon-contaminated soils will be sealed into a remote location in the mine. Through Gartner Lee Ltd. TeckCominco requested comment from an additional technical expert on the subject. As a result, Dr. Chris Burn was requested to respond to the question of storage of hydrocarbon contaminated soils in the mine. Dr. Burn's curriculum vitea and response is attached (Attachment #6).*
  - *Dr. Burn recommends that the stopes where the hydrocarbon contaminated soils are placed, have the floor wetted to ensure any voids in the rock are sealed by ice. This will be done.*
  - *It is important to note that the hydrocarbon contamination that is to be stored underground **is <u>not</u> in the free fluid phase**. It is attached to fine soil particles and as such will not mobilize in the underground environment. Complete freezing of the contaminated soil in conjunction with an impermeable boundary of ice (as outlined above) will ensure containment. The papers referred to in Mr. Burn's response deal with free flowing hydrocarbon contamination.*
  - *The review by Dr. Burn also clearly shows that there is no issue of permafrost degradation at the depths that the contaminated soil will be stored in the mine.*
  - *It is important to note that the hydrocarbons are encapsulated in a location remote from other mine workings. Access to the area is limited and as an additional measure of protection, the access tunnel will have a wetted earthen plug installed and allowed to freeze.*

**Fuel Tanks**

For the incineration of tank sludges, waste oil and maybe glycol, no details were provided on the type of incinerator to be used. An approved two stage incinerator should be used.

***<u>TeckCominco Response</u>***

- *The decommissioning work at the site is currently out for tender. Proposals from contractors include different methods for dealing with tank sludges, waste oil and glycol. It is premature to determine which methods will be used, but all of the methods described below are acceptable under current regulations and practices:*
  - *Place the recovered hydrocarbon sludge and/or glycol into approved shipping containment and transfer the materials to southern Canada where they will be either recycled and/or disposed of through a certified disposal company.*

- *Incinerate hydrocarbon waste sludges. There are no territorial regulations or guidelines governing the approval or operation of incinerators in Nunavut. There are also no Federal regulations or guidelines for the operation of small incinerators for non-hazardous materials. If incineration is selected as the preferred disposal method, a two-stage incinerator (as recommended by the reviewer) would be used to ensure thorough combustion of the products being incinerated.*

**Landfills**

EC has no significant concerns with the design or cover materials chosen. However, as indicated in Polaris Landfill Closure Plan it is recommended that further durability tests should be undertaken to evaluate "shale" as a cover material. EC concurs that further durability tests should be conducted in order to ensure long term stability of the cover materials from freeze/thaw degradation.

***TeckCominco Response***

- *Originally when the Closure Plan was developed, it was anticipated that the material to construct the landfill covers would consist of either gravel located adjacent to the Operational Landfill or shale from the New Quarry. Both materials are available for use at the site. As the gravel is closer to the Operational Landfill, it is the preferred material for that location.*
- *Shales are commonly known to be subject to slaking and it is assumed that this is the basis of the question raised by the reviewer. However, the calcareous shales that are typical of the area around the Polaris Mine are relatively competent. In practical terms, durability tests only simulate the active layer processes. This is an over-estimation as diurnal freeze-thaw cycles at this latitude are limited. In the event that the use of shale is selected for cover material, samples will be taken and submitted for standard ASTM freeze-thaw and mechanical breakdown testing prior to being used.*

**Marine Study**

There were indications of contamination of the marine environment surrounding the current works at Polaris mine, however, no recommendations were provided as to how this might be addressed. Understanding that the remediation of contamination in the marine environment may cause more problems than it solves, EC recommends that further monitoring should occur to determine if there is continued contamination into the future. For example, the site in front of the operational landfill should be monitored.

***TeckCominco Response***

- *Pre-mining sampling of ocean sediments conducted by DFO indicates the presence of metals above the CCME probable effects level (PEL) in some areas near the Polaris Mine site.*
- *In the area of Garrow Bay, no pre-mine data is available. Sampling conducted in 1999 by Gartner Lee Ltd. indicates that in Garrow Bay, adjacent to the Operational Landfill, some sediment contain metals concentrations above the CCME probable effects levels. While there is no information to suggest or to dismiss that the metals levels in the sediments are related to the effects of the adjacent Landfill, the Closure Plan proposes isolation of the Landfill in a manner that eliminates the potential for migration of metals contamination into the marine sediments.*
- *The proponent agrees with the reviewer's comment that in the marine environment attempts to remediate metals concentrations in sediments would cause more problems than it solves.*
- *The proponent agrees to monitor metals concentrations in sediments as recommended by the reviewer. Refer to Attachment #8 for revisions to the proposed post-closure sampling plan. The sampling plan includes sediment sampling at three locations upon the completion of remedial activities at the site in 2004 and again at the end of the proposed monitoring program in 2011.*

**Monitoring**

Post Closure Monitoring Phase I and II provides a general understanding of what will be done. However, there is need to develop a more detailed monitoring plan including the location of stations, a list of parameters to be measured and frequency of sampling/observations for each station. This is important when confirmatory testing of remediated soils is being conducted during Phase I of the post closure monitoring program.

***TeckCominco Response***

– *Refer to Attachment #8 for a detailed description of the post-closure monitoring plans.*

If you have any question or concerns please contact me at (867) 975 4639 or Email lawrence.ignace@ec.gc.ca

Sincerely

Lawrence Ignace
EPB, Iqaluit

cc. Stephen Harbicht, EPB, Yellowknife
Laura Johnston, EPB, Yellowknife

## Attachment # 4

**Department of Indian and Northern Affairs**

**By Michael Roy, dated October 26, 2001**

Nunavut Regional Office
P.O. Box 2200
Iqaluit, NU, X0A 0H0

Your file - Votre référence
**N4L3-0262**
Our file - Notre référence

October 26, 2001

Rita Becker
Licensing Administrator
Nunavut Water Board
P.O. Box 119
Gjoa Haven, NU, X0E 1J0

**Polaris Mine Decommissioning and Reclamation Plan**

Indian and Northern Affairs Canada (INAC), water management division, is pleased to present the following comments on Cominco=s Decommissioning and Reclamation plan for Polaris Mines.

INAC believes that Cominco has conducted sufficient studies and have revised their Decommissioning and Abandonment plan sufficiently over the years to remove any major concern. The only small question we have remaining concerns a Aworse case≅ scenario for Garrow Lake. Essentially, we would like a brief description of what Cominco plans to do should the layers of Garrow Lake suddenly mix, whether prior to or after the removal of the Garrow Lake Dam. Does Cominco plan on maintaining a dam indefinitely in such an event? Of course, since this represents more an emergency or worse case scenario, only a small paragraph or two would be required, not an overly detailed plan.

***TeckCominco Response***

– *Environment Canada's submission contains questions regarding the stability of Garrow Lake. A comprehensive response has been provided that discusses the potential metals concentrations in the surface layer of Garrow Lake under several different mixing scenarios. Even in the unlikely case of mixing the top two metres of the halocline with the surface layer, the surface water quality of Garrow Lake would not cause harm to the aquatic environment and would require no contingency action. Refer to Attachment #9 in which Paul Erickson (AXYS Environmental Consulting Ltd.) discusses this issue in detail.*

Also, INAC is aware that Environment Canada (EC) recommends that Cominco maintain the dam for 5 years after drawing down Garrow Lake back to its original level. The purpose of this is to monitor Garrow Lake and see if the results of the draw down match those predicted by Cominco=s models before removing the dam. Seeing how the draw down of Garrow Lake is an unusual procedure and the predicted results are in no way assured, there is definitely merit to EC=s suggestion. However, asking Cominco to return with heavy equipment 5 years later to remove the dam may be impractical. Although a 5 year study is certainly preferred, INAC is willing to accept a compromise; maintain the dam until everything else has been dealt with during the abandonment and restoration process. The removal of Garrow Lake Dam would therefore be the final step in the abandonment and restoration of Polaris Mine, just prior to the final evacuation of all the heavy equipment.

***TeckCominco Response***

- *The proponent agrees with the reviewer that leaving the dam in place for a 5-year period to monitor the lake is impractical. Removing the dam in 2004 does not represent a risk to the aquatic environment in the proponent's and consultants opinion as outlined in Attachment #3 (Submission from Environmental Protection Branch).*
- *The proponent has revised its Closure Plan so that the dam removal is scheduled for the spring of 2004 which is the final year that contractors are planned to be working at the site.*
- *TeckCominco has proposed to decommission the dam by removing only part of the dam. This preserves the ability to re-construct the dam more easily than if it were completely removed.*
- *In response to Environment Canada's submission, TeckCominco proposed that if monitoring results identify a significant departure from the predicted water quality over two successive sampling periods, TeckCominco will discuss with the Water Board and through it, to other regulatory agencies, the course of action that may be necessary. If there is concern for the water quality exceeding the applicable standards, then one of the options that will be considered is the re-construction of the dam for the purpose of temporarily preventing discharge while a solution is implemented.*

According to Cominco=s closure schedule (Table 2.1), the draw down of Garrow Lake will end in 2002, when the waters level will be below its original level to allow the removal of the dam. The removal of the dam should take place in 2003, and the heavy equipment will be removed on November 30, 2004. With the compromise suggestion, Garrow Lake will hopefully be finished be being drawn down to its natural level by early 2002, the lake could be monitored during the remainder of the season of 2002 and throughout 2003. In 2004, Cominco could finish drawing down the lake to levels adequate enough to remove the dam. The dam could therefore be removed in the fall of 2004 provided the accumulated data indicates the lake is stable.

***TeckCominco Response***

- *Drawing down Garrow Lake to restore its original elevation will not be completed until 2003 with removal of the dam planned to occur in 2004. This is the last year that TeckCominco will have equipment on the island.*
- *While dam removal is being proposed for the year following completion of draw down, there is a two year period between cessation of depositing tailings into the bottom of the lake and the removal of the dam. During this period, the concentrations of Zn in the surface layer of the lake will continue to decrease. In 2004, immediately following dam removal, even if the top two metres of the halocline were to mix with the surface layer (a highly improbable event), the resulting concentrations of Zn in the surface layer would be 0.31 ppm. This concentration is 38% below the concentration of Zn permitted under the current water licence (0.5 ppm).*

If you have any question, please feel free to contact me at your earliest convenience.

Sincerely,

***Original Signed By:***

Michael Roy
Baffin Regional Coordinator, Water Management
INAC - Nunavut Regional Office
P.O. Box 2200, Iqaluit, NU, X0A 0H0
(867) 975-4555
fax: (867) 975-4560
roymjp@inac.gc.ca

## Attachment # 5

**Department of Fisheries and Oceans**

**By Jordan DeGroot, dated October 26, 2001**

Fisheries and Oceans | Pêches et Océans

Fish Habitat Management
P.O. Box 358
Iqaluit, Nunavut
X0A 0H0

Oct 26th, 2001

Bruce Donald
Teck Cominco Ltd.
Bag 2000, Kimberly B.C.
Canada V1A 3E1
Phone: 250-427-8256
Fax: 250-427-8206

**RE: Polaris Mine - Decommissioning and Reclamation Plans**

Dear Mr. Donald:

This letter is to advise that Department of Fisheries and Oceans staff have reviewed the above plans. Department of Fisheries and Oceans-Fish Habitat Management (DFO-FHM) concerns include decommissioning of the dock and adjacent shoreline, and removal of the Garrow Lake Dam. Additional information on the decommissioning plans will be required prior to issuance of a *Fisheries Act* authorisation:

*Decommissioning of the Dock* - Although plans to remove the dock with recontouring of the shoreline to approximate natural shoreline slope is considered the preferred alternative, additional detailed, finalized construction information and finalized blasting plans are required.

***TeckCominco Response***

- Detailed information is provided in following sections of this submission in the same order that the specific comments are identified.

*Removal of the Garrow Lake Dam* - Information is also required regarding the timing and construction methods used to remove the dam. Teck Cominco Ltd. does not provide sufficient assessment of the more environmentally acceptable alternative of complete dam removal and site rehabilitation. Moreover, there is good reason to defer decommissioning actions on the dam until the natural surface water elevation of Garrow Lake has been restored and monitoring reveals that erosion of the halocline and mixing with the surface waters will not occur and contaminants will be retained at depth.

***TeckCominco Response***

- *As above, detailed responses to the reviewer's questions have been inserted in subsequent sections of this letter in response to specific comments.*
- *The proponent does not agree with the comment that there is 'good reason to defer decommissioning actions on the dam' or that complete removal is more environmentally acceptable.*

In addition to the above, DFO-FHM has yet to receive a "No Net Loss" plan from Teck Cominco Ltd. An acceptable "No Net Loss" plan, outlining compensation measures, will be required prior to issuance of a *Fisheries Act* Authorisation.

***TeckCominco Response***

1. *The application for authorization by the proponent involves two distinct and separate projects. The proponent's objectives in both projects are to restore rather than to harmfully alter fish habitat. While mitigative measures are required to protect habitat while the restoration work is in progress, the objective is to avoid Harmful Alteration, Disruption, or Destruction of Fish Habitat (' HADD'). The proponent believes the submission of a no net loss plan at this stage is premature for the following reasons:*
   a) *TeckCominco believes that DFO views the lowering of Garrow Lake as an activity that has the potential for HADD. It is unclear to the proponent whether DFO's concern for HADD relates to Garrow Lake aquatic habitat or effluent water quality from the lake into Garrow Bay or both. In addition, it is not clear to the proponent what specific elements of the habitat require protection.*
      i. *If the concern for HADD relates to loss of fish habitat due to reducing the area of the surface layer in Garrow Lake, the proponent does not agree. Referring to the 'Decision Frame Work for the Determination and Authorization of Harmful Alteration, Disruption or Destruction of Fish Habitat' by the Department of Fisheries and Oceans Habitat Management and Science (1998), states:*

         > *'Consequently, when reviewing project proposals, habitat managers strive, pursuant to the No Net Loss guiding principle, to maintain the current productive capacity of fish habitats supporting Canada's fishery resources, such that the habitat is able to produce fish suitable for human consumption.'*

         *There is no current or historical fishing of Garrow Lake for either sport or human consumption as there has never been any fish of interest for either sport or human consumption. It is the proponents understanding that recent legal interpretations of the Fisheries Act have identified this as a key issue in the determination of whether a project presents a HADD.*

         *Additionally, in 1981 Garrow Lake was designated as a 'tailings impoundment area' under the Metal Mining Liquid Effluent Regulations by the Minister of Fisheries and Oceans.*
      ii. *If the concern for HADD relates to the water quality of the surface layer of Garrow Lake discharging into Garrow Bay, the proponent does not agree that there is a HADD. In the remainder of this letter, we have provided detailed responses to reviewers' questions and/or comments related to the water quality issues. The proponent maintains that the metals concentrations in the surface layer of Garrow Lake and the discharge from Garrow Lake will not only remain within current Water Licence and other regulatory requirements but will improve subsequent to cessation of tailings being deposited into the bottom of the lake.*
   b) *The second component of the remedial plan is to restore the dock and adjacent shoreline to a more stable and natural configuration. The proponent has proposed this work with the specific objective of improving aquatic habitat. It is our understanding that DFO also views this proposal as beneficial provided appropriate mitigation methods are utilized during the work process. It is our understanding that DFO does not view this as a HADD contingent on appropriate construction methods being utilized.*
2. *The proponent requests further discussions with DFO in resolving the issue of whether or not there is a HADD.*
   - *If it is determined that there is a HADD, then discussions would be requested to develop an initial scoping of a compensation plan. Ultimately, the objective in this circumstance would be to develop a formal Approval in Principal ('AIP') in which a letter is issued by DFO outlining their conditions for the approval. A compensation plan would be part of this approval.*
   - *If it is determined that there is no HADD or if HADD can be prevented through a series of mitigative actions, then in discussions with the proponent, DFO can develop and issue a 'Letter of Advice' under which DFO agrees what actions are required to prevent a HADD. The proponent is of the opinion that there is no HADD and that a Letter of Advice is the appropriate approach. The letter would contain requirements for mitigative actions rather than compensation.*

If you have any questions concerning the attached comments, please contact me at (867) 979-8007 or by fax at (867) 979-8039.

Sincerely,

*Original Signed by:*

Jordan DeGroot
Habitat Management Biologist
Fish Habitat Management
Department of Fisheries and Oceans- Eastern Arctic Area

**Comments provided by Bruce Fallis on decommissioning of the dock, Garrow Lake Dam removal, and Garrow Lake water quality:**

## Dock Removal

"*Teck Cominco Ltd. Report for: Decommissioning of Dock Facilities at Polaris Mine Little Cornwallis Island, Nunavut*" Revision 1, October 2001, Westmar Consultants Inc.

The cover letter dated October 4, 2001 refers to "Revision 2 of our report" but the title page of the report states "Revision 1". If an updated version of the report is available, it should be provided.

***<u>TeckCominco Response</u>***

- *The cover letter from Westmar referred to Revision 2 of their report in error. The attached report referred to (Revision 1) was the most current version.*

The proposal to remove the refrigerant from the cells of the dock requires greater detail with respect to the nature of the refrigerant, the quantity of refrigerant to be recovered, the manner in which the refrigerant will be removed, and the ultimate method of disposal of the refrigerant.

***<u>TeckCominco Response</u>***

- *A review of the type and potential quantity of refrigerant, a detailed protocol for removal and methods of disposal completed. Attached is a memo describing this information in detail (Attachment #11).*

Plans for removal of the styrofoam used against the interior of the piles should also be provided.

***<u>TeckCominco Response</u>***

- *The styrofoam is above the water line only, and is comprised of sheets that are 10 ft. long, 2 ft. wide and 4 in. thick.*
- *The frozen fill will be excavated while the sheet piles are still in place, although some of the fill along the sheet piles will remain in place as long as possible to keep the interior as dry as possible during excavation.*
- *The styrofoam sheets will likely come out in large sections, but may be damaged from drilling, blasting, excavation and pile extraction, and so smaller pieces may be broken off from the larger sheets . Pieces of styrofoam that are not removed by machine will be removed by hand and disposed of at the land disposal site. Pieces of Styrofoam will not be allowed to enter the environment.*

The proposal to cut off the steel cell sheeting should be submitted to the Canadian Coast guard for review to ensure that the depth below the low tide level at which the cells will be cut, meets their specifications under the provisions of the ***Navigable Waters Protection Act***.

***<u>TeckCominco Response</u>***

- *Find attached a letter from Rick McLean A/Superintendent, Navigable Waters Protection, Coast Guard, Central and Arctic Region (Attachment #12). Mr. McLean reviewed the permits held with the Coast Guard and states that they have no interest in the project so long as the sheet piles are either extracted or cut off at least 2 metres below low tide level and the beach is re-profiled to minimize erosion.*

Details are needed with respect to the nature of the "rejects from the mine operation" that were disposed of in the dock cells and whether the level of excavation in the cells during decommissioning will leave such rejects exposed, causing leaching of contaminants into the ocean. If much of the dock fill to be left in place consists of "mine rejects" it should be removed and disposed of underground.

**TeckCominco Response**

- *Originally there was uncertainty regarding the source of the material to fill the dock cells. We have since acquired a video showing construction of the dock with the fill coming from the berthing area of the barge. We have also received a letter from Jean Barthe of Tower Arctic (who constructed the dock cells) confirming that the fill material originated from the barge berthing area excavation (Attachment #13).*

Pg. 1- The "detailed design work" advocated as being necessary prior to decommissioning is not a part of the report provided. Such information should be submitted IN ADVANCE of any approvals being granted to proceed. Mitigation methods to be employed to reduce sediment dispersion have not been detailed.

**TeckCominco Response**

- *Pg 1 of the report recommends the following design work be done prior to decommissioning:*
  1. *Prepare detailed hydrographic surveys surrounding the site.*
     - *Detailed hydrographic surveys were originally taken in order to design and install the dock facilities. As the option selected for decommissioning the dock involves excavation of shore material to a maximum of 2 metres below low tide elevation, there is no need for further hydrographic surveys to be conducted.*
  2. *Incorporate the remedial excavation proposed by Gartner Lee Ltd.*
     - *Westmar Consulting Engineers ('Westmar') have revised their drawings to reflect the remedial excavation proposed by Gartner Lee Ltd. These revised drawings are attached (Attachments #14).*
  3. *Finalize the excavation plane to minimize cut and fill volumes.*
     - *Refer to item #2. above for the appropriate drawings (Attachment #14).*
  4. *Develop detailed procedures for excavation process to ensure protection of the aquatic environment*
     - *There are four components of the decommissioning plan that require protocols to protect the aquatic environment:*
       - i. *Removal of glycol from freezing pipes located in the dock.*
         - *The procedure is described in Attachment #11.*
       - ii. *Blasting of fill to be removed*
         - *Blasting will be minimized as much as possible. During the summer when the active layer has thawed, surface layers of fill can be removed without blasting. Then the next layer of fill will gradually thaw and can then also be removed without blasting. This process will be repeated if the thawing is efficient. Until this process is attempted, it can not be determined how successful it will be. Blasting will be used as a last resort and will be done during the early winter as discussed later in this letter.*
       - iii. *Sediment Control*
         - *The majority of the fill to be removed is located within the sheet pile cells in the dock area. During removal of the fill from the cells, the sheet piles will remain in place at an elevation higher than the fill. This will ensure that there is always a physical barrier between the fill being removed and the ocean.*
         - *In areas of the shore where there are no sheet piles to act as a silt barrier, excavation below sea level will be sequenced so there is a berm of undisturbed fill between the excavation and the ocean. The berm will be the last material below sea level to be removed. A conventional silt barrier would not be functional due to damage from random ice flows that come and go during normally ice-free periods.*
         - *Where blasting is required to loosen fill, it will be done during the period of the year when the ocean is ice covered. In these conditions the ice will form a barrier to prevent fill from spilling into the ocean.*
         - *The new shoreline will be graded to make it a smooth as practical to minimize the rate of erosion once it is exposed to wave action. A key aspect of the design parameters of the shoreline is the flat slope of the new shoreline to minimize erosion rates.*
         - *In addition to the contractor's supervision, TeckCominco will assign an environmental monitor to regularly observe the work while in progress to ensure*

*procedures are being followed. The observer will also monitor for signs of any sediment getting into the ocean and will have the authority to direct the contractor to take appropriate action.*

iv. *Prevention of hydrocarbon spills during the work process*
   - *Equipment working on the foreshore or in the water will be inspected for potential hydrocarbon leaks and necessary repairs made. Any equipment working in the water will be steamed to remove surface oils and greases.*
   - *Spill kits (hydrocarbon containment / absorbent booms) will be available in the event of a hydrocarbon spill. Operators and supervisors working near the shoreline will have training and written procedures to follow in the event of a spill.*
   - *No equipment will be refueled or greased within 50 metres of the shoreline.*
   - *In addition to the contractor's supervision, TeckCominco will assign an environmental monitor to regularly observe the work while in progress to ensure procedures are being followed.*

Pg. 3- The extent of the area of contaminated surface material to be deposited underground should be identified along with the techniques to be used to differentiate between contaminated and uncontaminated materials.

***TeckCominco Response***

- *In addition to the area around the mill and product storage building, the area of the dock and shoreline targeted for reconfiguration will have contaminated surface materials removed. The contaminated surface layer has been caused by spillage and/or tracking of fine-grained concentrates from the mill, concentrate storage and concentrate load out conveyor system. Once this layer has been excavated and transported back to the mine, the underlying dock fill will consist of uncontaminated rock originating from the barge berthing area.*
- *As the surface layers of fill are removed, field screening methods will be used to assist in identifying the separation of the contaminated surface fill from the underlying clean fill. The site currently has a laboratory that is adequate for screening level testing of fill, but it is assumed that it will not be practical to maintain this capability through to the end of the reclamation project. If an on-site lab is not practical, there are electronic tools commercially available that would be adequate for use as a screening tool. A tool such as a NITO 700 Series Multi-Element Analyzer could be utilized. The NITON instrument is a hand held analyzer that utilizes a radioisotope source to analyze for 15 metals (including Pb and Zn) and is specifically designed for this type of application. It reads bulk soil samples and is rated to detection limits of less than 150 mg/kg for zinc and less than 70 mg/kg for lead. A PID will be used as a field screening tool for hydrocarbon contamination.*
- *Once the screening tools indicate that the contaminated surface materials have been removed, confirmatory samples will be collected and shipped to a licenced commercial laboratory for confirmation*.

Materials associated with decommissioning of the temporary dock should also be disposed of underground, since the rock associated with this structure was originally identified as being well mineralized (Pb and Zn).

***TeckCominco Response***

- *Any mineralized rocks located above or within a metre of the low tide elevation will be removed and disposed of underground. Some of the rip-rap used to control erosion along the shoreline have been identified as containing mineralization and will be removed.*

While alternative proposals may be appropriate, regulators will base approval on plans that are approved prior to commencement of work and any deviation from such plans should receive approval prior to implementation.

Pg. 12- It is indicated that rip rap of the dimensions required is not available in any quantity on Little Cornwallis Island, however no alternative source for such materials is suggested. The source for the materials needed should be specified.

***TeckCominco Response***

- *Alternate sources of rip-rap off-island have not been identified for several reasons:*
  - a) *A source for rock off Little Cornwallis Island would require mobilizing equipment crews to a new site, requiring the following to enable mining of rip-rap:*
    - *a new dock at that site*
    - *shelter for the crews*
    - *fuel storage*
    - *maintenance facilities*
    - *roads from the quarry to the dock and site facilities*

    *A new quarry would need to be developed, rock blasted, the rip-rap loaded on a barge, transported back to Little Cornwallis Island, and then finally off loaded and placed along the shores.*
  - b) *Both new land leases and a mining lease would be required prior to disturbing a new site on an adjacent island. This is a difficult task in itself.*
  - c) *Encapsulating the dock with rip-rap was viewed as unacceptable option due to the large area of habitat on the ocean floor that would be buried by the placing of the rip-rap.*
  - d) *Clearly the costs to do the above work would be prohibitive.*

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Pg. 14- Once again, the contingency measures to be implemented to minimize sediment dispersal need to be specified along with the site(s) selected for disposal of excavated materials.

***TeckCominco Response***

- *Refer to response to comments regarding Pg. 1 above for discussion of sediment control plans.*
- *Contaminated fill will be disposed of in the mine as detailed in the drawings in Attachment #10. Clean fill will be used for re-contouring up-slope areas of the dock.*

Pg. 15- The methods for distinguishing the materials that are contaminated with concentrate dusts should be specified.

***TeckCominco Response***

- *Refer to comments related to Pg. 3 of this submission above.*

The "detailed final blasting design" should be part of the proponent's application for a ***Fisheries Act*** Authorization and be evaluated and approved in advance of issuance of any Authorization.

***TeckCominco Response***

- *Blasting in the area of the dock is both very expensive and very complex to ensure that there is no harm to the aquatic environment. The complexity of the design is apparent from Appendix H of the Westmar report 'Decommissioning of Dock Facilities at Polaris Mine, Little Cornwallis Island, Nunavut – Revision 1' (Attachment # 15) submitted by Westmar with their report on decommissioning the dock. Pacific Blasting has also provided us with a specific example (Attachment # 16) of the details required to blast a row located approximately 7 metres from the outside edge of the dock structure. The example shows holes 7.9 metres deep, 7 explosive decks per hole with a maximum charge weight per delay of 5 lbs. Each row blasted requires each one of these parameters to be changed due to changing distances from the ocean and changing hole lengths.*
- *If TeckCominco is required to submit a 'detailed final blasting design' it would be necessary to assume that the entire quantity of fill to be removed would be blasted. This would require 34,500 kg of nitroglycerin type explosives. If TeckCominco were successful in removing even 1 metre of fill by non-blasting methods, then the <u>entire</u> blast design would need to be completely redone.*
- *TeckCominco intends to remove as much of the fill as possible by mechanical means by cyclically stripping the active layer as it thaws. This will involve the removal of thawed active layer as the permafrost table degrades. It is unclear at this time if this approach will be efficient, however it is the view of TeckCominco that this approach will minimize potential environmental impact. Given the*

- *above, it is unclear the extent of blasting that may be actually be required and as a result it is not reasonable to provide a 'final' blast design at this point in time.*
- *It is proposed that, as the requirements for blasting evolve during the decommissioning of the dock, a detailed blasting plan is submitted at that time that would comply with the design parameters proposed in Attachment #15. This would be submitted for final approval from DFO in advance of the work being conducted. This is normal practice within the BC Coastal region where blasting in and around aquatic environments is not an uncommon occurrence.*

Pg. 17- The timing of the detailed topographic survey needed to finalize the cross-sections and volumes for detailed design, tendering and construction should be indicated. Review of the finalized construction plans is a prerequisite to the issuance of any ***Fisheries Act*** Authorization. The timing of the detailed topographic survey is critical in this regard.

***TeckCominco Response***

- *Topographic surveys have been completed. Westmar has utilized this information in conjunction with information on remedial excavations to develop final cross-sections that will be given to contractors to direct their work. The cross-sections are provided in Attachment #14.*

Pg. 18 4th bullet - Uncertainty is expressed here with respect to how the sheet piles will be decommissioned. Clarification is needed so that the proposal may be assessed by the Canadian Coast Guard with respect to the need for permitting under the ***Navigable Waters Protection Act***.

***TeckCominco Response***

- *The Coast Guard has approved both the removal of the sheet piles or cutting them off provided they are at least two metres below low tide elevation. Refer to Attachment #12 (Letter from R. McLean of the Coast Guard).*

In summary, removal of the dock with recontouring of the shoreline to approximate natural shoreline slope is considered the preferred alternative, pending the provision of additional detailed, finalized construction information and finalized blasting plans.

## Garrow Lake Dam Removal

"*Garrow Lake Dam Decommissioning, Polaris Mine Operations, Nunavut*", Project No. 0101-94-11552.002. Prepared by EBA Engineering Consultants Ltd. Edmonton, Alberta. March 2001

This report needs to be reviewed in the context of the history of the Polaris operation, taking into consideration that Garrow Lake was designated as a tailings impoundment area for use in depositing tailings at depth below the natural halocline in Garrow Lake. Failure of Cominco's tailings line resulted in the discharges of tailings into the surface waters of Garrow Lake and the elevation of lead and zinc concentrations. In order to meet the discharge limits at the outflow of Garrow Lake, the dam on Garrow Creek was constructed. It is this very dam that is the subject of the report. The report advocates the formation of a cut through the dam to restore the Garrow Creek flow path. The report does not present a cost-benefit analysis associated with total removal of the dam vs. making a cut through the dam to reinstate flow to Garrow Creek. Such a cost benefit analysis should be provided. In the absence of such an analysis, the entire dam should be removed and the affected area decommissioned to its pre-construction state. If the tailings system had been operated as intended, there would have been no need to construct the dam. If it is decided to leave the dam in place, Teck Cominco Ltd. should post an irrevocable letter of credit to cover the cost of the removal of the dam. Any liability for the dam should not be passed on to future generations. Since the amount of material to be removed for the cut through the dam is more than a third of the total volume of material in the dam, removal of the entire dam would appear to be both logical and cost effective.

***TeckCominco Response***

– *Attachment #17 from A. Eglauer of EBA Engineering Consultants Ltd. ('EBA') includes a cost benefit analysis of complete removal of the dam compared to partial removal of the dam. Complete removal of the dam would at least double the cost and does not provide any additional environmental benefits.*
– *Within this submission and the submission from Environment Canada there are requests for a contingency plan in the event that the water quality discharged from in Garrow Lake becomes unacceptable. The Closure Plan proposes to remove only approximately 30% of the Garrow Lake dam. If it were to become necessary to re-construct the dam, logistically and from a cost standpoint, the reconstruction is much more practical if the majority of the dam remains intact after closure as proposed.*

Timing of the decommissioning actions is critical to the success of the undertaking. It is suggested that the work be conducted in early spring prior to the thaw to optimize vehicle traffic under frozen conditions.

***TeckCominco Response***

– *The proponent agrees with the reviewer's comments with regard to the timing of the dam removal. Attachment #17 from EBA also recommends removal of the dam during winter months.*

Drilling and blasting is proposed for the removal of materials but there is no assessment of the effects of blasting on the integrity of the remaining structure if the entire dam is not removed. Such an assessment should be part of the suggested cost-benefit analysis.

***TeckCominco Response***

– *The effects of blasting are not of concern with respect to stability of the remaining dam structure. EBA included this aspect in their cost-benefit analysis presented in Attachment #17.*

There is good reason to defer decommissioning actions on the dam until the natural surface water elevation of Garrow Lake has been restored and monitoring reveals that erosion of the halocline and mixing with the surface waters will not occur and contaminants will be retained at depth. Once the dam is removed, there is no contingency identified to restrict movement of surface waters enriched with lead and zinc out of Garrow Lake. The target discharge concentrations at the outflow of Garrow Lake at decommissioning should be based on the ALARA principle and preferably comparable to pre-development concentrations. Designation of Garrow Lake as a tailings impoundment area was based on the understanding that "Cominco Ltd. has undertaken to dispose of tailings in such a manner … that the surface layer of Garrow Lake remain substantially unaltered." The fact that the surface waters of Garrow Lake have been substantially altered, necessitates that a plan be provided identifying the strategies to minimize contaminant discharges upon decommissioning. No forecast of the total loadings of contaminants that will be discharged from Garrow Lake subsequent to cessation of tailings disposal has been provided. Such an estimate should be part of the decommissioning plan.

***TeckCominco Response***

a) With respect to comments that the surface waters have been 'substantially altered'
   – *Garrow Lake was designated as a 'Tailings Impoundment Area pursuant to Subsection 5(2) of The Metal Mining Liquid Effluent Regulations' ('MMLER') under the Fisheries Act by the Minister of Fisheries and Oceans in 1981. As DFO has defined this lake as a tailings impoundment, the criteria specified in MMLER regulations are the controlling regulatory values. Within the context of the MMLER, the proponent disagrees with the reviewer that the surface layer of Garrow Lake has been 'substantially altered'. The metals concentrations within the surface waters have never exceeded the levels permitted in the MMLER.*
   – *The concentrations of zinc in the surface layers of Garrow Lake have consistently remained below thresholds for the protection of aquatic life. The metals concentrations in the surface water have never exceeded the current Water Licence permit levels (0.5 mg/L). Other standards for zinc for the protection of aquatic life support this concentration. BC's Water Quality Criteria (1998 updated January 2001) recognizes that the toxicity of zinc is related to the hardness of water. The*

*hardness of water measured in mg of $CaCo_3$/L in the surface waters of Garrow Lake were reported by BC Research to be 700 mg/L using 1975 data. The 30 day average concentration for zinc for the protection of aquatic life would be 0.47 mg/L at this hardness. Recent sampling and analysis by Polaris staff indicates the water is at least as hard as previously reported. The CCME guideline for zinc is much lower at 0.03 mg/L but it does not provide for the mitigating effect of hardness.*

b) *The reviewer comments that target discharge concentrations at the outflow of Garrow Lake at decommissioning should be based on the ALARA principle.*

- *The ALARA principle was developed in relation to protecting people working primarily in the nuclear industry from radiation hazards. It advocates keeping exposures as low as reasonably possible taking both economic and social factors into account. The proponent is not aware of the Federal Government adopting this principle as a formal policy in the application of DFO regulations.*
- *As described in a memorandum from Mr. Paul Erickson of AXYS Environmental Consultants (Attachment #9), the discharge concentrations from Garrow Lake do not pose a significant risk under any reasonable scenario. The potential for mixing of the top two metres of the halocline are very low, but even if that unlikely event were to occur, concentrations of metals in the surface layer of water discharged into the ocean would not pose a threat to aquatic life. Mr. Peter Chapman and Ms. Cathy McPherson of EVS Environment Consultants were asked to comment on the potential effects of the discharge water quality from Garrow Lake on Garrow Bay marine organisms. Their comments are provided in Attachment #18. In summary they state:*

  > *'Even assuming that worst case predictions regarding zinc concentrations in Garrow lake surface waters were to occur, removing the tailings dam to allow surface waters to flow into Garrow Creek and thus into Garrow Bay, will not create any risk of harm to the marine organisms in Garrow Bay.'*

c) *The reviewer states that the dam should be left in place as a contingency until the natural water elevation is restored and it can be demonstrated that mixing of the surface layer with the halocline will not occur.*

- *This is not necessary for protection of water quality (as discussed in both (a) and (b) above).*
- *TeckCominco has been sampling the water quality of Garrow Lake for excess of 20 years and has invested in a comprehensive model that has been regularly updated. This provides TeckCominco with a high degree of certainty in regards to predictions in terms of water quality objectives and the behaviour of Garrow Lake upon closure of the Polaris Mine.*
- *The cost of leaving the dam in place is substantial. It is also impractical from a logistics perspective. Leaving the dam in place after the island is abandoned would require personnel returning to the island each discharge season, establishing a camp and remaining on the island to operate the siphon system. This would be required on an annual basis until the decision is made to remove the dam. At that time, substantial heavy earth moving equipment, crews, a camp and fuel storage facilities would need to be re-established on the island. Roads would either need to left intact after mine closure or need to be re-activated to transport fill removed from the dam to the designated disposal area in Little Red Dog quarry.*
- *The Closure Plan proposes that Garrow Lake dam to be decommissioned by partially removing the dam. This in itself is a contingency. If conditions were to occur that required containment of the lake surface waters, it would be possible to reconstruct the dam, as approximately 70% of the material would still be in place.*
- *If during or after mine closure, monitoring results identify a significant departure from the predicted water quality over two successive sampling periods, TeckCominco will discuss with the Water Board and through it, other regulatory agencies, the course of action that may be necessary. If there is concern for the water quality exceeding the applicable standards, then one of the options that will be considered is the re-construction of the dam for the purpose of temporarily preventing discharge while a solution is implemented.*

d) *The reviewer recommends that forecasts of the total loading of contaminants that will be discharged from Garrow Lake subsequent to cessation of tailings disposal should be part of the decommissioning plan.*

- *Mr. Erickson has updated his forecasts utilizing SNP data collected in 2001 and extended time frame for the water quality forecasts originally presented in the Closure Plan. Utilizing this data, Mr. Erickson has developed a metal loading forecast for the potential metal of concern (Zn) as requested by the reviewer. This information is provided in Attachment #9.*

Appendix B

Section 1000 pg. 1 item 3 - It is indicated here that "tailings were deposited in the reservoir upstream of the dam". The fate of these tailings as part of the decommissioning process needs to be detailed. Clarification is needed as to whether tailings are present in the area between the historic outlet of Garrow Lake and the upstream dam face.

***TeckCominco Response***

– *The tailings referred to in the above section are the tailings deposited into Garrow Lake as per the Water Licence. It would have been clearer to refer to this as Garrow Lake rather than 'in the reservoir upstream'. At no time have tailings been deposited in the area between the dam and Garrow Lake.*

Section 1001 pg. 1 3.0 - In addition to a coffer dam, discharge during construction should be managed with a small diameter siphon that enables work in the vicinity of the dam to be conducted under dry conditions.

***TeckCominco Response***

– *As an update to the plan, removal of the dam will be scheduled for early spring conditions when there is no water flowing. If there is any residual work to be later, then any flowing water will be diverted around the work as a sediment control strategy. A pump or small diameter siphon would be used under these conditions.*

Section 1002 2.0.2 b - Excavation plans require finalization and approval prior to implementation.

***TeckCominco Response***

– *The proponent agrees.*

Section 1002 3.0 - "non-conventional excavation" methods should be submitted for approval at least five business days prior to proposed implementation.

***TeckCominco Response***

– *The proponent agrees.*

## Garrow Lake Water Quality

"*Garrow Lake Dam, Effect of Removal on Lake Stability and Outflow Water Quality*", Prepared by AXYS Environmental Consulting Ltd. and Applied Ocean Sciences, March 2001.

This report assesses the possibility of halocline erosion and tilting in Garrow Lake subsequent to the return of the lake to its historic elevation (1005.7 m?). While the model predictions indicate that it is unlikely that the waters below the halocline will mix into the surface layer there appears to be no monitoring program to assess the validity of the model predictions subsequent to restoration of the lake to its historic level. Vertical profiles of water chemistry within the lake should be undertaken annually in order to verify that the modeled predictions are correct. In this regard, removal of the dam or opening of a cut through the dam, should be deferred. Once the dam is removed there is no contingency presented to address elevated contaminant levels that may arise in the surface waters of Garrow Lake. Deferred removal of the dam would provide a contingency plan should it be needed. During the monitoring period, siphoning over the dam at a rate comparable to the historic Garrow Creek flow could be undertaken.

***TeckCominco Response***

- *The historic lake elevation is 1005.7 m.*
- *There has been regular monitoring of the vertical profile of the lake conducted 3 times per year as per requirements of the water licence. This has been done while the lake has had both an increasing and a decreasing thickness of the surface layer.*
- *The Closure Plan for Polaris contains proposals for monitoring of the lake as recommended by the reviewer (Section 7.1 'Post Closure Monitoring' in Volume 1). The monitoring plan has been subsequently updated specifying more detail and is presented in Attachment #8. This was done in response to reviews of the Closure Plan conducted by Environment Canada.*
- *The only mechanism that can supply the energy to mix the surface layer of Garrow Lake with the top of the halocline is wind energy. Paul Erickson of AXYS in his memorandum (Attachment #9) discusses the low probability of the top 2 metres of the halocline mixing with the surface layer of Garrow Lake. Using wind data from 1961 to 1990, the peak wind speed measured that lasted for approximately one hour was 105 km/hr. This peak wind speed would need to be continuously sustained for a 2.5 hour period to cause mixing of the top 1 metre of halocline. To mix the top 2 metres of the halocline a storm event would need to maintain a maximum wind speed of 105 km/hr continuously for at least 8 hours. At the same time, the storm event must also occur during the brief (or some times non-existent) ice-free period on the lake and the direction of the wind would need to be aligned along the length of the lake. Even if this highly unlikely event were to occur, the resulting zinc metal concentration in the surface layer of the lake would be 0.31 ppm compared to the current licence limit of 0.5 ppm. In addition, as the mine will not be placing water and tailings into Garrow Lake upon cessation of mining activities, both the quantity of water and the concentration of metals discharged from the lake will be reduced. As a result, metals loading discharged from the lake will be even lower.*
- *Peter Chapman and Cathy McPherson of EVS (Attachment #18) have reviewed the potential loading data and conclude that there is a lack of risk to aquatic life even if mixing of the top 2 metres of the halocline were to occur. In summary they state:*

  > *'Even assuming that worst case predictions regarding zinc concentrations in Garrow lake surface waters were to occur, removing the tailings dam to allow surface waters to flow into Garrow Creek and thus into Garrow Bay, will not create any risk of harm to the marine organisms in Garrow Bay.'*
- *The proponent strongly disagrees with the suggestion that the dam remain in place beyond 2004. The available data and facts do not identify a significant risk in partially removing the dam as planned. As previously identified by TeckCominco, the requirement to maintain the dam in place after 2004 would be extremely expensive and logistically impractical.*

The extent to which the area between the historic Garrow Lake outlet and the east face of the dam have been contaminated since construction of the dam has not been addressed. The potential for mobilization of contaminants from this area subsequent to restoration of the historic level of Garrow Lake should be addressed.

***TeckCominco Response***

- *The proponent assumes the above comment relates to the previous reference to' tailings being deposited in the reservoir upstream of the dam' ( Appendix B, Section 1000, pg. 1 item 3 of the Garrow Lake Dam Decommissioning report by EBA). As indicated earlier, this refers to the deposition of tailings into Garrow Lake as per the conditions in the Water Licence. It was not intended to refer to deposition of tailings into the flooded area between the dam and the lake, which has never occurred.*

The extent to which the inundated shoreline of Garrow Lake is likely to erode due to meltback of the permafrost has not been addressed. In the early 1970's Kuhulu Lake east of the Nanisivik Mine suffered this fate after a dam at the outlet of the lake was removed and the water level was lowered. Increased erosion around the perimeter of the lake does not appear to have been factored into the Garrow Lake stability modeling (increased TSS and TDS, increased settling of particles, etc.)

***TeckCominco Response***

- *The elevation of Garrow Lake is being reduced gradually over a number of years. This allows for gradual exposure of the shoreline and the re-establishment of permafrost to pre-mining conditions. The situation at Kuhulu Lake is not comparable to Garrow Lake. In Kuhulu Lake, the dam at the outlet of the lake failed catastrophically resulting in a sudden draw down of the lake. The shoreline was re-exposed in a very short period of time not allowing for either draining of the saturated shoreline materials or the re-establishment of permafrost. It is not clear whether the erosion of concern at the lake was the result of the shoreline being re-exposed in a short time period or the scouring of the old creek bed from the flood event resulting from the dam failing. The information related to Kuhulu Lake is discussed in the letter from EBA in Attachment #17.*
- *As proposed by EBA in Attachment #17, the proponent has modified the monitoring plan presented in the Closure Plan to include both regular measuring of TSS in the surface layer of Garrow Lake and visual monitoring of the shore stability (Attachment #8).*

The original Garrow Lake discharge permit limit (pg. 1) for zinc was 0.1ppm. During operations this limit was increased to 0.5 ppm, yet it now appears that a discharge of 0.3 ppm Zn will be permitted after decommissioning. The post decommissioning zinc concentration in the outflow from Garrow Lake should be comparable to the historic concentration in the surface waters of Garrow Lake rather than merely "below 0.3 ppm". To permit an ongoing discharge above the original permit level of 0.1 ppm would be irresponsible given the associated excess loading to Garrow Bay that would result from a higher limit. The water license limits for the post-decommissioning period should be revised accordingly.

***TeckCominco Response***

- *The memorandum previously referred to by Paul Erickson of AXYS (Attachment #9) forecasts that metals concentrations in the surface layer of the lake will return to less than 0.1 ppm by 2010.*
- *The reviewer states that to permit ongoing discharge above the original permit level of 0.1 ppm <u>is irresponsible.</u> The reviewer does not present any technical basis supporting this contention. However,*
  - *As presented in Attachment #18, EVS's expert opinion is that the metals loading (even if the top 2 metres of the halocline were to mix with the surface layer) does not present <u>any</u> risk of harm to the marine organisms in Garrow Bay.*
  - *Under renewal of the water licence in 1993 (which approved zinc concentrations in the surface layer of Garrow Lake up to a maximum of 0.5 mg/L) which underwent an environmental screening under the Environmental Assessment and Review Process Guidelines Order, the Minister stated:*

    > *'I am satisfied that any potentially adverse environmental and related socioeconomic effects that may be caused by this project are insignificant or mitigable with known technology'.*

    *If metals concentrations were to exceed the current licence and regulatory limits, then mitigation strategies using known technologies would be required. As long as metals concentrations remained within the licence permit levels, the environmental effects were stated to be 'insignificant'.*
  - *Current Metal Mining Liquid Effluent Regulations under the Fisheries Act authorize discharges of effluent from tailings impoundment (i.e. Garrow Lake) with concentrations of zinc up to 0.5 mg/L.*
  - *Forth-coming federal legislation under the Fisheries Act (Metal Mining Effluent Regulations) are expected to become law in 2002. Schedule 4 of the gazetted regulations <u>authorize</u> a discharge limit of 0.5 mg/L for zinc containing effluent from a tailings impoundment. Garrow Lake is specifically identified in these regulations as a 'tailings impoundment'.*

***Teck Cominco <u>strongly disagrees</u> that the plans proposed are 'irresponsible'***. *Being in compliance with current licences and regulations, proposing plans that are in compliance with current and forth-coming legislation, and having independent, expert opinions that the discharge does not present a risk to the marine environment based on science is not 'irresponsible'.*

Pg. 5 The fact that wind speeds sufficient to mix the top metre of the halocline with the surface water within an hour have occurred on site indicates the future possibility of such an event. The analysis does not examine sequential mixing, one year to another, that could result in progressive cumulative erosion of the halocline, especially if global warming results in gradual extension of the open water period on Garrow Lake thereby increasing the period for wind mixing events to occur. In theory it appears that progressive erosion of the halocline is a distinct possibility.

***TeckCominco Response***

- *The wind speed sufficient to mix the top metre of the halocline with the surface layer within an hour have not been measured or documented. This was stated on Page 5 of the report contrary to the reviewer's comment above. However, as stated in Attachment #9 from AXYS, Paul Erickson identifies that there was an error in Figure 4 of their report in the Closure Plan. The vertical axis in Figure 4 should have read duration in 'days' not 'hours'. The proponent assumes that this is the information that led the reviewer to believe that wind speeds have been sufficient to cause mixing of the top metre of the halocline.*
- *It should be noted that Mr. Erickson also states in the report in the Closure Plan that 'It is noteworthy that in the 18 years of mine operations, there has been no wind induced mixing of the main halocline'.*

Pg. 6 - Annual monitoring of the structure of the lake (DO, Temperature, salinity/conductivity, lead and zinc) at 2 m intervals in the surface layer, 1 m intervals in the halocline, and 2 m intervals beneath the halocline should be undertaken to document post-decommissioning changes. A post-decommissioning assessment of the presence of aquatic biota in the surface waters of Garrow Lake should be undertaken.

***TeckCominco Response***

- *As identified in a previous response to a question in this submission, TeckCominco has proposed regular sampling of the vertical composition of the lake substantially as requested by the reviewer. Details are included in Attachment #8.*
- *With respect to the request for a post-decommissioning assessment of the presence of aquatic biota in the surface layers of Garrow Lake, TeckCominco does not agree that this is necessary for the following reasons:*
  - *Garrow Lake was designated as a 'Tailings Impoundment Area' pursuant to Subsection 5(2) of The Metal Mining Liquid Effluent Regulations' under the Fisheries Act by the Minister of Fisheries and Oceans in 1981.*
  - *During the application period for the current Water Licence, DFO had requested studies to relate the relevance of data on metal concentrations in the water to those concentrations in fish and macro-invertebrates. The Water Licence granted did not require these studies to support the application or as a condition of the Licence.*
  - *New federal Metal Mining Effluent Regulations have been gazetted and it is expected that they will come into effect in 2002. Under the proposed legislation, Garrow Lake is specifically named as a tailings impoundment area. It is one of 5 lakes in Canada with this designation. Under the proposed regulations (which will be administered by Environment Canada), there will be the requirement to conduct Environmental Effects Monitoring ('EEM'). It is important to note that under the regulations, it is required to conduct the EEM downstream of the discharge point of Garrow Lake and not in the lake.*
- *TeckCominco does not propose to conduct an assessment of the presence of aquatic biota in the surface waters of Garrow Lake. However, if Environment Canada or DFO wishes to undertake an assessment program, TeckCominco would be prepared to provide logistical support for the work while we have facilities on the island.*

**Engineering Comments provided by Rick Gervais and Chris Katopodis are detailed below:**

## Polaris Mine Decommissioning

**Cominco Ltd. plans to decommission the Polaris Mine at the southwest end of Little Cornwallis Island, Nunavut, in 2002. The mine, which produces and ships lead and zinc**

**concentrates, is nearing the end of its life. There are two components to the proposed decommissioning plan: The Garrow Lake Dam and the Dock Facilities. Cominco Ltd. retained EBA Engineering Consultants Ltd. (EBA) to develop a closure design for the Garrow Lake Dam and Westmar to examine concepts for decommissioning the Dock Facilities and adjacent shoreline. The following comments are based on the review of the EBA (March 2001) and Westmar (October 2001) reports submitted to DFO by Cominco Ltd.**

## Garrow Lake Dam

The EBA report provides a fairly detailed examination of one alternative for decommissioning the Garrow Lake Dam. This alternative involves the partial removal of the dam and is heavily dependent on modelling predictions for the geothermal stability of the remaining dam embankments. Cominco Ltd., through this report, does not provide sufficient assessment of the more environmentally acceptable alternative of complete dam removal and site rehabilitation. In our opinion, the total removal of the dam and rehabilitation of the site would be the better choice for the following reasons:

- It minimizes or eliminates potential downstream sediment problems that may result from the gradual or sudden failure of the remaining dam embankments. Such failure may occur given long-term uncertainties with regards to temperature (global warming), modeling limitations, which may prove insufficient for accurate predictions, and the channeling of flow and erosion potential of Garrow Creek through the remaining embankments.

### TeckCominco Response

- *The slope of the banks of the partially removed dam are designed to be very flat (4H to 1V) and are similar in slope to the surrounding natural terrain. Complete removal of the dam does reduce the potential for slope failures any more than for the surrounding terrain.*
- *The shell material covering the residual dam structure is coarser and more erosion resistant than the natural surrounding hillsides providing a more erosion resistant cover than if the dam was completely removed.*

- According to the EBA report, removing the central portion of the dam would involve the removal of approximately 12,750 m3 of material with an additional 6,200 m3 of material to be over-excavated and then back-filled. Removal of the entire dam would involve approximately 49,000 m3 of material. A cost benefit analysis is needed to compare the alternatives of partial or complete dam removal, especially considering additional costs associated with correcting potential problems, which may result from partial dam removal.

### TeckCominco Response

- *Attachment #17 from A. Eglauer of EBA Engineering Consultants Ltd. ('EBA') includes a cost benefit analysis of complete removal of the dam compared to partial removal of the dam. Complete removal of the dam would at least double the cost and does not provide environmental benefits.*
- *The consultant views that both options are technically equivalent but the complete removal of the dam is $1,249,000 compared to $450,000. Complete removal of the dam is estimated to cost more than 2.7 times the cost of partially removing the dam.*
- *The Closure Plan proposes that Garrow Lake dam to be decommissioned by partially removing the dam. This in itself is a contingency. If conditions were to occur that required containment of the lake surface waters, it would be possible to reconstruct the dam, as approximately 70% of the material would still be in place. This would require less equipment to be re-mobilized, a smaller crew, and less support facilities would be required. Potential the work could be completed in a shorter time period as well.*

- The objective of the mine decommissioning plan, which was part of the original agreement, should be to rehabilitate the site to as close to it's natural state as possible.

### TeckCominco Response

- *The contouring of the partial removal of the dam will be done in a manner that blends it into the surrounding* terrain in a way that minimizes the unnatural appearance*. Given the local conditions it would not be possible to completely eliminate the visual impact of the dam regardless of whether the dam is completely removed or not.*

## Polaris Mine Dock Facilities

We agree that based on the 3 conceptual options for decommissioning the Polaris Mine Dock facilities presented in the Westmar report, the preferred option (Option 1) is the best choice to be investigated further. This option involves removing the dock 2 to 3 m below low tide (excavate or cut-off sheet piles underwater) and re-grading the beach to a low slope of 17.5H:1V for erosion control.

**In reviewing the drawings in Appendix D, a significant drop off (approx. 10 m) between the proposed ground-line and the existing ground-line will still exist where the dock sheet piles are presently located (see appendix D - sections sheet 3). The report states…"regardless of whether the sheet piles are cut-off or are extracted, the frozen fill will erode very slowly, and is not expected to have an impact on seabed habitat." However, because of vertical face of the drop off at this location and since the material in this face (probably) contains fill used in the sheet pile cells, justification as to why this vertical face will experience gradual erosion while other areas are being re-graded to a 17.5V:1H slope should be provided.**

### *TeckCominco Response*

- *After reviewing construction methods further since the submission of the Westmar report, contractors have indicated their preference to cut-off the sheet piles 2 metres below low tide level rather than to completely remove them. This approach to decommissioning the dock leaves the face of the dock 2 metres below low sea level undisturbed. The Coast Guard has approved this approach as discussed earlier in this submission.*
- *The sheet piles have been in place for over 20 years and remain in good condition. In addition, the residual sections of sheet pile would remain submerged, exposed to lower oxygen levels than near surface areas. Corrosion of the sheet piles will continue to be an extremely gradual resulting in a very slow process of deterioration.*
- *The foreshore at sea level is exposed to erosion from wave action. To minimize the erosion rates, the foreshore near sea level has been designed to a 17.5:1 slope. Wave energy reduces with depth and so slopes at increasing depth below sea level are exposed to less erosion than those at sea level.*

Prior to decommissioning, the results from the required detailed design work identified in the report (and restated below) should be supplied to DFO for review before any work is undertaken.

- Prepare accurate hydrographic surveys of the surrounding site.
- Incorporate the remedial excavation proposed in "Polaris Mine Decommissioning and Reclamation Plan" by Gartner Lee Ltd.
- Finalize the excavation plane through the dock to minimize the cut and fill volumes, within the ranges discussed in this report and based on remedial excavation requirements, while protecting the aquatic environment by minimizing erosion and sedimentation.

- Develop detailed procedures for the excavation process of the dock area to ensure protection of the aquatic environment during the process.

### ***TeckCominco Response***

- *The above comments are similar to ones made by Mr. B. Fallis in the section titled 'Dock Removal' and have been responded to by TeckCominco in that section of this submission.*

- Determine the gradations of the natural beach and fill materials to evaluate their rates of erosion.
- Assess the need to perform a thermodynamic analysis on the natural beach and fill materials, to determine the suitability of the proposed beach material to resist erosion based on the beneficial effect of permafrost.

### ***TeckCominco Response***

- *Referring to the photographs in the Westmar report in Volume 2 of the Closure Plan, photograph #5 of the shoreline at Station 1800 indicates the natural beach gravel has a mean size of approximately 10 mm. Note that the date is August 10, 2000 and the shoreline is already frozen. Photograph #8 is located closer to the dock (at Station 1600 N) and the fill material is all –300 mm with a mean size of 25 mm. In general the fill material is coarser on average than the natural beach material. Other photographs in the above report show areas nearer to the dock where rip-rap has been placed on the foreshore and are not representative of the material sizes that will be present after re-contouring of the dock and adjacent shorelines.*
- *The fill material exposed upon completion of re-sloping the dock and adjacent shore will consist of material originating from the hillside immediately up slope from the dock and consequently will be the same rock types that the original natural beaches were composed of. The fill material has been blasted and excavated from the hillside and placed in the dock cells and shore area. As a result, its mean size is larger than the original beach material.*
- *There is a very short period of the year where the foreshore above the high tide elevation remains thawed. As can be seen by the pictures referred to above, the exposed shoreline was frozen by mid August. The relative stability of the fill material can be seen in the photographs as evidenced by the steep slopes of the fill even in areas where they are not protected by rip-rap. The proposed flat slopes of the re-contoured beach will significantly reduce erosion rates over the current steep slopes.*
- *In arctic beaches, there are two distinct areas of degradation of permafrost (Taylor, 1980). The backshore areas experience limited permafrost degradation and is generally a thermally stable environment. Given this, it is expected in the backshore areas above this high water mark and wave action on the beach profile that permafrost will protect the area from erosion. Taylor (1980) shows that in the lower beach and foreshore areas, the permafrost table tends to be deeper primarily due to brine water moving in interstitial pore spaces in the beach material. Given this, there is typically no 'beneficial' effect of permafrost in arctic foreshore areas. However, it is important to note that these comments apply to the brief ice-free period at this latitude. With respect to slope processes, solifluction lobes and nivation hollows (see Figure 3 – Surface Geology Polaris Mine Area – 1999 Environmental Site Asessment, Volume 3 of the Closure Plan) are absent in the dock areas demonstrating the stability of local slopes.*

## Comments provided by Dennis Wright on blasting proposal:

## Review of Blasting Proposal – Decommissioning of Dock Facilities at Polaris Mine, Little Cornwallis Island

As requested, I have reviewed the blasting plan for the decommissioning of the dock facilities at the Polaris Mine site on Little Cornwallis Island. My comments are as follows:

The document is extremely deficient in terms of information concerning the project and therefore I am unable to render any decisions or provide the proponent with any recommendations. The proponent has gone to considerable effort to calculate the weight of charge to could be used at certain distances from the sheet piling in order to meet the DFO Explosives Guidelines overpressure maximum of 100 kPa. However, basic information such as timing of the project is missing from the project description. Without this basic information, I am unable to determine if the minimum requirements outlined in the guidelines will suffice with respect to the protection of fish and marine mammals from the harmful effects of explosives.

The proponent has also failed to provide any description of the existing biological environment. If the project is undertaken during the spring when there is still full ice cover in the area, then, marine mammals concerns will be minimized. However, if the project is to be undertaken during the open water period, the noise produced by the detonations may be disturbing to marine mammals, perhaps as far away as the walrus haul-out on Brooman Point on Bathurst Island. Similarly if pelagic fish eggs are present at the time of the blasting, the shock waves produced may be detrimental to the eggs. The DFO Explosives Guidelines provides a guideline of 13mm•$sec^{-2}$ as to the maximum peak particle velocity permitted where eggs are incubating in the substrate. However, we do not know the overpressure required to damage pelagic eggs, and so we would implement the precautionary principle if pelagic eggs were present and require the proponent to delay blasting until the eggs had hatched and the fry had developed.

***TeckCominco Response***

1. *The reviewer correctly identified that the application did not contain a description of the biological environment. While the Closure Plan contains a description of the marine environment, additional information has been researched and are provided below.*
   - *A dive survey in the vicinity of the dock took place in May 1999 and reported blennies, sculpins, other small bottom feeding fish, snails, clams, crabs, and shrimp in the vicinity. BC Research also described the areas of Garrow and Polaris Bays as providing habitat for pelagic arctic fish species such as arctic cod, which would presumably be found in Crozier Strait as well. BC Research reported that walrus have been seen in Crozier Strait and that there is evidence of them feeding in the vicinity of the dock. Seals, predominantly ringed seals, are also reported to use the area. The substrate is mainly sand and silt with some rocks which has been colonized with clams, anemones, urchins and various crustaceans such as shrimp and amphipods.*
   - *The sculpin likely spawns in the early spring as the literature reports that pelagic larvae begin to show up in samples in July. Arctic cod spawn under ice midwinter (end of December to early February). Generally marine mammals are not present in the area until the ice breaks up, however Polaris staff report the occasional observation of seals during the winter months.*
2. *Timing of Blasting*
   - *Blasting is planned to take place when there is full ice coverage during early winter months (late September to mid December). The primary reason is to avoid impact to spawning fish. There are no pelagic eggs present during this period and fry from the previous year have had an opportunity to develop. Prior to initiating a blast, a search for marine mammals within 500 m of the dock area would be made to ensure there are no animals present.*

The proponent states that it will be necessary to use an air-curtain to reduce the overpressure for certain shot configurations. However, no specifications for the construction, installation and operation of the air-curtain are provided. Similarly, the proponent gives no details as to mitigation techniques to be utilized should shaped linear charges be used to sever the sheet piling used in the dock cells.

***TeckCominco Response***

- *There were two references to the use of air curtains.*
  - a) *The use was proposed in relation to shaped linear charges. After receiving further information from contractors proposing to do the work, the proposal to use shaped linear charges has been deleted and consequently the use of bubble curtains are not required for this purpose.*
  - b) *The tables and discussions of blasting provided in Appendix H of the Westmar dock decommissioning report also made reference to the use of bubble curtains for blasting in near proximity to the dock face under the heading 'Blast Design' and in the attached calculation tables. This would be required if blasting were to be done within 1 metre of the dock face (see*

*calculations in Table 1 of Appendix H) or if blasting were to be conducted at a time when pelagic eggs were present. TeckCominco will not blast within one metre of the dock face, and the timing of blasting as discussed above will be done when no pelagic eggs are present. The use of a bubble curtain will not be required.*

As a minimum the proponent needs to complete the application forms (Appendices IV and V) provided in the DFO Explosives Guidelines, Canadian Technical Report of Fisheries and Aquatic Sciences 2107.

***TeckCominco Response***

– *The use of application forms in Appendices IV and V in the DFO Explosive Guidelines were not used for the following reasons:*
  - a) *Appendix IV is an 'Application Form for Authorization to Destroy Fish By Means Other Than Fishing'.*
    - – *The work methods proposed to conduct the work have been developed (and deficiencies are being addressed based on submissions from DFO and others) to protect the marine environment during the work process. These include protocols for the removal of glycol from freeze pipes, sediment control measures, monitoring of the work processes, timing of the work and developing blast designs consistent with DFO guidelines.*
    - – *A contractor with extensive blasting experience in and around aquatic environments was engaged to develop the designs proposed (Pacific Blasting and Demolition Ltd. in Vancouver, BC). They were contracted to ensure that the blasting designs are protective of the aquatic environment by complying with DFO guidelines with respect to controlling the maximum induced pressures in the aquatic environment and other parameters.*
  - b) *Appendix V is an 'Application Form to Harmfully Alter, Disrupt or Destroy Fish Habitat'.*
    - – *The proponent's plan to decommission the dock and shoreline has the specific objectives of restoring a more natural shoreline, providing a more stable shoreline in the long term and creating additional aquatic habitat. The intent of the proponent is to enhance the aquatic habitat of the site and not to harmfully alter it. DFO in this submission agrees that the proponent's proposal is the preferred approach subject to providing more detailed information.*
    - – *The application form selected for the submission ('Application for Authorization for Works or Undertakings Affecting Fish Habitat') was originally based on a request from DFO after reviewing the scope of the project as presented in the Closure Plan.*

*In summary, TeckCominco does not believe that above Appendices IV and V forms are appropriate and applicable for the decommissioning of the dock facility at the Polaris Mine.*

# ATTACHMENT # 6

## Response to Concerns Regarding Impoundment
## of
## Contaminated Soils in Permafrost

## Polaris Mine, Little Cornwallis Island, Nunavut.

## Dr. C Burn, dated December 4, 2001.

**Author**

The author is Professor of Geography at Carleton University, and has primary research interests in Permafrost and Ground Ice. The author's research is field-based, with the principal investigations being conducted near Mayo, central Yukon, and near the western Arctic coast. In 2001, Burn completed 20 consecutive summers' in the Mayo area. The field research in the western Arctic has been continuous since 1987. Burn has published 29 articles in refereed journals, 11 of which are in the *Canadian Journal of Earth Sciences*, Canada's flagship periodical for Earth Science. Burn has been retained by Water Resources Division, DIAND, Yellowknife, to provide advice regarding permafrost aspects of diamond mine developments in the Slave Province. Further details are listed on the attached vitae.

In 1995 Burn supervised a Master's thesis at Carleton University by Kim Winnicky entitled "On the permeability of frozen silt to organic contaminants". In 1996-97 he also conducted several tests to determine the permeability of frozen soil to diesel fuel. These were falling-head permeability tests conducted at temperatures down to -10ºC with sand and silt at various water contents. The results are unpublished due to a problem with the experimental apparatus, but the general behaviour of these media was qualitatively determined.

## Introduction

Mr Paul Partridge, Department of Sustainable Development, Government of Nunavut, has raised an important question in review of the Polaris Decommissioning and Reclamation Plan regarding the long-term effectiveness of permafrost as a containment medium for soil contaminated with hydrocarbons. The question is posed in Mr Partridge's letter of October 25, 2001, to Phillipe di Pizzo and Carl McLean. Mr Partridge provided further details in an email communication to Wayne Savigny, BCG Engineering, sent on November 21, 2001.

The question is whether permafrost may be considered impermeable to organic contaminants. Four recent papers were cited in support of this point, all published in the *Proceedings of a Workshop/seminar on Assessment and Remediation of Contaminated Sites in Arctic and Cold Climates* held in Edmonton during 1999. These papers are by Biggar and Nahir, Chuvilin *et al.*, Dyke, and White. The citations are:

Biggar, K.W., and Nahir, M. 1999. The behaviour of petroleum spills in permafrost soils. In *Proceedings, Workshop/seminar on Assessment and Remediation of Contaminated Sites in Arctic and Cold Climates, Edmonton, Alta., May 3-4, 1999*. pp. 45-51.

Chuvilin, E.M., Naletova, N.S., and Miklyaeva, E.M. 1999. Behabiour mineral and organic contaminants in permafrost. In *Proceedings, Workshop/seminar on Assessment and Remediation of Contaminated Sites in Arctic and Cold Climates, Edmonton, Alta., May 3-4, 1999*. pp. 52- 56.

Dyke, L.D. 1999. Solute migration from abandoned drilling mud sumps, Mackenzie delta area, N.W.T. In *Proceedings, Workshop/seminar on Assessment and Remediation of Contaminated Sites in Arctic and Cold Climates, Edmonton, Alta., May 3-4, 1999*. pp. 57.

White, T.L. 1999. Hydraulic properties of hydrocarbon contaminated permafrost affected soils. In *Proceedings, Workshop/seminar on Assessment and Remediation of Contaminated Sites in Arctic and Cold Climates, Edmonton, Alta., May 3-4, 1999*. pp. 58.

The abstract by Dyke has recently been published in full as:

Dyke, L.D. 2001. Contaminant migration through the permafrost active layer, Mackenzie Delta area, Northwest Territories, Canada. *Polar Record*, **37**: 215-228.

This response will outline the contributions of the papers that are pertinent to the question under discussion. These points will then be discussed in the context of the Polaris decommissioning plan. The stability of permafrost in the mine will be considered with respect to potential climate change.

## Contaminant migration into frozen soils

Frozen soils are multi-phase media, consisting of soil particles, ice, water, and vapour. If saturated, the pore space of frozen soils comprises ice and water. If unsaturated, the pore space comprises water and varying amounts of ice or air. The water is held in tension as films on the surfaces of the soil particles, and does not behave as free or bulk water, the substance we commonly encounter. Instead, the water is at a lower energy state due to electrical forces emanating from the edges of the soil particles. The water is adsorbed on to the soil particles and cannot move freely. As a result, frozen soil has a relatively low hydraulic conductivity.

The adsorbed water is commonly referred to as "unfrozen" water. The amount of unfrozen water in a soil depends on its temperature, the surface area of soil particles and the solute concentration in the water. The amount declines with temperature below 0ºC, but increases with the surface area of soil particles and the concentration of solutes in the pore water. The unfrozen water content of a soil is directly related to its hydraulic conductivity. So frozen sands, with a low surface area have little unfrozen water and very low hydraulic conductivity, and frozen clays the reverse. For further details see Williams and Smith (1989).

### Miscible and immiscible contaminants

There are, essentially, two types of contaminants. They are termed miscible in water or immiscible in water. Miscible contaminants dissolve in water and lower the freezing point of the solution. Road salt is a well-known miscible substance. When miscible contaminants are introduced into frozen ground, the pore ice dissolves in the contaminated, unfrozen, pore water. As a result, the contaminant may migrate into "frozen" ground, because the ground, below 0ºC has less pore ice to impede the flow of the solution through the pores. This is the type of contaminant migration described by *Dyke*, in his consideration of dispersion of drilling muds from sumps in the Mackenzie Delta area. The contaminants at Polaris are hydrocarbons, which are immiscible. These alter the behaviour of freezing soil in a different way.

Hydrocarbons do not dissolve in water, but they may be adsorbed by soil particles. *White* indicates that soil contaminated with hydrocarbons may change its microstructure upon freezing and thawing, so as to increase the permeability. The reorganization of the microstructure is achieved by aggregation of silt and clay in the presence of the contaminant, which tightens the packing of these particles. In other words, the contaminant is adsorbed onto the surfaces of the soil particles and increases the inter-particle attraction. The tightening of particle packing was accompanied by an increase in void space.

**Movement of hydrocarbons into unsaturated soil**

*Chuvilin et al*. present firm evidence from the laboratory that immiscible contaminants in the free liquid form may penetrate frozen soil. The observations in the laboratory are that hydrocarbon liquids, when applied to soil that is unsaturated by water (ice) and below 0ºC infiltrate the soil. The observations were replicated by Winnicky (1995) and in our own work. However, if the soil is saturated and frozen, little or no migration of contaminant into the soil has been detected. Similar observations are reported by Neufeld and Biggar (1996) as described by *Biggar and Nahir*. In some cases, however, in the experiments of Neufeld and Biggar (1996) a small amount of contaminant migration into saturated, frozen soil was detected. This was interpreted to be the result of infiltration into shrinkage cracks, not infiltration through the pore spaces of the soil.

*Biggar and Nahir* present field evidence for migration of hydrocarbons into frozen soil. These data come from assessment of contaminant levels in the active layer and permafrost at sites of fuel spills at Alert and Isachsen. The extent of infiltration of the contaminant into permafrost recorded at these sites was greater than possible by diffusion (movement of contaminant through the pore network). Again, the conclusion reached by *Biggar and Nahir* was that the movement of contaminant was along fissures and cracks in the soil. These authors also reported very high concentrations of contaminants above ice lenses, interpreting the lenses as barriers to hydrocarbon migration. They also noted that at Isachsen, where the top of permafrost was relatively icy, there was little concentration of contaminant. However, beneath the ice-rich zone, where the ground has less ice, the contaminant levels were higher. This suggests (1) that the movement of contaminants was through cracks penetrating the ice-rich layer, because under diffusion we would expect higher concentrations near the source of contamination – the soil surface; (2) that the hydrocarbons were absorbed into the drier ground once they had bypassed the ice-rich zone. *Biggar and Nahir* conclude that "(t)he mechanisms responsible for the contaminant migration are believed to be gravity drainage through interconnected air voids in fill material, or through fissures in the soil induced by thermal contraction."

In all of the cases described, the movement was from a source of liquid contaminant. *Biggar and Nahir* report that the lateral movement of contaminant in the fuel spills at Alert and Isachsen was limited, even within the active layer, possibly several years after the spills occurred. These data are important, because they may confirm the laboratory observations of *White* at field scale. Over several years there would be time for lateral migration of the contaminant within the active layer, but the limited dispersal may be because it was adsorbed by the soil. These field observations are of free liquid infiltration of unsaturated frozen ground, through empty void spaces and cracks, coupled with adsorption of contaminant by soil particles.

The following points summarize the foregoing discussion of contaminant mobility:

(1) Migration of contaminants into frozen ground has only been observed in the free liquid form.

(2) Soil particles absorb hydrocarbons onto their surfaces and bind them in the soil matrix.
(3) Ice lenses act as an effective barrier to the movement of contaminants in frozen ground.

### Impoundment of contaminants in permafrost at Polaris

The decommissioning plan for Polaris includes storage of contaminated soil underground. The soil has a low contaminant content, by weight up to 1.7%. There is no free liquid hydrocarbon in the contaminated soil. Rather, we must assume, following *White*, that the contaminated soils, have undergone several freeze-thaw cycles in the active layer at the ground surface, and, as a result, have adsorbed the hydrocarbons to their particle surfaces. In this state, the hydrocarbons are effectively immobilized, and as *Biggar and Nahir* reported from at Alert and Isachsen, their movement is arrested.

The data presented by *Biggar and Nahir* from field observations at Isachsen and laboratory studies by Neufeld and Biggar (1996) indicate that saturated, frozen ground, with the pore spaces blocked by ice is an apparently effective barrier to migration of contaminants. Therefore, the Polaris decommissioning plan may consider saturating and freezing the floors of the underground containment areas before depositing contaminated soil there. If the floors are marginally flooded several times with fresh water, then any pore spaces and fissures will be blocked, and the ground should be effectively impermeable to contaminants while it remains frozen.

### Operational data

The successful operation of the Polaris mine is also evidence of the impermeability permafrost, because the mine is close to the Ocean and below sea level. Data collected by mine staff indicate that during drilling below the 730 level of the mine (270 m b.s.l.) flooding occurred when the drill reached about 150 m depth (420 m b.s.l.). The flooding was by salt water. This observation indicates that the groundwater beneath the mine is under hydrostatic pressure. Staff have pointed out that pumping has not been necessary for mining at Polaris, indicating that the permafrost surrounding the mine has prevented seepage of groundwater. They conclude that the permafrost surrounding the mine workings is an impermeable barrier.

## Permafrost and climate change

The long-term use of permafrost to contain waste safely is predicated on the stability of ground temperatures. The prospect of climate warming due to an enhanced greenhouse effect has led to concern over the stability of permafrost in Northern Canada. The geothermal simulations presented in the Decommissioning Plan have been based on the scenarios provided by the Government of Canada for the Polaris region. These indicate an increase in mean annual air temperature of 3º to 5ºC over the next century. The diagrams describing the geothermal simulations for the landfill closure (Figs 3 – 6 in Supplementary Report 2) indicate that the present near-surface ground temperature is about –15º to -13ºC. These simulations have used a geothermal gradient of 0.0396ºC/m, obtained from earlier work by R.J.E. Brown.

**Thickness of permafrost at Polaris**

The thickness of permafrost, z, is given by:

[1] $$z = \frac{T_s}{g}$$

where $T_s$ is the surface temperature and $g$ the geothermal gradient. In this case, eq. [1] predicts a permafrost thickness of 378 m or 328 m for $T_s$ of –15ºC or –13ºC , respectively. These predictions are validated by the ground temperatures at Polaris presented in Fig. 7 of the Reclamation Plan. Figure 7 also indicates that "frozen" ground occurs at temperatures below -3ºC, because the surrounding groundwater is saline. The depth to the -3ºC isotherm is about 300 m below ground surface.

When the ground surface temperature changes, near-surface temperatures respond relatively rapidly, but ground temperatures at depth take longer to change. As the surface warms up, there is a very gradual warming at the base of permafrost due to geothermal heat flowing from the Earth's interior.

**Thawing of permafrost from below**

The rate of thaw of permafrost from below depends on the geothermal heat flux and the volumetric latent heat of the permafrost. At Polaris, staff have estimated the porosity of the bedrock to be between 6 and 16%. Using a value of 10% for bedrock porosity, and 3.0 x $10^8$ J/$m^3$ for the latent heat of fusion of ice, the volumetric latent heat of fusion of the bedrock is 3.0 x $10^7$ J/$m^3$.

The geothermal heat flow in the Polaris area is about 0.05 W/$m^2$ (Judge 1973). The rate of thaw of permafrost from below is:

[2] $$\frac{dz}{dt} = \frac{0.05\ Wm^{-2}}{3.0\,x10^{7}\ \ Jm^{-3}} = \frac{0.05\,x\,3.15\,x10^{7}\ \ Jm^{-2}\,yr^{-1}}{3.0\,x10^{7}\ \ Jm^{-3}} \approx 5\,cm\,yr^{-1}$$

**Time for ground to respond to climate warming**

Osterkamp (1984) describes the time constant, $\tau$, the time it takes permafrost of thickness *z* and fixed basal temperature to respond to a change in surface temperature:

$$[3] \qquad \tau = \frac{z^2}{4\kappa}$$

where $\kappa$ is the thermal diffusivity. The time constant is the time for the temperature gradient to become a straight line from the new ground surface temperature to the base of permafrost. In the case of Polaris, z is approximately 300 m for the frozen ground, and $\kappa$ for limestone is about 40 $m^2$/yr (Williams 1982, Tables 5.1, 5.2). The time constant for permafrost at Polaris is therefore about 550 years. During this time, the base of permafrost will have advanced upwards about 25 m, due to the geothermal heat flow.

The stopes proposed for impoundment of contaminated soil are presently at a temperature of between –7º and -8ºC. They are about 110 m above the -3ºC isotherm, or the base of frozen ground. If the ground surface temperature rises to -10ºC, then the equilibrium thickness of frozen ground, i.e. the depth to the -3ºC isotherm, will be about 175 m. According to Fig. 7, the contaminated soil storage areas will be above this level, i.e. in frozen ground. Therefore, the surface temperature will need to rise above -10ºC before there is a prospect of the area containing contaminated material being raised above -3ºC. However, it will take over 2,500 years for temperatures at depth to evolve to this state, due to the rate of heat flow from the Earth's interior.

**Conclusion**

The following points summarize the data on permafrost and climate change:

(1) Permafrost at Polaris will take over 500 years to respond at depth to changes in the ground surface temperature regime predicted for the next 100 years.
(2) During this time, the base of permafrost may migrate upwards about 15 m.
(3) A change in ground surface temperature of more than 5ºC will be needed to raise the base of permafrost into the areas where contaminated soil is to be stored.
(4) It will take several millennia for ground warming of this magnitude to occur at the depths in question.

## References

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Osterkamp, T.E. 1984. Response of Alaskan permafrost to climate. In *Proceedings, 4th International Conference on Permafrost, Fairbanks, Alaska, July 17-22, 1983*. National Academy Press, Washington, DC. Vol. **2**: 145-152.

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Williams, P.J., and Smith, M.W. 1989. *The Frozen Earth: Fundamentals of Geocryology*. Cambridge University Press, Cambridge.

Winnicky, K.L. 1995. *On the permeability of frozen silt to organic contaminants*. M.A. thesis, Department of Geography, Carleton University.

**Curriculum Vitae**

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*Current Position*: Professor of Geography, Carleton University

*Research topic*: Permafrost and ground ice in Yukon and Northwest Territories
1982-01 Arctic winter fieldwork for over 69 weeks,
summer field experience of over 42 months.

*Education*: B.Sc. (Geography) 1981, Durham University.
M.A. (Physical Geography) 1983, Carleton University
Ph.D. (Geology) 1986, Carleton University
PDF (Permafrost) 1986-88, UBC

*Honours*:
- 1981-86 Canadian Commonwealth Scholarship.
- 1989-98 NSERC University Research Fellowship.
- 1994-02 Associate Editor, *Canadian Journal of Earth Sciences*
- 1996 Fellow, Arctic Institute of North America
- 1997-98 President, Canadian Geomorphology Research Group
- 1998 Fellow, Royal Canadian Geographical Society
- 1998 Invited opening plenary lecture, 7th International Permafrost Conference
- 1998-01 Chair, Advisory Board to the Polar Continental Shelf Project, Natural Resources Canada
- 1999 Carleton University Research Achievement Award
- 2000 Governor, Royal Canadian Geographical Society

**Industrial experience**

- 2001 DIAND: Field course on Permafrost aspects of oil and gas development in the Mackenzie delta area.
- 2000 Yukon Energy Corporation: permafrost and ground ice conditions along proposed transmission line route between Mayo and Dawson City.
- 2000 Gartner Lee Ltd.: permafrost aspects of decommissioning of Polaris Mine, Little Cornwallis Island.
- 1998-2001 DIAND: permafrost aspects of Diavik Diamond Mines Application for Water Licence.
- 1996-1997 DIAND: permafrost aspects of mine proposals, Carmacks and Minto areas, YT.
- 1995 Yukon Energy Corporation and Mougeot Geoanalysis: implications for permafrost of lake level fluctuation, Aishihik Lake, YT.

1992 DIAND: permafrost aspects of pit wall design in placer mines, YT.
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1989 Life Member, Arctic Institute of North America.
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1985- Member, Canadian Quaternary Association.
1993- Research Associate, Northern Research Institute, Yukon College, Whitehorse.
1994- Research Associate, Aurora Research Institute, Aurora College, Inuvik.
1996- Member, Association of Geoscientists of Ontario

*Graduate students*:

Master's: 7 completed, 4 in progress
Doctoral: 1 in progress
Post-doctoral Fellows: 1 completed

# ATTACHMENT # 7

## LETTER TO B. DONALD FROM BART KOPPE

## OF CANTOX ENVIRONMENTAL

## REGARDING COMMENTS ON THE

## POLARIS MINE DECOMMISSIONING

## AND RECLAMATION PLAN

## SPECIFICALLY RELATED TO

## THE HUMAN HEALTH AND ECOLOGICAL RISK

## ASSESSMENT

CANTOX ENVIRONMENTAL INC.
#1800, 840 – 7 Avenue SW
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Telephone: 403 237-0275
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December 13, 2001

Mr. Bruce Donald, P.Eng.
Reclamation Manager – Polaris Mine Closure Plan
Teck Cominco Metals Ltd.
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Kimberley, B.C.
V1A 3E1

Dear Mr. Donald:

Re: Comments on the Polaris Mine Decommissioning and Reclamation Plan, specifically related to the human health and ecological risk assessment.

Please accept this correspondence as CANTOX ENVIRONMENTAL INC.'s (CEI) response to the concerns raised by the Department of Sustainable Development, GN in their October 25, 2001 letter addressed to the Nunavut Water Board and Indian and Northern Affairs (author: Paul Partridge: Coordinator, Claims Implementation and Land Use). The letter questions the adequacy of the human health and ecological risk assessment, as outlined by the following statements:

> *"… (CEI) consistently overlooked or dismissed rudimentary facts on wildlife such as the endangered status of the Peary caribou, or that they made the broad assumption that muskox are just large caribou; failing to take into consideration the differences in niches, the fact that they are more sedentary than caribou, and their increased ability to forage in hard snow conditions. It appears that they failed to do more than give wildlife a superficial glance in determining the acceptable limits for the [soil quality remediation objectives], as they fail to consider the influence of contaminants on anything but adult wildlife, which would be when wildlife is arguably the least susceptible to contaminants."*

To best alleviate these concerns regarding the derivation of the soil quality objectives, a concise overview of the ecological risk assessment protocol is presented, followed by clarification on the choice of the Peary caribou (*Rangifer tarandus*) as the representative key herbivorous species in the region and the assumptions employed to describe their potential exposure to the contaminants of concern.

## 1.0 Overview of the Ecological Risk Assessment Approach

Environment Canada (1994) states that the "ultimate goal of an ecological risk assessment (ERA) is to determine whether or not, and to what extent, remediation is necessary and, in cases where required, to help specify appropriate remediation targets".

Generic soil quality guidelines are derived to protect the *most sensitive* life stages of the *most sensitive* receptors that inhabit soils, sediment, or water. Guidelines relevant to soil contamination tend to be conservative values that are protective of a wide range of receptors under a broad range of environmental conditions.

The framework outlined in the National Contaminated Sites soil protocol provides the opportunity to move from these generic guidelines to site-specific remediation objectives, which in turn "allow the proponent to ensure that the assumptions used in the soil protocol apply to the site specific conditions." (CCME, 1999).

Although the guidelines are appropriate for use under a diverse array of environmental conditions, site-adapted environmental quality remediation objectives may be necessary under certain circumstances, such as at sites having:

- atypical characteristics (*e.g.*, high natural background levels of a contaminant);
- complex mixtures of contaminants;
- unusual exposure scenarios (*e.g.*, the presence or absence of relevant populations or receptors).

The unique nature of the Polaris mine site suggests that application of the generic soil quality guidelines would not have been appropriate for remediative purposes. The scarcity of vegetation in the area of the Polaris Mine results in a limited number of wildlife. The "barren and rugged" terrain of Little Cornwallis Island (Graham, 1982) precludes and/or limits the use of the area by both wildlife and human receptors. The atypical characteristics and unusual exposure scenarios indicative of the Polaris mine site necessitated the development of site-specific soil quality remediation objectives. The site-specific remediation objectives were determined through a CCME recommended risk-based approach (*i.e.*, risk assessment).

The guidance manual for the determination of soil quality remediation objectives states that:

> *When site conditions are outside what was considered in developing the guidelines using the soil protocol, or beyond the limited modifications outlined under the [criteria-based approach], the site-specific conditions may lead to a recommendation to perform risk assessment as the basis for developing site-specific remediation objectives (CCME, 1999, p 19).*

The use of risk assessment as the basis for developing remedial objectives is necessary where unique ecological conditions or land use differs considerably from the conditions used to develop the generic guidelines or the limited modifications allowed under the protocol modification method. Given the unique High Arctic ecology, and the Inuit traditional land use patterns, there was sufficient reason to apply risk assessment methodology in the development of the site-specific objectives for the Polaris mine site.

## 2.0 Derivation of Soil Quality Remediation Objectives

Soil quality remediation objectives are determined using the most sensitive receptors that may be exposed to the contaminants onsite. This means that the soil objectives derived for the Polaris mine site are considered protective of *any* terrestrial wildlife receptors expected to spend time at the reclaimed mine site.

Ecological receptor characterization evaluates basic biological characteristics and behaviour patterns of the selected ecological receptors, including detailed characterization of such receptor parameters as breathing rates, body weight, food ingestion rates, *etc*. The terrestrial wildlife receptors selected as part of the ecological risk assessment were not intended to include each of the large number of species that potentially could be found within the study area. Rather, the selection of the ecological receptors was based on careful consideration of several factors including: behavioural patterns that would increase the potential for chemical exposure, food chain structure, relative abundance and percentage of time spent within potentially impacted areas, availability of biological data describing their characteristics, traditional resource patterns and professional experience. It was assumed that by selecting those receptors that have the greatest exposure to chemicals of potential concern, the likelihood for occurrence of adverse effects to receptors receiving lower exposures would be adequately addressed.

Special consideration in ecological risk assessment is always given to any species that are classified as "endangered" or "threatened". The Committee on the Status of Endangered Wildlife in Canada has listed Peary Caribou as "threatened"[1] because of their low overall numbers.

The ecological risk assessment of the Polaris mine incorporated assessment endpoints that would potentially result in the reduction of such "threatened" populations as the Peary caribou. Assessment endpoints are in turn translated into measurement endpoints. To ensure the survivability and sustainability of all local wildlife, the ecological risk assessment selected such measurement endpoints as effects on survival, reproduction and growth. In other words, the assessment evaluated the most sensitive stages of a population's life cycle.

Muskox (*Ovibos moschatus*) was excluded from the ecological risk assessment for several reasons. On a "per body weight" basis, onsite exposure for muskox would actually be expected to be lower than those predicted for the caribou. Considering that the exposure limits would be the same between the two ungulates, ecological risks would actually be estimated to be higher for caribou. Caribou were assumed to represent all ungulate species that may spend time at the mine site (*e.g.*, foraging, breeding, *etc.*). Concerns related to the dwindling caribou populations were commonly voiced by regional Inuit hunters (from the communities of Resolute Bay and Grise Fiord).

CEI agrees with the Department of Sustainable Development's assertions that muskox are likely more sedentary than caribou and have an increased ability to forage in hard snow. It is important to note that the exposure assessment of the Peary caribou employed a number of conservative assumptions to ensure that potential risks would not be underestimated for this "threatened" species. The assessment assumed that caribou spend up to 25% of their time directly on the mine site. This would mean that local caribou populations would spend one quarter of their time on the relatively

---

[1] "threatened" classification refers to species that are likely to become endangered if limiting factors are not reversed

small area of the decommissioned mine site. Time spent onsite would therefore include foraging and breeding activities. The exposure assessment effectively assumed that caribou were sedentary. The same assumptions would have been made for the evaluation of muskox exposure. It is also important to note that Little Cornwallis Island has been characterized as a transition area for both caribou and muskox and that the actual time spent at or near the Polaris Mine area would be minimal for both groups of animals.

Interestingly, if local caribou populations would have been assumed to spend all their time feeding and breeding onsite, the results of the ecological risk assessment would not have changed and the soil quality remediation objectives would remain the same.

## 3.0 Closing

CEI is confident that the soil quality remediation objectives derived for zinc and lead at Teck Cominco's Polaris mine site will be adequately protective of both terrestrial wildlife and human health under the area's current and intended land use (as indicated by the community consultation). This conclusion seems to be supported by the Department of Sustainable Development, as outlined by their statement,

> *"It is understood that the mine is located in an area of marginal habitat, and that areas where the mine contributed to significant contributions of contaminants, as defined by the [soil quality remediation objectives] study, will be remediated. This, coupled with the fact that there were areas of high lead and zinc concentration exceeding these recommended limits prior to the mines inception, would support use of the values proposed by the study."*

In closing, the choice of Peary caribou as the representative ungulate species should be considered appropriate for the characterization of ecological risks because:

- caribou are listed as "threatened"
- caribou were assumed to be as sedentary as muskox
- caribou were expected to be exposed to a greater degree on a "per body weight" basis than muskox (i.e., higher potential chemical dose)

I trust that this information will satisfy your present requirements. Should you have any concerns or questions regarding this material, please don't hesitate to contact me directly at 403-237-0275.

Sincerely yours,
CANTOX ENVIRONMENTAL INC.

Bart Koppe, B.Sc., PBD (Tox)
Environmental Scientist

References

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# ATTACHMENT # 8

LETTER TO B. DONALD FROM S. MORISION
OF GARTNER LEE LTD.

REGARDING ‘RESPONSE TO ENVIRONMENT CANADA

REGARDING POST-CLOSURE MONITORING’

Dated December 21, 2001.

**Gartner Lee Limited**

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- Vancouver
- Whitehorse
- Yellowknife
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- Toronto
- St. Catherines
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January 2, 2001

TeckCominco Ltd.
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**Attention: Bruce Donald**
**Reclamation Superintendent**

Dear Mr. Donald,

**Re: Response to Environment Canada Letter re Post-Closure Monitoring**

This memorandum responds to the comments made by Lawrence Ignace of Environment Canada, Environmental Protection Branch on page 3 of the letter addressed to Dionne Filiatrault of the Nunavut Water Board on October 26, 2001.

## Background to Marine Studies

The results of analyses of sediment collected from Garrow Bay 1999 and comparisons to 1981 and 1984 data indicate that Garrow Bay has not been impacted by potential sources of metal contamination (Tables 8.4 and 8.5, Polaris Mine Decommissioning and Reclamation Plan, Volume III). Two of the three sediment samples collected from Polaris Bay (stations 3B and 3C on Figure 15, Volume III) contain zinc levels above the CCME probable effects level (PEL) and one of these (3B) contain lead levels above the CCME PEL. These results cannot be compared to baseline conditions as no pre-operational samples were collected here. Lead and zinc levels at these sites are higher than those at an upcurrent site farther from the shoreline (3A). Lead and zinc concentrations in soft tissue collected from station 3C were higher than levels in upcurrent station 3A (Table 8.6 Volume III). It is difficult to compare this data to pre-operational data collected in 1975 and 1978 as the locations sampled in these years are not clear.

While there is no information to suggest or to dismiss that the metals levels in the sediments of Polaris Bay are related to the effects of the adjacent landfill, the Closure Plan proposes isolation of the landfill that eliminates the potential for migration of metals contamination into the sediments.

All of the seven sediment samples collected from Crozier Strait in 1999 contain cadmium, lead and zinc levels above the corresponding CCME PEL. These results cannot be compared to baseline conditions as no pre-operational samples were collected here. As the area up-current from the dock and shoreline operations (station 4A) also contains these metals at high levels (above the PEL), it is possible to attribute these results to a naturally occurring dyke of mineralization associated with the Polaris ore body. Levels of cadmium, lead and zinc in soft tissue are elevated in samples collected from this area in 1984 and 1999. While there is no information to suggest or to dismiss that the metals levels in the sediments of Crozier Straight are related to the effects of the adjacent mine operations, the Closure Plan proposes remediation of the contaminated soil that eliminates the potential for migration of metals contamination into the sediments.

Environment Canada commented that in the marine environment, attempts of remediation of contamination may cause more problems than it solves and has recommended that "further monitoring [of the marine environment] should occur to determine if there is continued contamination into the future." This recommendation has been incorporated into the post closure monitoring plan outlined below.

## Post Closure Monitoring - Phase I

Environment Canada requested a more detailed monitoring program including the location of stations, parameters and frequency of sampling/observations. In response, the Phase I program is described below and clearly outlined in Table 1. In general, the Phase I program refers to monitoring conducted during the decommissioning and reclamation of the site from mid 2002 to October 2004.

### Dock Removal and Shoreline Grading

During the dock removal and shoreline re-contouring, best management practices will be followed to minimize impacts to marine habitat and life. This work is temporary in nature with the final result being improved shoreline habitat. A TeckCominco staff member will be assigned to monitor the shoreline work from an environmental perspective. This will include ensuring that:

- Work is done "in the dry" as much as possible;
- Deleterious substances are stored in a designated area away from the shoreline (50 m);
- Refueling of equipment is conducted away from the shoreline;
- Equipment to be used in the water is free of leaks and in good working order;
- Sediment-laden water is kept isolated from marine water as much as possible by physical barriers or by pumping it to settling locations;
- The mitigative measures outlined in the work plans (including dock removal process, refrigerant handling, blasting and timing) are followed; and
- Contingency measures are in place to deal with accidents including a written emergency response plan, presence of spill kits and workers trained in these procedures.

### Confirmatory Sampling for Excavation of Metals and Hydrocarbons in Soil

An excavation plan has been prepared that is based on analysis of soil samples from test pits and boreholes as compared to the soil quality remediation objectives (SQRO's). However, it is likely that the depth of excavation will vary from this design in some areas due to localized effects. A contaminant concentration confirmation procedure will be implemented that will ensure that the remedial objectives are achieved in an efficient and timely manner. During remediation of the areas indicated on Figure 19 of Volume I for lead and zinc and the areas indicated on Figure 20 in Volume I for petroleum hydrocarbons, on-site screening and confirmatory sampling will be conducted. The objective will be to capture at least 95% of soils containing contaminants in excess of the SQRO's in each remediation area. Contaminant concentrations in any residual soils will not exceed twice the SQRO's. This objective provides a realistic recognition of our experience in soil remedial work.

On-site screening of soil samples for contaminant concentrations will be conducted. This approach will prevent the delays and increased costs that would be encountered by the exclusive use of an off-site laboratory for on-site control. The on-site screening procedure will utilize analytical instruments that are designed for this purpose.

In areas where the design depth of excavation is 1.0 metres or less, the full design depth will be excavated prior to screening analysis. In areas where the design depth of excavation is greater than 1.0 metres, screening analysis will take place at the design depth and then at approximately 0.5 metre depth increments.

Excavation floor sampling will take place on a 25 metre grid (25 m by 25 m) wherein the area is divided into four quadrants. One discrete sample will be collected from each of the four quadrants and the four samples will be mixed together to form a composite for analysis. Excavation wall sampling will take place by each 25 metre wall length. One composite sample will be created from four discrete samples collected every 6.25 metre wall length at approximately 0.25 metres from the floor. One discrete sample will also be analysed for approximately every five composites to verify the representation of the composite method. The sample collection details may be modified slightly in the field based on the professional judgement of the field technician where this is necessary to maintain rigorous control in unique field conditions.

A screening analysis will be conducted on each sample collected. For screening analyses of metal concentrations, an instrument similar to the NITON 700 Series Multi-Element Analyzer might be utilized. The NITON instrument is a hand held analyzer that utilizes a radioisotope source ($^{109}Cd$) to analyze for 15 metals (including lead and zinc) and that is specifically designed for this type of application. The instrument is factory calibrated and reads bulk soil samples (i.e. no sample preparation required). The instrument must be licensed with the Atomic Energy Control Board of Canada because of the radioisotope source, which is a standard procedure. NITON information quotes detection limits of less than 150 mg/kg for zinc and less than 70 mg/kg for lead. For screening analyses of hydrocarbon concentrations, a photo ionization detector (PID) as well as visual and olfactory observations might be used.

Other field analytical instruments are available and could be utilized that operate in a similar manner to those described above. The detection limits and accuracy of analysis for the selected instruments would be confirmed prior to utilization at the mine site. This procedure will compare duplicate analyses of a suite of soil samples provided from the mine site utilizing the field analyzer and a professional, accredited laboratory. The duplicate suite of samples will attempt to be representative of soil types on the mine site and will consist of at least 25 soil samples.

A dedicated field technician will conduct the field screening analyses. A complete technical log of all sample analyses and locations will be maintained on the site by the technician. Sample locations will be ascertained by tape/chain survey.

Excavation of contaminated soils will proceed until the on-site screening procedures indicate that the excavation objectives have been achieved. At that time, a suite of confirmatory soil samples will be collected according to the sampling method described above for the field screening analyses. The confirmatory samples will be analyzed at an accredited off-site laboratory. Backfilling of excavated areas or other similar work in the areas of excavation will proceed only subsequent to the receipt of favourable results from the off-site laboratory.

**Garrow Lake Water Quality**

TeckCominco proposes to conduct routine monitoring at Garrow Lake from mine closure to 2004 based on a modified Water License Surveillance Network Program (SNP, to expire December 31, 2002). Note that the plan assumes that the dam will be decommissioned in 2004 and that the current monitoring associated with the input of tailings to the lake will not be required, as this operation will be discontinued in 2002. This routine monitoring includes:

- Measuring the water level of the lake (at the lake centre, station 262-3) during break-up and prior to freeze-up;
- Measuring the height of the tailings pile at station 262-2 on a monthly basis, when not prohibited by ice until deposition of tailings ceases in late summer 2002;
- Collection of water samples from station 262-3 three times a year during mid-winter, maximum ice thickness and maximum ice melt. Water will be collected from depths of 3, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22 and 40 m during mid-winter and maximum ice thickness and from depths of 0, 1.5, 3, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22 and 40 m during open water. Analyses of each sample will be for total lead, total zinc, pH, temperature and conductivity;
- Collection of water samples from station 262-3 three times a year during mid-winter, maximum ice thickness and maximum ice melt from depths of 3 and 10 m during mid-winter and maximum ice thickness and from 0, 1.5 m, 3 and 10 m depths during open water. Analyses of each sample will be for total copper, cyanide, cadmium, antimony, nickel, arsenic and mercury;
- Collection of water samples from station 262-3 three times a year during mid-winter, maximum ice thickness and maximum ice melt from a depth of 1.5 m for analysis of total suspended solids;
- Visual inspection to note stability of the Garrow Lake shoreline weekly between ice break-up and freeze-up;
- Collection of water samples from station 262-7 (the water discharge siphons at the dam) every 7 days during periods of discharge for analysis of total lead, total zinc and pH; and
- Daily measurements of effluent volume during discharge at station 262-7.

**Landfill Temperatures**

Monitoring of the temperatures at the Operational Landfill will continue on a monthly basis except during placement of the engineered cover. Once the cover is completed, three monitoring holes will be maintained (or re-established, if damaged) so the thermal conditions of the engineered cap and the landfill can be monitored on a monthly basis during Phase I. Monthly monitoring of the temperatures at the LRD Landfill will begin following placement of the engineered cap by establishing three monitoring holes.

**Metals in Vegetation**

During the summer of 2004, a vegetation sampling program similar to that conducted in 2000 (an expansion of the 1974 and 1999 programs) to determine metal levels in vegetation in areas around the mine site will be conducted. The year 2000 program included collection of up to four discrete vegetation samples:

1. the entire vegetative body of lichen (*Thamnolia subuliformis*);
2. the current season's growth of leaves and stalk from the Arctic willow (*Salix arctica*);
3. the current season's growth of leaves and stalk from grass (*Alopecurus alpinus*); and
4. cleaned roots of the Arctic willow.

Where these species are present at each of 13 sites (B, C, D, E, G, H, I, J, K, L, M, N, O, Figure 3 of Volume IV), analysis of each discrete dry sample (up to 4) at each site will be undertaken for lead and zinc concentrations. This data will be compared to previous results from 1975, 1999 and 2000 to note any changes in metal levels.

### Metals in Marine Sediment

A marine sediment sampling program will be conducted from the ice in May or early June of 2004 to monitor the status of lead and zinc sediment concentrations. Samples will be collected from station 3B (offshore from the Operational Landfill) in Polaris Bay and from stations 4A and 4C in Crozier Straight (Figure 15, Volume III). At each of these sites, three samples will be collected and composited for analyses of metals and other relevant parameters. These three sampling locations represent an up-current "control" site and locations with current lead and zinc concentrations that exceed federal guidelines.

## Post Closure Monitoring - Phase II

The Phase II program involves measurements, analyses and visual inspections following the mine closure through until 2011. The program is described below and clearly outlined in Table 2.

### Garrow Lake

At station 262-3 on Garrow Lake, a vertical profile of temperature, salinity and conductivity is to be completed while the ice is still on the lake (May or June) during 2005, 2006, 2008 and 2011. At the same time, water samples are to be collected from each of the surface layer, the halocline and the deep water layer for analyses of total lead and total zinc. A water sample will be collected from a depth of 1.5 m for TSS analysis.

Wind speeds will be monitored at the climate station on Resolute Bay from late July to freeze-up from 2005 to 2011. During open water, if a wind event occurs that could result in the mixing of the top 1 m of Garrow Lake (see Figure 3 in Section 3 of Volume II) a vertical conductivity profile of the lake is to be taken at station 262-3 and water samples collected here at the surface and from the halocline for total zinc analysis. This work will be done prior to freeze up, if it is safe to do so.

### Surface Water

Brief inspections (1 to 2 days) are planed to occur in late July/early August of 2005, 2006, 2007, 2009 and 2011. During these visits, if surface water is present at the discharge point from Garrow Lake, a water sample will be collected and analyzed for pH, total lead, total zinc and TSS. Water samples will be collected from the Loon Lake outlet creek and analyzed for pH, total lead and total zinc. Where surface water is present on the site samples will be collected and analyzed for pH, total lead, total zinc and if required, hydrocarbons.

### Landfill Temperatures and Visual Observations

Additional monitoring tasks to be completed during the late July/early August of 2005, 2006, 2007, 2009 and 2011 scheduled visits includes:

- Recording temperature readings from the three thermistor strings at the Operational Landfill and from the three thermistor strings at the LRD Quarry Landfill;
- Visual observations to confirm stability of the physical features of the site, primarily related to erosion, including at:
    - Garrow Lake and Garrow Creek - surrounding slopes
    - Operational Landfill - surface
    - LRD Quarry Landfill - surface

- Site roadways - surface and side slopes
- Marine shoreline - along the length of the decommissioned area
- New quarry area - ground surface
- Underground mine workings - ground surface above this area
- Mine subsidence area - confirm that there is no significant ground movement that would present a public safety hazard; and
- Visual inspection of the integrity of the seals at each mine entrance.

**Metals in Vegetation**

During the summer of 2011, a vegetation sampling program will be completed similar to that conducted in 2000 and 2004 (an expansion of the 1974 and 1999 programs) to determine metal levels in vegetation in areas around the mine site. The year 2000 program included collection of up to four discrete vegetation samples:

1. the entire vegetative body of lichen (*Thamnolia subuliformis*);
2. the current season's growth of leaves and stalk from the Arctic willow (*Salix arctica*);
3. the current season's growth of leaves and stalk from grass (*Alopecurus alpinus*); and
4. cleaned roots of the Arctic willow.

Where these species are present at each of 13 sites (B, C, D, E, G, H, I, J, K, L, M, N, O on Figure 3 of Volume IV) an analysis of each discrete dry sample (up to 4) at each site will be undertaken for lead and zinc concentrations. This data will be compared to previous results from 1975, 1999, 2000 and 2004 to note any changes in metal levels.

**Metals in Marine Sediment**

A marine sediment sampling program will be conducted from the ice in May or early June of 2011 to monitor the status of lead and zinc sediment concentrations. Samples will be collected from station 3B (offshore from the Operational Landfill) in Polaris Bay and from stations 4A and 4C in Crozier Straight (Figure 15, Volume III). At each of these sites, three samples will be collected and composited for analyses of metals and other relevant parameters. These three sampling locations represent an up-current "control" site and locations with current lead and zinc concentrations that exceed federal guidelines. This data would be compared to previous results, including the results of the 2004 sampling program, to identify significant trends.

We hope that the marine sediment comments and post closure monitoring plan outlined above provides the information required. Please contact the undersigned at (403) 262-4299 with any questions.

Yours truly,
GARTNER LEE LIMITED

S.R. Morison, Manager Northern Canada and Alberta

**Table 1. Outline of Post Closure Monitoring - Phase I**

| Area | Station Locations | Parameter(s) | Frequency | Duration |
|---|---|---|---|---|
| Dock and shoreline | dock removal and shoreline grading | visual environmental monitoring | daily | Through period of excavation |
| Metal contaminated soils | see Figure 19 in Volume I of Polaris Closure Plan | lead, zinc | screening and confirmatory sampling during remediation | Until remedial objectives achieved |
| Hydrocarbon contaminated soils | see Figure 20 in Volume I of Polaris Closure Plan | petroleum hydrocarbons | screening and confirmatory sampling during remediation | Until remedial objectives achieved |
| Garrow Lake | 262-3 (lake centre) | water level | during break-up and prior to freeze-up | mid 2002 to October 2004 |
| Garrow Lake | 262-2 (above tailings discharge point) | height of tailings pile | monthly, when not prohibited by ice | mid 2002 to late summer 2002 when tailings deposition ceases |
| Garrow Lake | 262-3 (lake centre) at water depths of 3, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22 and 40 m and also at 0 and 1.5 m during open water | total lead, total zinc, pH, temperature, conductivity | 3 times per year (mid-winter, maximum ice thickness and max ice melt) | mid 2002 to October 2004 |
| Garrow Lake | 262-3 (lake centre) at water depths of 3 and 10 m and also at 0 and 1.5 m during open water | total copper, cyanide, cadmium, antimony, nickel, arsenic, mercury | 3 times per year (mid-winter, maximum ice thickness and max ice melt) | mid 2002 to October 2004 |
| Garrow Lake | 262-3 (lake centre) - at water depth of 1.5 m. | TSS | 3 times per year (mid-winter, maximum ice thickness and max ice melt) | mid 2002 to October 2004 |
| Garrow Lake | perimeter of lake shoreline | visual observation for stability of shoreline | weekly between break-up and prior to freeze up | mid 2002 to October 2004 |
| Garrow Lake Dam | 262-7 (water discharge siphons at dam) | total lead, total zinc, pH | every 7 days during periods of discharge | mid 2002 to October 2004 |
| Garrow Lake Dam | 262-7 (water discharge siphons at dam) | volume of effluent | daily during periods of discharge | mid 2002 to October 2004 |
| Frustration Lake | | water volume | monthly total pumped in $m^3$ | mid 2002 to October 2004 |
| Garrow Lake Dam | dam core | temperature | monthly | mid 2002 to October 2004 |
| Operational Landfill | 3 monitoring holes | temperature | monthly | mid 2002 to October 2004 |
| LRD Quarry Landfill | 3 monitoring holes | temperature | monthly, following capping | mid 2002 to October 2004 |
| Vegetation | B, C, D, E, G, H, I, J, K, L, M, N, O on Figure 3 of Volume IV of Polaris Closure Plan | lead and zinc in dry Arctic willow roots, Arctic willow shoots, grass shoots and whole lichen body | once | Summer of 2004 |
| Marine sediment sampling | stations 3B, 4A, 4C on Figure 15 of Volume III | lead and zinc in sediment | once | May/June 2004 |

## Table 2. Outline of Post Closure Monitoring - Phase II

| Area | Station Locations | Parameter(s) | Frequency | Duration |
|---|---|---|---|---|
| Garrow Lake | 262-3 (lake centre) at surface, halocline and deep layers | total lead, total zinc, pH, temperature, conductivity, salinity | annually during May/June | 2005, 2006, 2008, 2011 |
| Garrow Lake | 262-3 (lake centre) - at water depth of 1.5 m | TSS | annually during May/June | 2005, 2006, 2008, 2011 |
| Resolute Bay | climate station | wind speed | annually from late July to freeze-up of Garrow Lake | 2005 to 2011 |
| Garrow Lake | 262-3 (lake centre) at water depths of 3, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22 and 40 m | total lead, total zinc, pH, temperature, conductivity, salinity | following a wind event that could result in the minxing of the top 1 m of the lake (see Figure 3 in section 3 of Volume II) | during open water (late July to freeze-up) from 2005 to 2011 |
| Garrow Lake | discharge point | pH, total lead and zinc, TSS | annually during July/August visit, if discharging | 2005, 2006, 2007, 2009, 2011 |
| Site surface water | any observed surface flows | pH, total lead and zinc, hydrocarbons | annually during July/August visit, if discharging | 2005, 2006, 2007, 2009, 2011 |
| Loon Lake outlet creek | at discharge to ocean | pH, total lead and zinc | annually during July/August visit, if discharging | 2005, 2006, 2007, 2009, 2011 |
| Operational Landfill | 3 monitoring holes | temperature | annually during July/August visit | 2005, 2006, 2007, 2009, 2011 |
| LRD Quarry Landfill | 3 monitoring holes | temperature | annually during July/August visit | 2005, 2006, 2007, 2009, 2011 |
| Garrow Lake and Garrow Creek | surrounding slopes | visual inspection of physical stability | annually during July/August visit | 2005, 2006, 2007, 2009, 2011 |
| Operational Landfill | surface | visual inspection of physical stability | annually during July/August visit | 2005, 2006, 2007, 2009, 2011 |
| LRD Quarry Landfill | surface | visual inspection of physical stability | annually during July/August visit | 2005, 2006, 2007, 2009, 2011 |
| Site roadways | surface and slopes | visual inspection of physical stability | annually during July/August visit | 2005, 2006, 2007, 2009, 2011 |
| Marine shoreline | area of decommissioning | visual inspection of physical stability | annually during July/August visit | 2005, 2006, 2007, 2009, 2011 |
| New quarry area | ground surface | visual inspection of physical stability | annually during July/August visit | 2005, 2006, 2007, 2009, 2011 |
| Underground mine workings | ground surface | visual inspection of physical stability | annually during July/August visit | 2005, 2006, 2007, 2009, 2011 |
| Mine subsidence area | ground | visual inspection of ground movement | annually during July/August visit | 2005, 2006, 2007, 2009, 2011 |
| Mine entrances | seals | visual inspection of integrity of seals | annually during July/August visit | 2005, 2006, 2007, 2009, 2011 |
| Vegetation | B, C, D, E, G, H, I, J, K, L, M, N, O on Figure 3 of Volume IV | lead and zinc in dry Arctic willow roots, Arctic willow shoots, grass shoots and whole lichen body | once | summer of 2011 |
| Marine sediment sampling | stations 3B, 4A, 4C on Figure 15 of Volume III | lead and zinc in sediment | once | May/June 20011 |

# ATTACHMENT # 9

# MEMORANDUM TO B. DONALD FROM PAUL ERICKSON of AXYS ENVIRONMENTAL CONSULTING LTD.

## REGARDING

## ‘GARROW LAKE DAM – EFFECT OF REMOVAL ON LAKE

## STABILITY AND WATER QUALITY RESPONSE TO

## COMMENTS BY DFO’

**dated December 14, 2001.**

AXYS | Axys Environmental Consulting Ltd
PO Box 2219, 2045 Mills Road West
Sidney, British Columbia, Canada. V8L 3S8

# Memo

**To:** Bruce Donald, Teck Cominco

**From:** Paul Erickson

**Date:** December 14, 2001

**Re:** **Garrow Lake Dam – Effect of Removal on Lake Stability and Water Quality Response to Comments by DFO**

## 1. Background

Bruce Fallis of DFO asked whether sequential or progressive mixing of the halocline had been considered. In addition, he was concerned about the loading of contaminants in particular Zn that would be discharged from Garrow Lake subsequent to closure of the mine. These questions are addressed below:

## 2. Sequential Mixing

There was an error in Figure 4 of our report. This may have resulted in some confusion about what was stated on page 5. The vertical axis in figure 4 should read Duration in days not hours. The text on page 5 of the report which refers to Figure 4 is correct however.

Sequential (year to year or event to event) mixing of the top of the halocline into the surface layer is possible. The present model assumes there is some annual mixing of the top of the halocline but at a low rate. Major wind events over open water will result in higher rates of mixing. As the halocline is mixed into the surface layer however, the surface layer deepens and the energy to further mix the top of the halocline increases. A summary of the wind speeds and duration required to mix the halocline into the surface layer by 1 m increments in a single event or in a series of isolated or individual events is given in Tables 1 and 2 (attached). Actual mixing times to mix more than the top 1 m will be longer since the percentage of wind-derived energy reaching the top of the halocline will be less than the 4 % assumed.

It should be stressed that even if the present halocline with its Zn maximum were to be mixed into the surface layer after draw down of the lake, there would still be a halocline present and the stability of the lake not threatened. The increased salinity of the surface layer (12.9 ppt) would still be far less than in the bottom layer (68 ppt). A “new” halocline would separate the deeper more saline surface water from the bottom layer.

## 3. Zinc Loading

The following discussion looks at dissolved Zn. Lead concentrations are currently more than a factor of 10 less than the current License limits and, as there is no longer a maximum present in the halocline, no source of excess Pb exists in Garrow Lake that might increase surface layer concentrations.

Concentrations of Zn in the Surface Layer are considered below for three different post-dam scenarios: 1) no mixing of the halocline with the surface layer (greater than already assumed in the model); 2) mixing of the top 1 m of the halocline into the surface layer, and 3) mixing of the top 2 m of the halocline including the Zn maximum into the surface layer. **Predictions are given for the first year of natural drainage after the dam is removed which represents a worst case situation. Zn concentrations are expected to decrease each year after removal of the dam. Model predictions have been updated to include the 2001 SNP data.**

### a) No Mixing

Current model predictions are that the surface layer will have Zn concentrations of 0.24 ppm when the dam is removed in 2004. Concentrations are predicted to decrease to less than 0.1 ppm by 2010 (figure 1). The Zn maximum in the halocline is expected to decrease to 0.88 ppm by 2004 and to about 0.33 ppm by 2010 (figure 2).

### b) Partial Mixing

If the top metre of the halocline were mixed into the surface layer in the first summer after removal of the dam, the Zn concentration in the surface layer would increase by 0.015 ppm to 0.26 ppm, the surface layer depth would increase to 8.5 m and the mean salinity to 9.4 ppt. In this situation, concentrations would still decrease to 0.1 ppm by 2010.

### c) Mixing of the Zn maximum in the halocline into the Surface Layer

Should the top 2 m of the halocline be mixed into the surface layer after removal of the dam, Zn concentrations would increase by 0.07 ppm to 0.31 ppm, the surface layer depth would increase to 9.5 m and the mean surface salinity increase to 12.9 ppt. Natural processes would decrease Zn concentrations to less than 0.1 ppm in nine years.

## 3.1 Zinc loading in Garrow Creek after dam removal

Although the title of the report referred to outflow water quality, the report gave only predicted concentrations of Zn in the surface layer of the lake. There is a tendency to assume that the concentrations of metals in Garrow Creek will be the same as those in Garrow Lake. This is not the case.

Until Garrow Lake clears of ice, the water at the surface of Garrow Lake is a combination of ice and snow melt. Because of its lower density, melt water floats on top of the brackish water of the surface layer isolating the surface water of Garrow Lake from Garrow Creek. Concentrations of Zn under these conditions reflect melt water concentrations regardless of the Zn concentration in the surface layer.

When the Lake is ice free, the melt water can be mixed by wind into the underlying surface layer producing a well mixed surface layer. However, even under these conditions, the water in Garrow Creek has lower concentrations of Zn than in the surface layer of the lake presumably as a result of dilution with surface run-off. Based on SNP data from 1985 to 1989, Zn concentrations were never more than half of the corresponding concentrations of Zn at the surface of Garrow Lake (note: 1985 to 1989 were the years prior to constructing the dam when surface layer Zn concentrations were increasing as a result of a tailings spill in the winter of 1985).

Calculating a loading of Zn to Garrow Bay must therefore take into account these factors. Estimates of Zn loading relative to original license limits are estimated in Table 3 for the predicted post-mine surface layer Zn concentration and for the Zn concentration that would be present should the upper 2 m of the halocline be mixed into the surface layer as described above. These calculations are for a year where the lake becomes ice free by the beginning of August and assume a dilution factor of 2 in the open water period. Although in the years from 1982 – 1989 more than 70 % of the flow in Garrow Creek occurred while the lake was ice covered, a figure of 60 % has been used in the calculations. The total flow through Garrow Creek has been set at 2.3 $Mm^3$ which was the maximum flow through Garrow Creek from 1982 – 1989 (less the contribution from tailings input). The calculations therefore present a worst case scenario for total loading in Garrow Creek. The estimates indicate that in the case of predicted post mine concentrations in Garrow Lake, the loading in Garrow Creek would be less than the original licence limit, and about 35 % greater than the original licence limit assuming a worst case scenario of mixing in Garrow Lake and dilution in Garrow Creek.

An actual total Zn loading through Garrow Creek is also given for 1989 based on SNP data from station 262-5. This provides a good reference for the post-mine scenarios as 1989 was a year in which there was natural outflow from Garrow Lake, the lake cleared of ice in August and mean surface layer Zn concentrations (as high as 0.36 ppm) were close to the predicted level of 0.31 ppm should the top 2 m of the halocline be mixed into the surface layer. The total loading in 1989 was about half the calculated worst case post mine loading scenario.

## 4. Revised Model Predictions

The 2001 SNP data has been used to provide updated predictions of Garrow Lake properties. Figures 1 through 5 give observed values through 2001 and predicted values for:

- Dissolved zinc in the surface layer
- Dissolved zinc in the halocline
- Bottom layer salinity
- Surface layer salinity
- Vertical salinity/depth profile for 2001.

### TABLE 1. POST-MINE MIXING OF THE HALOCLINE INTO THE SURFACE LAYER

| Layer to be Mixed metres | Mixing Work $10^6$ ergs/cm$^2$ | Wind Energy $10^6$ ergs/cm$^2$ | Wind Duration hours |
|---|---|---|---|
| 7.5 – 8.5 | 0.45 | 11.3 | 2.7 |
| 8.5 – 9.5 | 1.39 | 34.7 | 8.1 |
| 9.5 – 10.5 | 1.99 | 49.7 | 11.6 |
| 10.5 - bottom* | 28.36 | 708.9 | 166.2 |

### TABLE 2. POST-MINE SINGLE EVENT MIXING

| Depth of Mixing metres | Mixing Work $10^6$ ergs/cm$^2$ | Wind Energy $10^6$ ergs/cm$^2$ | Duration hours |
|---|---|---|---|
| 8.5 | 0.45 | 11.3 | 2.7 |
| 9.5 | 1.84 | 46.0 | 10.8 |
| 10.5 | 3.83 | 95.7 | 22.4 |
| Bottom* | 32.19 | 804.7 | 188.6 |

***Note:** The starting point for these calculations is the salinity distribution expected after mill activity ceases, and after draw down has restored the lake to its original level. The surface mixed layer will be 7.5m deep with salinity 8 ppt and temperature 2 $^0$C; the bottom mixed layer will have salinity 68 ppt and temperature 8 $^0$C; and the halocline will be 2m thick with salinity increasing linearly between the surface and bottom layers.

Mixing work is that required to mix the indicated layer into the overlying surface mixed layer, and is set to a constant 4 percent of surface wind-derived energy. This is a good approximation for the initial case of surface layer depth of 7.5 m but the percentage will be less as the surface layer gets deeper. However, for the purposes of these calculations 4 % has been used regardless of surface layer depth. Wind duration is calculated for the maximum hourly wind speed recorded at Resolute (29 m/s; 105 km/h). For other wind speeds W the duration should be multiplied by the factor $(29/W)^3$, e.g., for W = 14.5 m/s (52 km/h) listed duration values should be multiplied by 8. **The bottom depth was taken as the mean depth for the lake of 24.5 m.**

## Table 3. Annual Discharge of Dissolved Zinc through Garrow Creek

### i) Original Water License Limit

Original water licence allowed for average Zn concentrations in Garrow Creek of 0.1 ppm. Assuming the maximum flow of 2.3 $Mm^3$ recorded in Garrow Creek between 1982 and 1989, the total loading limit for a season was therefore:

$2.3\ Mm^3 \times 0.1\ g/m^3 =$ **230 kg.**

### ii) Post-Mine

Present predictions are that the surface layer Zn concentrations will be 0.24 ppm the first year that natural outflow occurs from the lake after dam removal.

Maximum loading in Garrow Creek would be:

Loading while the lake is ice covered + loading when the lake is ice free, or

$(1.38\ Mm^3 \times 0.066\ g/m^3) + (0.92\ Mm^3 \times 0.24/2\ g/m^3) =$ **206 kg**

assuming a flow of 2.3 $Mm^3$, 40 % of the flow when the lake is ice free and a two fold dilution. The Zn concentration used while the lake is ice covered is the mean Zn concentration in 1987 to the end of July in Garrow Creek – in 1987 there was natural outflow from Garrow Lake and surface layer Zn concentrations were similar (0.23 ppm).

### iii) Post-Mine with halocline Zn maximum mixed into the surface layer

Under these worst case conditions the surface layer Zn concentration is predicted to be 0.31 ppm.

The maximum loading in Garrow Creek would be:

$(1.38\ Mm^3 \times 0.12\ g/m^3) + (0.92\ Mm^3 \times 0.31/2\ g/m^3) =$ **308 kg**

Using the same assumptions as in ii) above, with the exception that the Zn concentration while the lake is ice covered is that observed in 1989 when surface layer Zn concentrations were similar (see below).

### iv) Actual Zinc loading in 1989

This was the last year that there was natural outflow from Garrow Lake and the lake cleared of ice. Zinc concentrations reached 0.36 ppm in the surface layer (due to a tailings line failure in 1985) similar to the example above. The total flow was 1.5 $Mm^3$ with 79 % of the flow occurring by July 31. The Zn loading was:

| | |
|---|---|
| June 19 – July 31: | 143 kg |
| August 1 – September 17: | 21 kg |
| **Total** | **164 kg** |

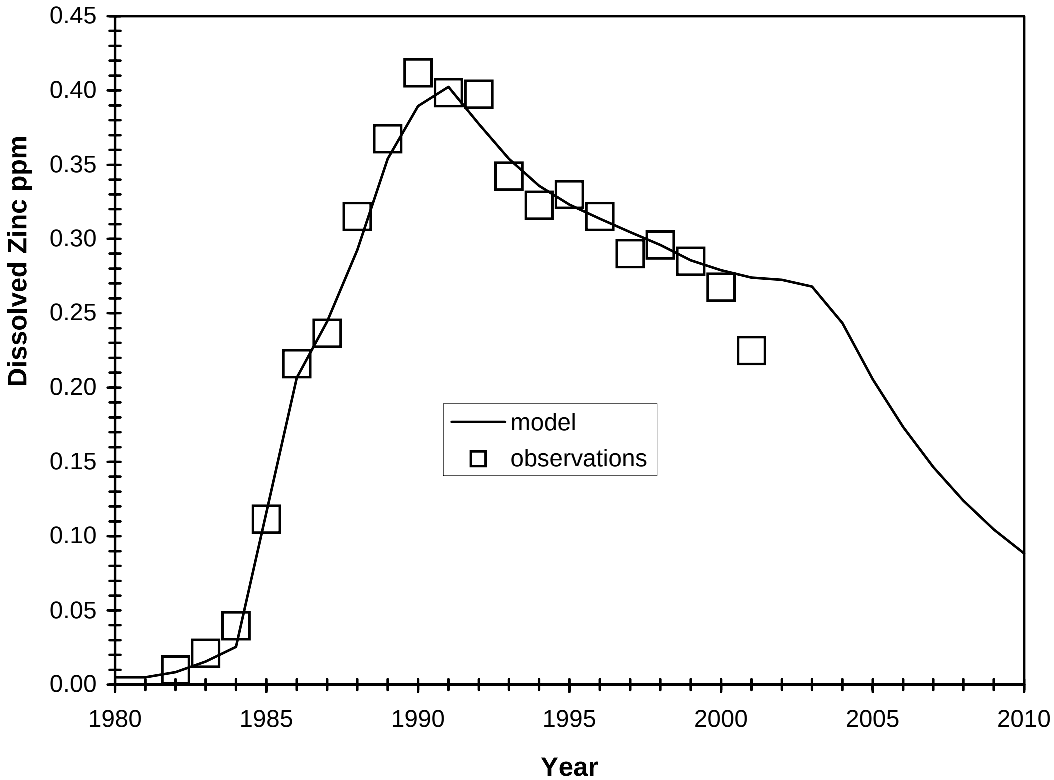



Figure 1. Predicted and Observed Concentrations of Zinc in the Surface Layer of Garrow Lake 1980 - 2010

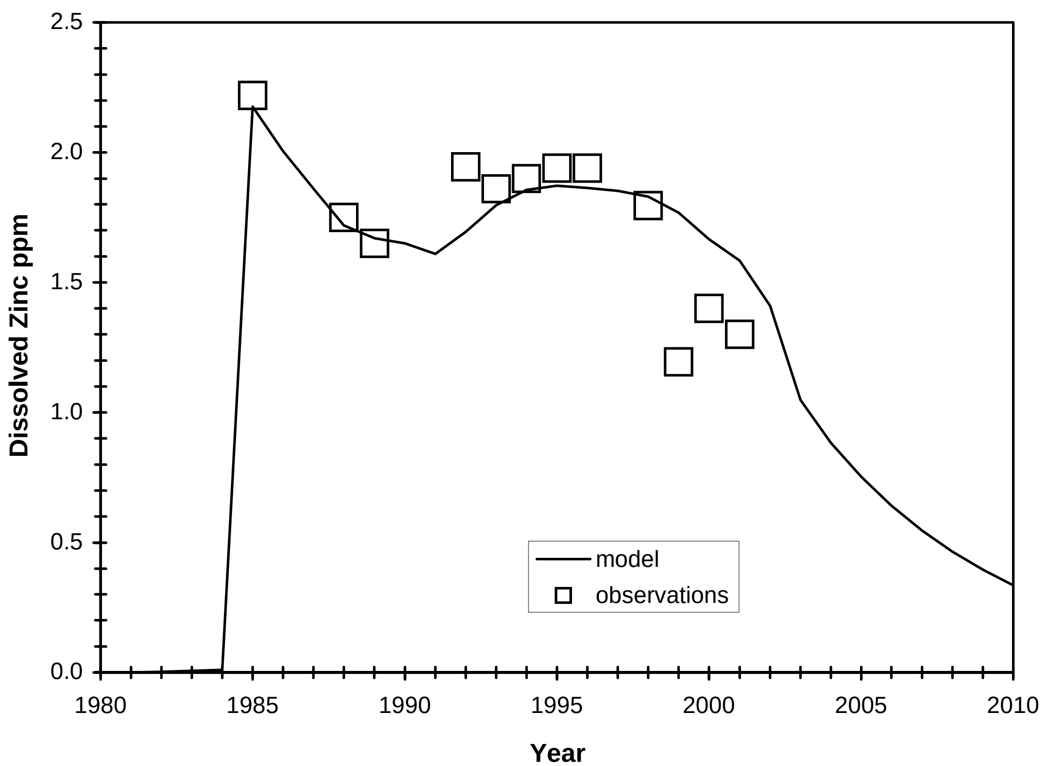



Figure 2. Predicted and Observed Maximum Concentrations of Zinc in the Halocline of Garrow Lake 1980 – 2010

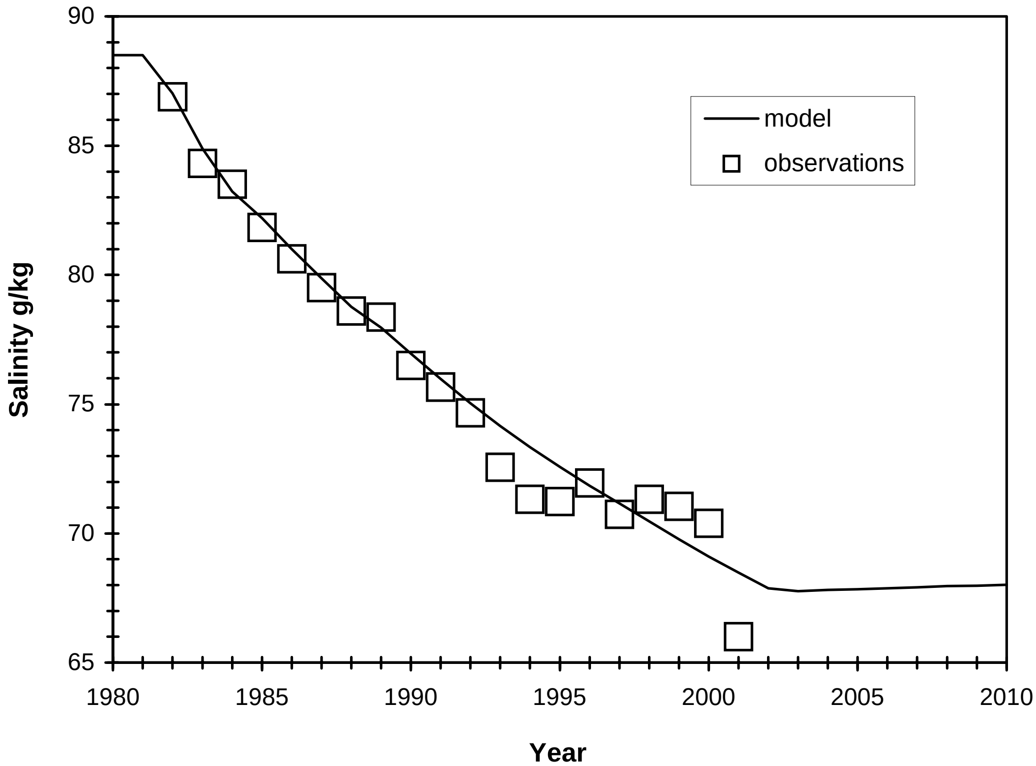



Figure 3. Predicted and Observed Salinity in the Bottom Layer of Garrow Lake 1980 – 2010

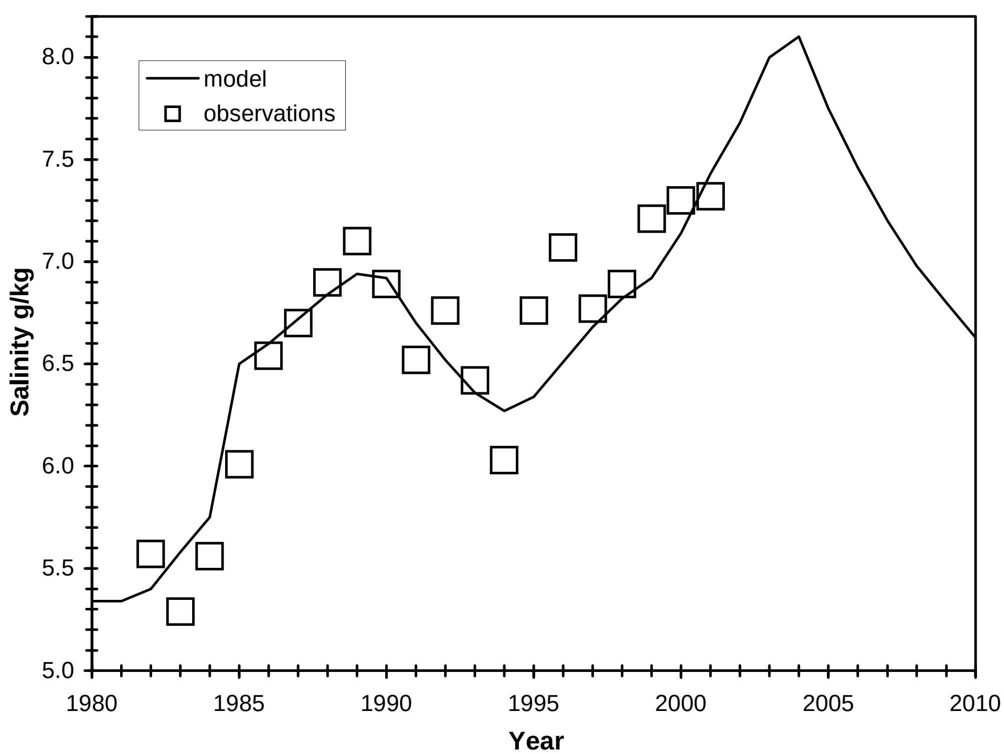



Figure 4. Predicted and Observed Salinity of the Surface Layer of Garrow Lake 1980 – 2010

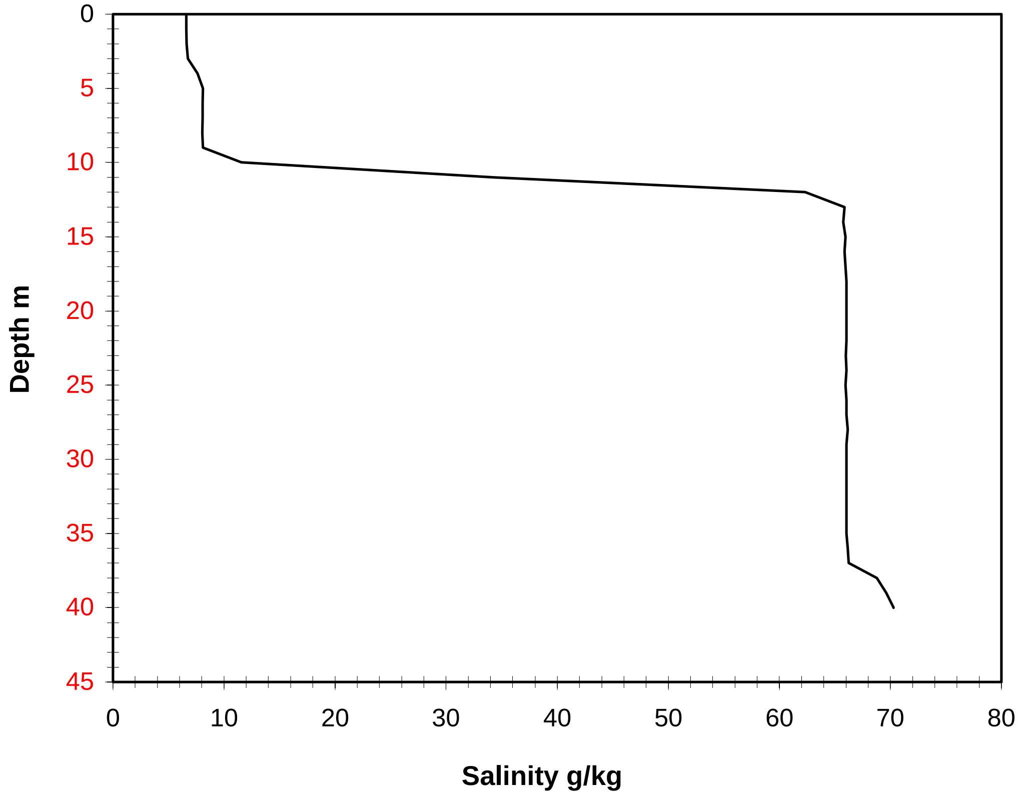



Figure 5. Salinity – Depth Profile, Garrow Lake January 2001

# ATTACHMENT # 10

## MEMORANDUM TO B. Willoughby From T. Feduniak

## REGARDING ‘CONTAMINATED SOILS STORAGE’

## dated December 21, 2001

# MEMO

## Polaris Mining Partnership

**To:** Bill Willoughby – Mine Superintendent
**From:** Trevor Feduniak – Mine Planning Engineer
**Date:** December 21, 2001
**Subject:** **Contaminated Soils Storage**

Below is a list of underground areas and corresponding volumes for placement of surface contaminated soils. Volume and percent fill values for the KEX Stopes were provided by Jesse Hall using MineSight. The volumes of the drifts were measured from our working drawings and the percent fill values were estimated based on our current backfilling techniques (8 yard Scoop and 950 Loader). Gartner Lee has provided the estimated volumes for both hydrocarbon and sulphide contaminated soils. The Keel Extension area has been reserved for hydrocarbon contaminated soil, all others areas will be used for sulphide contaminated material.

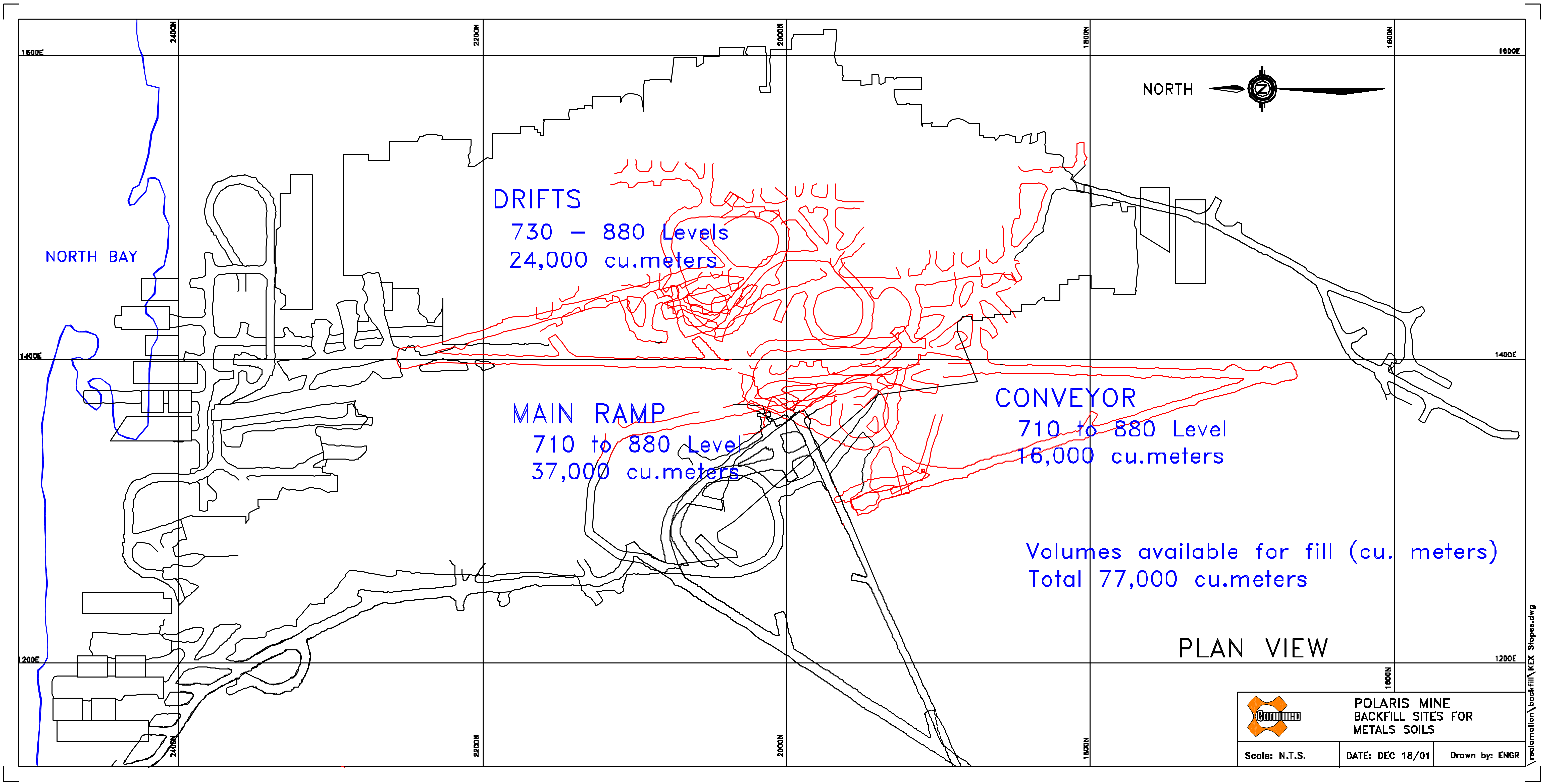
| LOCATION | EXCAVATED VOLUME ($m^3$) | PERCENT FILL | AVAILABLE VOLUME ($m^3$) |
|---|---|---|---|
| KEX-1 (Stope) | 23,400 | 75% | 17,550 |
| KEX-2 (Stope) | 8,730 | 73% | 6,373 |
| KEX-3 (Stope) | 11,340 | 80% | 9,072 |
| KEX-4 (Stope) | 7,830 | 48% | 3,758 |
| **TOTAL** | **51,300** | | **36,753** |
| | | | |
| Main Ramp (710 to 880) | 41,047 | 90% | 36,942 |
| Conveyor (710 to 880) | 26,839 | 60% | 16,104 |
| Misc. Drifts (730 to 880) | 27,885 | 85% | 23,702 |
| **TOTAL** | **95,772** | | **76,748** |

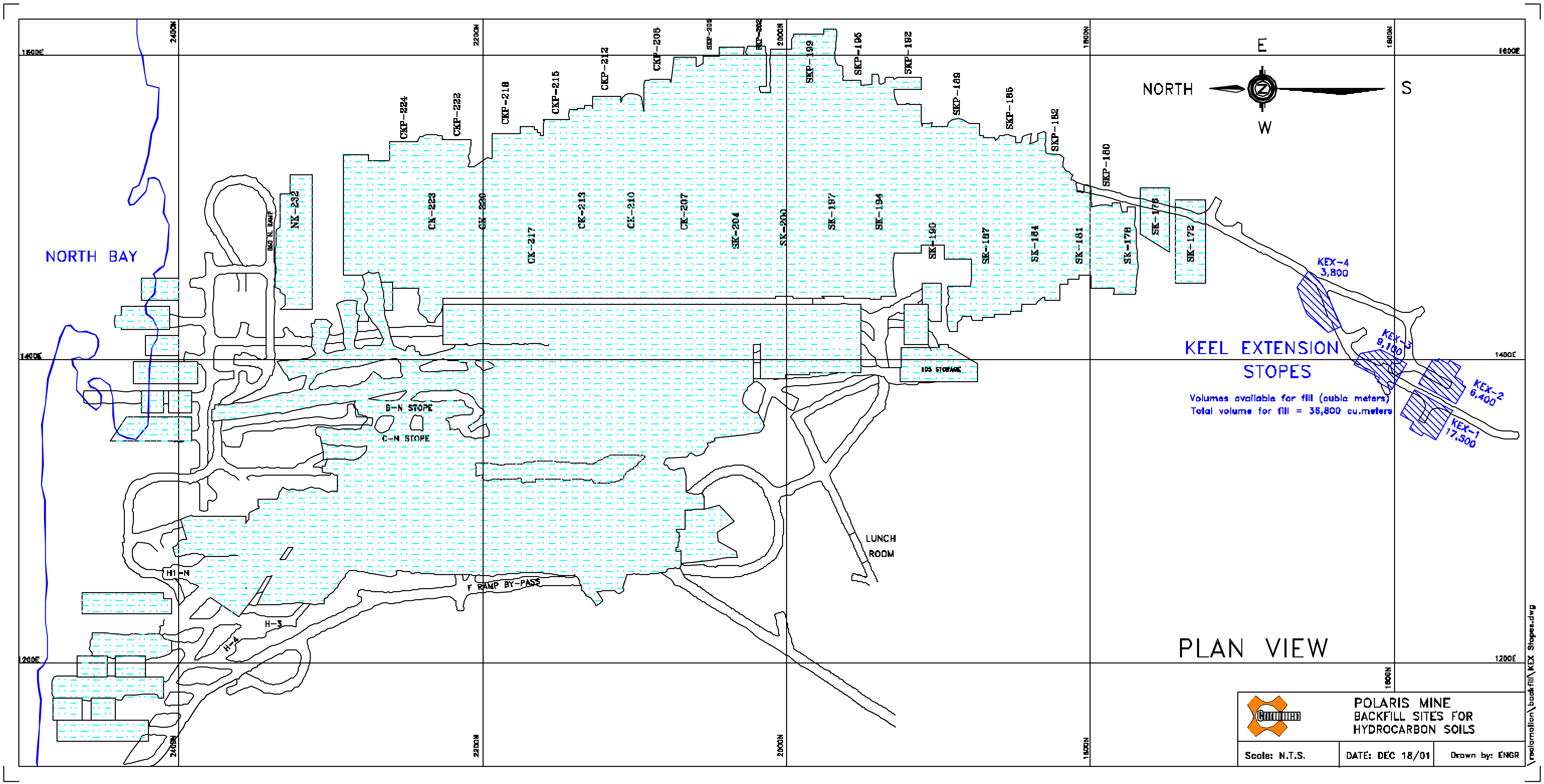
| CONTAMINATED SOIL | IN-SITU VOLUME ($m^3$) | PERCENT SWELL | REQUIRED VOLUME ($m^3$) |
|---|---|---|---|
| Hydrocarbons | 29,200 | 120% | 35,040 |
| Sulphides | 61,750 | 120% | 74,100 |

The areas listed above will provide the necessary required storage capacity to satisfy the contaminated soil volumes provided by Gartner Lee.

Attachments:

- Plan Drawings: Depicting locations of storage areas listed above.
- Memo: Capacity for Hydrocarbon Storage in the Keel Extension – Jesse Hall.


NORTH BAY
DRIFTS
730 – 880 Levels
24,000 cu.meters
MAIN RAMP
710 to 880 Level
37,000 cu.meters
CONVEYOR
710 to 880 Level
16,000 cu.meters
NORTH
Volumes available for fill (cu. meters)
Total 77,000 cu.meters
PLAN VIEW
POLARIS MINE
BACKFILL SITES FOR
METALS SOILS
Scale: N.T.S.
DATE: DEC 18/01
Drawn by: ENGR



NORTH BAY
NORTH
E
W
S
KEEL EXTENSION STOPES
Volumes available for fill (cubic meters)
Total volume for fill = 36,800 cu.meters
KEX-4 3,800
KEX-3 9,100
KEX-2 6,400
KEX-1 17,500
B-N STOPE
C-N STOPE
F RAMP BY-PASS
LUNCH ROOM
H1-N
H-3
H-4
PLAN VIEW
POLARIS MINE
BACKFILL SITES FOR HYDROCARBON SOILS
Scale: N.T.S.
DATE: DEC 18/01
Drawn by: ENGR
\reclamation\backfill\KEX Stopes.dwg

# ATTACHMENT # 11

## MEMORANDUM FORM B. DONALD TO J. DeGROOT

## REGARDING

## ‘RECOMMENDED PROCEDURES FOR THE RECOVERY AND DISPOSAL OF WASTE ANTIFREEZE FORM THE DOCK FACILITIES’

**dated December 15, 2001.**

**Teck Cominco Metals Ltd.**
Bag 2000, Kimberley, B.C. V1A 3E1
Phone: (250) 427-8256
Fax : (250) 427-8206
Email: bruce.donald@teckcominco.com

teckcominco

# MEMORANDUM

**Memo To:** **Mr. Jordan DeGroot** **Date:** December 15, 2001

**From:** Bruce Donald, Reclamation Manager

**Re:** **Recommended Procedures for the Recovery and Disposal of Waste Antifreeze from the Dock Facilities**

This memorandum is in response to the request for additional information on the nature, quantity and method of handling refrigerant from the freezing pipes installed in the dock.

## Background Information

According to the original construction records and engineering drawings prepared by Bechtel Canada, the dock was to be constructed by freezing the imported fill materials to form the permanent working platform. Freezing of the fill materials during the construction period was to be accomplished by a heat removal and exchange system. The initial system consisted of a 55 kw refrigeration plant and 250 – 150 mm diameter carbon steel coolant injection (freeze) pipes. Because of the natural freezing condition at the site, not all of the components in the original design were required during the construction of the dock facility and the number of freeze pipes actually used was significantly reduced. Anecdotal evidence indicates that actual number of freeze pipes used may have been in the order of 145.

Antifreeze with a design operating temperature of -20º C was used as the heat transfer medium for the freezing of the construction area. However, there is no available record of the type of glycol used for the application. Ethylene glycol was used throughout the balance of the process area and, as a conservative approach, it has been assumed that ethylene glycol was used for dock freezing as well. This will be confirmed prior to removal.

If all of the freeze pipes were used as designed, the estimated volume of glycol would be approximately 70,300 liters (18,600 US gallons). As indicated above, the actual volumes could be significantly less, if only a portion of the freeze pipes were installed and found to contain glycol. For planning purposes, a conservative approach has been taken and, until field investigation during reclamation indicates otherwise, it has been assumed that all initial freeze pipes were installed and filled with glycol. The following procedures will be followed to ensure the glycol is removed and disposed of in an environmentally acceptable manner:

- Through the use of a metal detector, original drawings, and hand excavation, confirm the locations and number of all freeze pipes that were installed during the construction phase of the dock facility. According to the original design, the freeze pipe was blind-flanged approximately 150 mm (6 inches) below the top of the rockfill.

- Each freeze pipe will be examined to identify and record which are "dry" pipes and which contain glycol. Identifying and recording the conditions as "dry" or "filled" for each freeze pipe will be adequate.

- Sample the waste antifreeze in several pipes and determine the chemical characteristics of it by a certified laboratory. Every pipe does not require sampling, as the same type of glycol will be in all of the freeze pipes.

- Obtain submersible pumps, discharge hoses and shut-off valves that are suitable for pumping ethylene glycol. Transport to site sufficient containers approved for shipment of ethylene glycol.

- Remove the blind flange carefully to minimize the loose overburden materials from falling into the injection pipe.

- Lower the submersible pump into the injection pipe and place the pump discharge hose into one of the drums before starting the pump. Drums will be located in a portable watertight containment pan during filling.

- Operate pumps in a manner to minimize surges. When the first drum is nearly filled, close the shut-off valve and transfer the pump discharge hose to the empty container, avoiding splashing and spillage.

- Pump, hoses and fittings must be stored on the containment pan after each recovery operation. Containment pan contents must be drained and transferred into an empty drum.

- Label all filled drums and relocate to a temporary storage area to hold for disposal by one of the following methods:
    a) Transport from site in approved shipping containers for recycling. The handling of the drums for shipping will be done by trained personnel, the drums will be labeled as required by regulations, shipments will be properly manifested and the drums will be shipped to a company approved to recycle or dispose of glycol.
    b) Incinerate on-site in an approved two stage incinerator. While this is a less likely option, it is still an acceptable approach under current regulations.

The NWB will be notified of which disposal method is selected in advance.

- Arrange a portable steam generator or a closed-loop hot water supply/recirculation system for the injection pipe thawing operation.

- Remove the blind flange and lower the steam injector slowly into the freeze pipe to thaw the soil materials immediately next to the freeze pipe. Start the thawing operation from the bottom of the injection pipe. Once thawed, freeze pipes will be extracted by crane, jacking, vibratory means or by cutting off the pipe after being exposed.

- The residual glycol and the liquid from the closed-loop system will be recovered and drummed and in a similar manner as described above.

## ATTACHMENT # 12

## LETTER TO B. DONALD FROM RICK McLEAN

## REGARDING 'DECOMMISSIONING OF THE WHARF FACILITY

## IN CROZIER STRAIT, CORNWALIS ISLAND, NT

## LITTLE CORNWALLIS ISLAND, NORTHWEST TERRITORIES'

## dated December 4, 2001

Fisheries and Oceans Canada
Pêches et Océans Canada

Coast Guard
Garde côtière

Central & Arctic Region
Région du Centre et de l'Arctique

201 N. Front Street, Suite 703
Sarnia, Ontario
N7T 8B1

Your file Votre référence

Our file Notre référence
8200-80-651

December 4, 2001

Teck Cominco Metal Limited
Bag 2000
Kimberley, BC V1A 3E1

Attention: Bruce Donald, Reclamation Manager

Dear Sir:

**Re: Decommissioning of the Wharf Facility in Crozier Strait, Cornwalis Island, NT Little Cornwallis Island, Northwest Territories.**

Reference is mad to your e-mail concerning the above noted project.

We have reviewed the information supplied and can advise the Canadian Coast Guard has no interest in this project provided that:

1. Extract or cut off steel piles at least 2 meters below low tide elevation.
2. Re-initiate a beach profile that will minimize erosion.

Should you have any further questions concerning the above, please contact the undersigned at (519) 383-1862.

Yours truly,

Rick McLean
A/Superintendent
Navigable Waters Protection

RAM/kab

Canada

## ATTACHMENT # 13

## FAX TO NORMAN ALLYN OF WESTMAR CONSULTING ENGINEERING FROM JEAN BARTHE OF TOWER ARCTIC REGARDING THE SOURCE OF THE FILL FOR THE DOCK CELLS

**dated November 14, 2001**

TOWER ARCTIC LTD

ARCTIC DESIGN
CONSTRUCTION
PERMAFROST SPECIALIST
MANAGEMENT SERVICES

Member

**Tower Group of Companies**
in the arctic continuously since 1946

11/14/01

Westmar Consulting Engineers,
400 - 233 West 1st St.,
North Vancouver, B.C.
V7M 1B3

Attention: Norm Allyn Fax: (604) 985-2581

Re: Polaris Mine Decommissioning

Norm,

In response to your fax of November 13, the material that was used to fill the dock cells came from the excavation of the berthing place for the barge. At that time the mine was not in operation and the access portal excavation was in progress.

It was an inaccuracy from our part to have stated that mine rejects were used as fill for the dock cells.

| CIRCULATE TO: | INITIAL |
|---|---|
| NFA | |
| | |
| | |
| | |
| | |
| | |
| ACTION BY | |
| FILE | |

Regards,

Jean Barthe

IQALUIT, NUNAVUT
P.O. BOX 717, X0A 0H0
TEL.: (867) 979-6465
FAX.: (867) 979-6591

MONTREAL, QC, H3A 2V4
1230 - 2045 STANLEY ST.
TEL.: (514) 849-3551
FAX.: (514) 982-6127

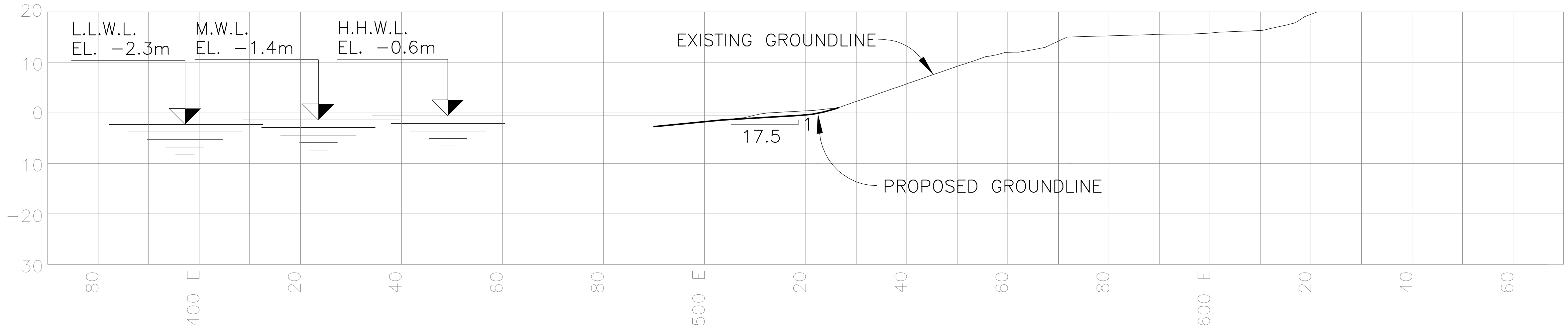
# ATTACHMENT # 14

## UPDATED DOCK & SHORELINE SECTIONS

## DRAWN BY WESTMAR CONSULTING ENGINEERS

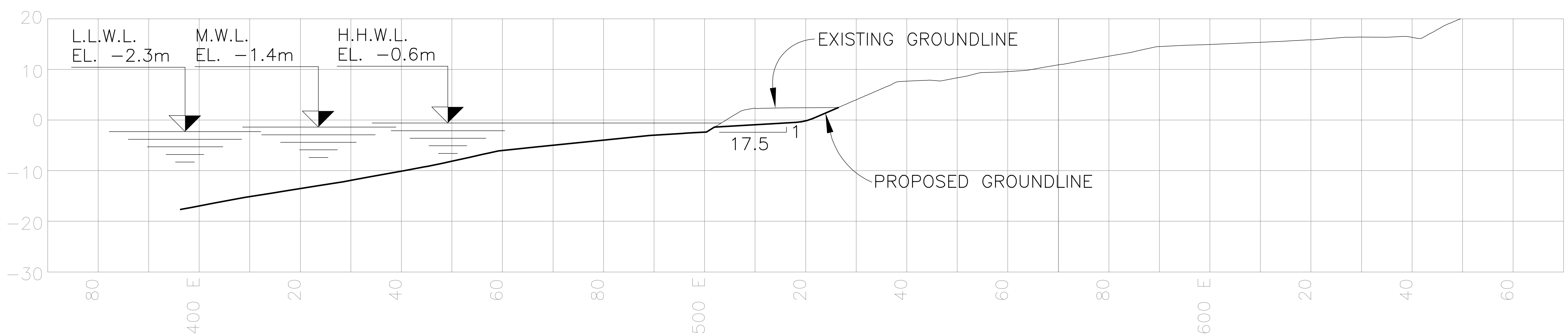
## REVISIONS DATED DECEMENBER 7, 2001

## dated November 14, 2001




## SECTION – 1700 N

1:1000




## SECTION – 1600 N

1:1000

NOTES:

1. FOR GENERAL NOTES SEE DWG. –01–101.
2. EXISTING GROUNDLINE ABOVE WATER FROM SURVEY PROVIDED BY TECK COMINCO LIMITED.
3. ORIGINAL GROUNDLINE BELOW WATER FROM INFORMATION PROVIDED ON BECHTEL CANADA DRAWINGS AND INTERPOLATED FROM SURVEY PROVIDED BY TECK COMINCO LIMITED.

CLIENT

teckcominco

PROJECT

POLARIS MINE
DECOMMISSIONING OF DOCK

Westmar

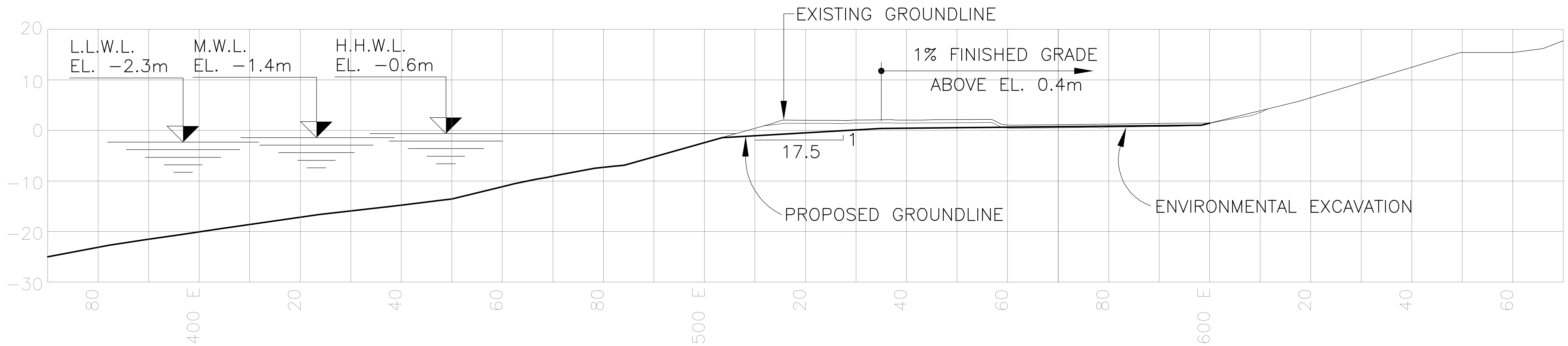
Maritime, Structural, Civil and Materials Handling Engineers

TITLE

SECTIONS – SHEET 1

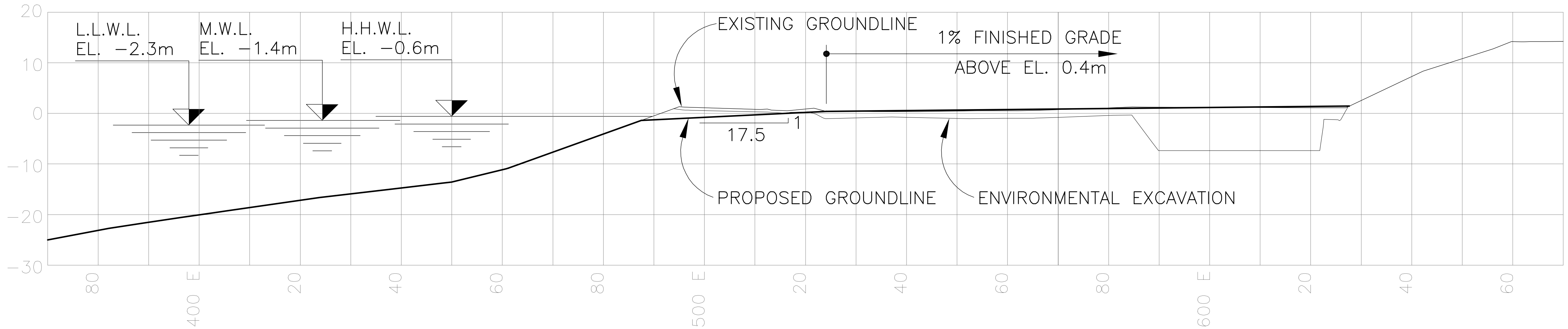
| SCALE | DATE | DRAWING NUMBER |
|---|---|---|
| SHOWN | DEC07/01 | 00282–01–102 |

Filename: P:\2000\00282\SURVEY\00282-01-102-107.DWG – Dec. 7/01 10:38am BMASSULLO




## SECTION – 1500 N

1:1000




## SECTION – 1450 N

1:1000

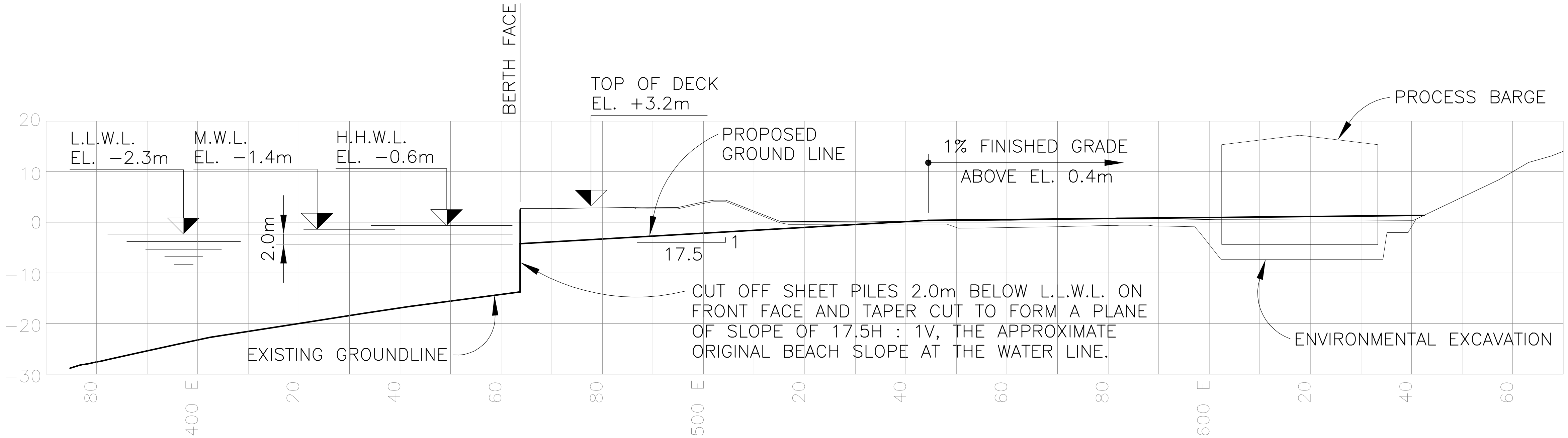
**NOTES:**

1. FOR GENERAL NOTES SEE DWG. −01−101.
2. EXISTING GROUNDLINE ABOVE WATER FROM SURVEY PROVIDED BY TECK COMINCO LIMITED.
3. ORIGINAL GROUNDLINE BELOW WATER FROM INFORMATION PROVIDED ON BECHTEL CANADA DRAWINGS AND INTERPOLATED FROM SURVEY PROVIDED BY TECK COMINCO LIMITED.

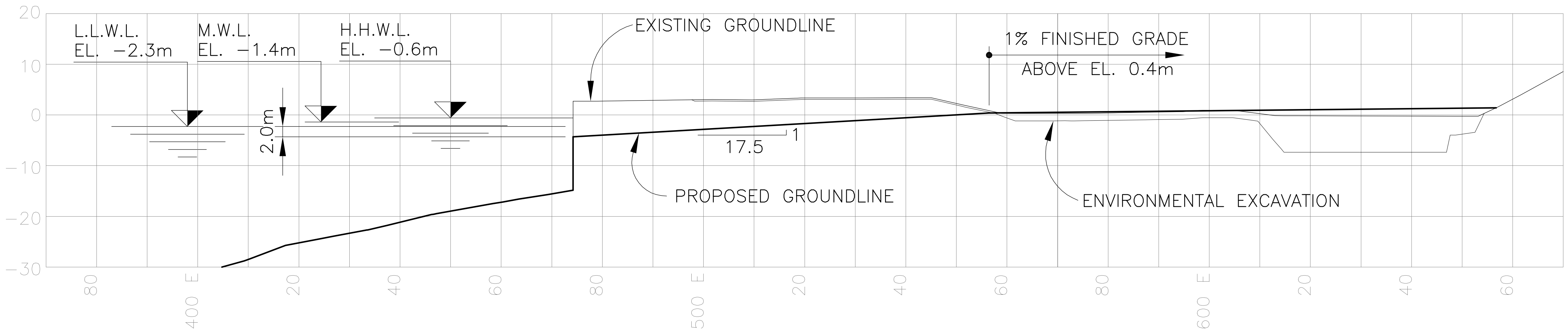
| CLIENT | |
|---|---|
| teckcominco | **Westmar** Maritime, Structural, Civil and Materials Handling Engineers |
| PROJECT: POLARIS MINE DECOMMISSIONING OF DOCK | TITLE: SECTIONS – SHEET 2 |

| SCALE | DATE | DRAWING NUMBER |
|---|---|---|
| SHOWN | DEC07/01 | 00282−01−103 |

Filename: P:\2000\00282\SURVEY\00282-01-102-107.DWG – Dec. 7/01 10:38am BMASSULLO




## SECTION – 1400 N
1:1000




## SECTION – 1350 N
1:1000

**NOTES:**

1. FOR GENERAL NOTES SEE DWG. −01−101.
2. EXISTING GROUNDLINE ABOVE WATER FROM SURVEY PROVIDED BY TECK COMINCO LIMITED.
3. ORIGINAL GROUNDLINE BELOW WATER FROM INFORMATION PROVIDED ON BECHTEL CANADA DRAWINGS AND INTERPOLATED FROM SURVEY PROVIDED BY TECK COMINCO LIMITED.

| | |
|---|---|
| CLIENT: teckcominco | Westmar — Maritime, Structural, Civil and Materials Handling Engineers |
| PROJECT: POLARIS MINE DECOMMISSIONING OF DOCK | TITLE: SECTIONS – SHEET 3 |

| SCALE | DATE | DRAWING NUMBER |
|---|---|---|
| SHOWN | DEC07/01 | 00282−01−104 |

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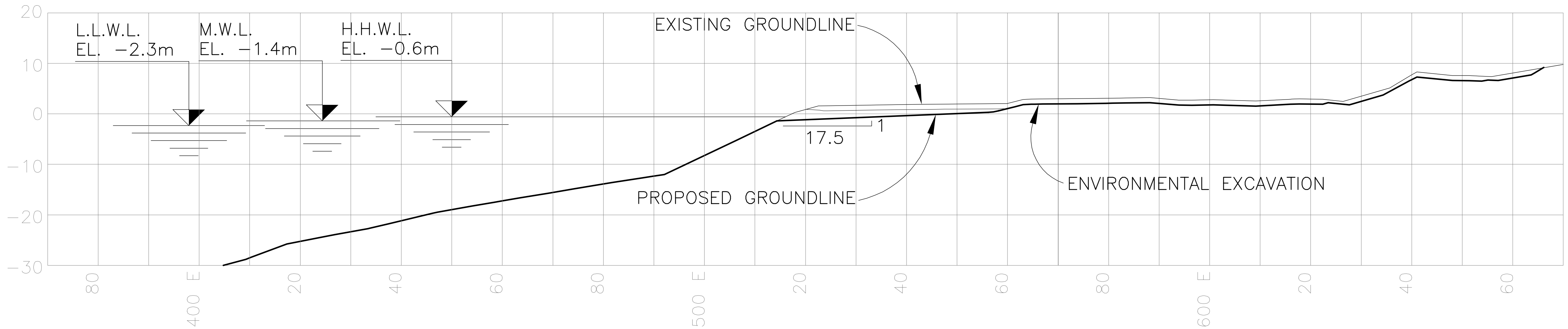
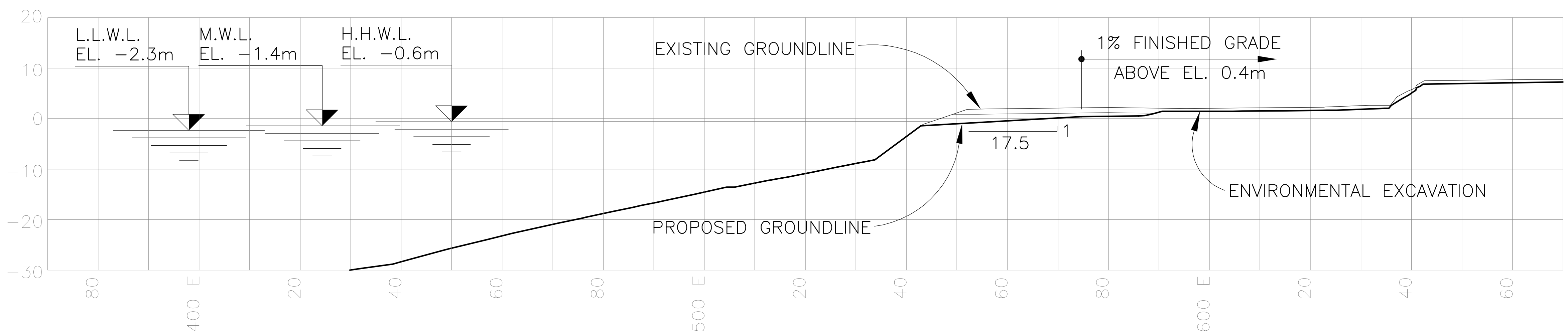



## SECTION – 1300 N

1:1000




## SECTION – 1200 N

1:1000

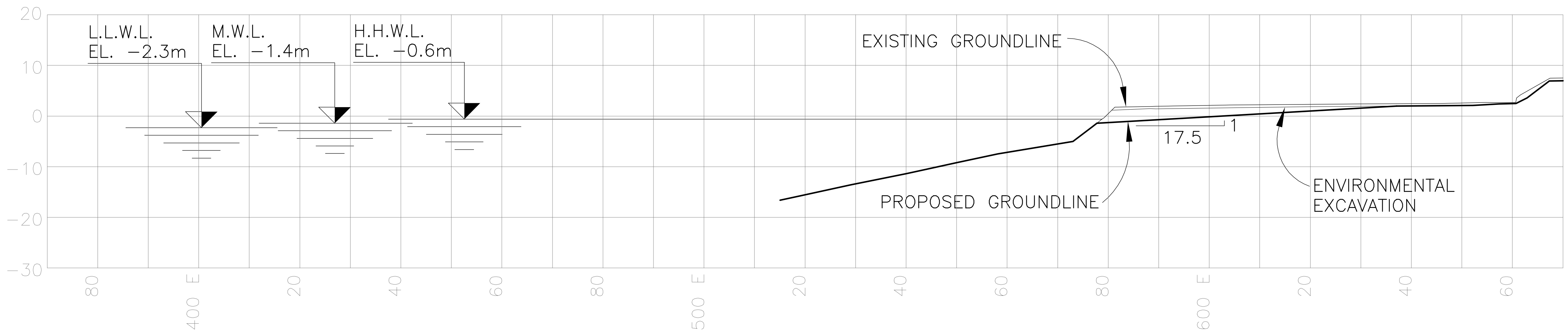
**NOTES:**

1. FOR GENERAL NOTES SEE DWG. −01−101.
2. EXISTING GROUNDLINE ABOVE WATER FROM SURVEY PROVIDED BY TECK COMINCO LIMITED.
3. ORIGINAL GROUNDLINE BELOW WATER FROM INFORMATION PROVIDED ON BECHTEL CANADA DRAWINGS AND INTERPOLATED FROM SURVEY PROVIDED BY TECK COMINCO LIMITED.

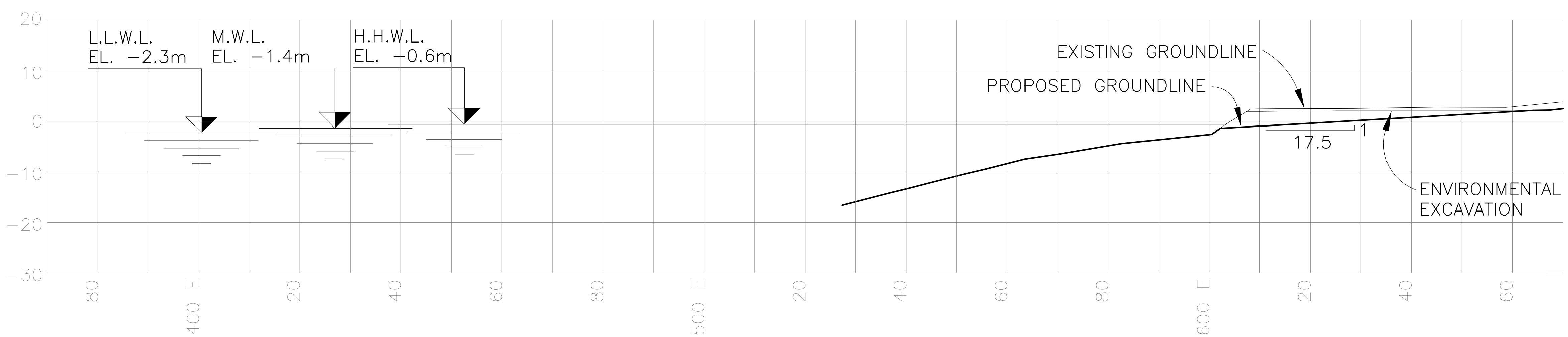
| | |
|---|---|
| CLIENT<br>teckcominco | **Westmar**<br>Maritime, Structural, Civil and Materials Handling Engineers |
| PROJECT<br>POLARIS MINE<br>DECOMMISSIONING OF DOCK | TITLE<br>SECTIONS – SHEET 4 |

| SCALE | DATE | DRAWING NUMBER |
|---|---|---|
| SHOWN | DEC07/01 | 00282−01−105 |

Filename: P:\2000\00282\SURVEY\00282-01-102-107.DWG – Dec. 7/01 10:38am BMASSULLO




## SECTION – 1100 N
1:1000




## SECTION – 1000 N
1:1000

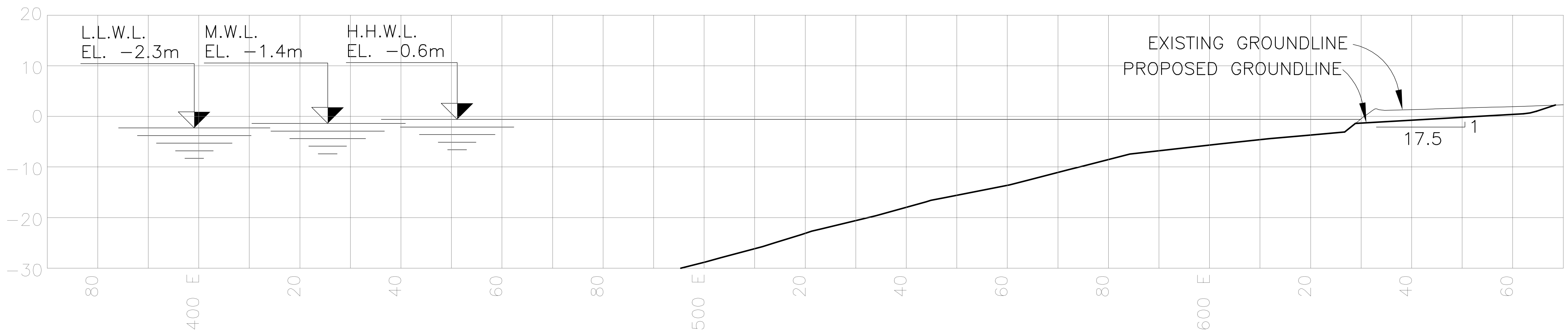
**NOTES:**

1. FOR GENERAL NOTES SEE DWG. −01−101.
2. EXISTING GROUNDLINE ABOVE WATER FROM SURVEY PROVIDED BY TECK COMINCO LIMITED.
3. ORIGINAL GROUNDLINE BELOW WATER FROM INFORMATION PROVIDED ON BECHTEL CANADA DRAWINGS AND INTERPOLATED FROM SURVEY PROVIDED BY TECK COMINCO LIMITED.

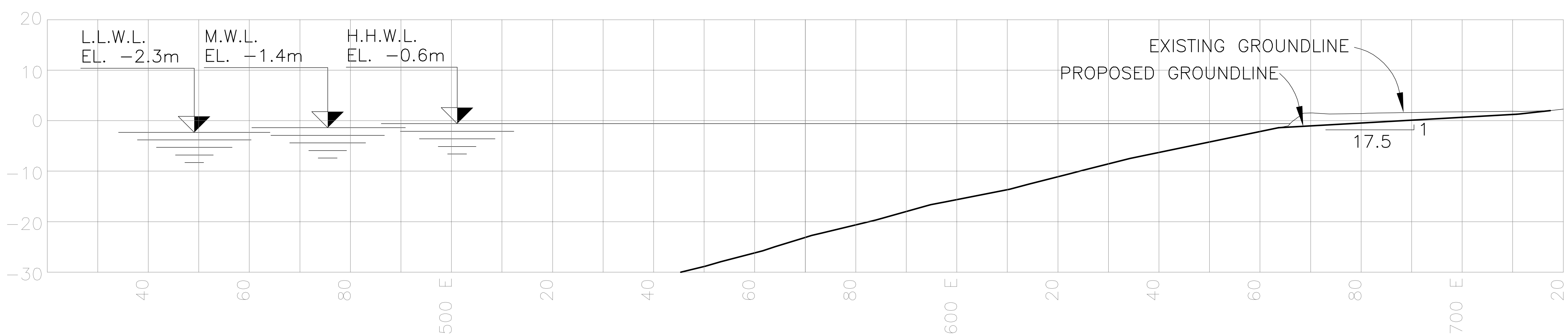
| | |
|---|---|
| CLIENT: teckcominco | Westmar — Maritime, Structural, Civil and Materials Handling Engineers |
| PROJECT: POLARIS MINE DECOMMISSIONING OF DOCK | TITLE: SECTIONS – SHEET 5 |

| SCALE | DATE | DRAWING NUMBER |
|---|---|---|
| SHOWN | DEC07/01 | 00282−01−106 |

Filename: P:\2000\00282\SURVEY\00282-01-102-107.DWG – Dec. 7/01 10:38am BMASSULLO




SECTION – 900 N
1:1000




SECTION @ 800 N
1:1000

NOTES:

1. FOR GENERAL NOTES SEE DWG. −01−101.
2. EXISTING GROUNDLINE ABOVE WATER FROM SURVEY PROVIDED BY TECK COMINCO LIMITED.
3. ORIGINAL GROUNDLINE BELOW WATER FROM INFORMATION PROVIDED ON BECHTEL CANADA DRAWINGS AND INTERPOLATED FROM SURVEY PROVIDED BY TECK COMINCO LIMITED.

CLIENT: teckcominco

Westmar
Maritime, Structural, Civil and Materials Handling Engineers

PROJECT: POLARIS MINE DECOMMISSIONING OF DOCK

TITLE: SECTIONS – SHEET 6

| SCALE | DATE | DRAWING NUMBER |
|---|---|---|
| SHOWN | DEC07/01 | 00282−01−107 |

Filename: P:\2000\00282\SURVEY\00282-01-102-107.DWG – Dec. 7/01 10:38am BMASSULLO

# ATTACHMENT # 15

## Appendix H from Revision 1 of

## ‘Decommissioning of Dock Facilities at Polaris Mine Little Cornwallis Island, Nunavut’

## by Westmar Consulting Engineers.

# *APPENDIX H*

---

## *Preliminary General Blast Design*

**REVISION 1**

Westmar

## Blasting Permafrost Conditions – Sheet Pile Cell Dock

### Introduction

The dock facility was constructed in 1981 and is comprised of four circular sheet pile cells, each approximately 26 m in diameter. Three interconnecting arcs on the front face tied the four cells together. The wall thickness of an individual steel sheet pile is approximately 1/2-inch. The cells were constructed by driving sheet piles through the ice and backfilled with rock and overburden available locally. The face of the dock is approximately 90 m long with a depth of approximately 13 m at low water.

Blasting in or near Canadian fisheries waters has demonstrated to cause disturbance, injury and/or death to fish and marine mammals and the alteration, disruption or destruction of marine habitat. The Department of Fisheries and Oceans (DFO) has prepared guidelines to assist proponents in conservation methods to protect marine life and habitat from the destructive forces of explosives. The guidelines entitled, "Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters, 1998", forms the basis of blast design for the Polaris project

### The Need for Blasting

The substrate underlying the sheet pile cell dock is comprised of overburden excavated from the barge dry dock facility that has been backfilled into the cells and compacted. The Polaris site exhibits permafrost conditions exceeding 100 m in depth and blasting will be required to sufficiently fragment the frozen fill to allow for cost effective excavation.

### Type of Explosives

The "Guidelines for the Use of Explosives In or Near Canadian Fisheries Water, 1998" state: "No use of ammonium nitrate-fuel oil mixtures occurs in or near water due to the production of toxic by-products (ammonia)."

Permafrost blasting is to be performed using nitroglycerin (NG) based dynamite, such as Orica Powerfrac in cartridge form.

Linear shape charges may be used to sever the steel sheet pile at the designed depth underwater. Linear shape charges (LSC) do not normally have trade names and are commonly manufactured to meet specific project conditions. Typically, RDX explosive is used in linear shape charges.

### Blast Design

Overpressure calculations, set at a peak pulse of 100kPa, were performed for the dock site and the results are presented in Figure 1. These calculations form the basis of blast design and configuration for the project area. The charge weight per delay limitations are depicted linearly in metres from the dock face towards the process barge. The use of a bubble curtain to limit blast-induced overpressure in close proximity to the dock face is mandatory.

Permafrost blasting requires approximately twice the powder factor required to break normal rock. The approximate volume of material in the dock area to blast is 28,700 cubic metres requiring approximately 34,500 kilograms of explosives in total (see Figure 2). Blasting must be performed in small discrete shots, within the overpressure guidelines, so that excavation equipment can dig out the shot material before it re-freezes. Actual blast size will depend on the size and capability of the excavator on site. A generalized blast plan is illustrated in Figure 3, showing an 8-blasthole shot containing about 50 cubic metres of material. Maximum depth of blasting in the sheet pile cell dock area is about 7 metres.

Multi-deck loading and blasting techniques are required. Between 2 to 4 explosives decks per hole will be required to fragment the cell material in order to maintain the overpressure guidelines. The charge weight per delay will vary depending upon the proximity of the shot to the front face of dock (see Figure 1). The blasting contractor must: have a full understanding of marine blasting; be able to blast to Fisheries guidelines; have the ability to calculate the specific charge weight per delay for each blast; and be able to adjust the blast pattern or utilize a bubble curtain as the need arises. Experience in blasting permafrost conditions is also required.

Overpressure modeling was performed for the use of linear shape charges (LSC) to sever the sheet pile below water level (see Table 1). Since bubble cutains have effectively reduced the pressure pulse by a 10-fold factor, the overpressure limit for the model was set at 1,000kPa for various linear shaped charges. The results indicate that a 10-foot length of LSC may be detonated, within the Fisheries guidelines, with the proper use of a bubble curtain.

**Detonation Depth**

Blast depth varies throughout the project site, however, a maximum depth of 7 m is to be blasted in the sheet pile cell dock area. As noted previously, the charge weight per delay will depend on the distance of the blast from the water as illustrated on Figure 1. Detailed calculations for setback distances from 1 meter to 14 meters can be found in Tables 2-15 in the Appendix.

**Method of Detonation – Electrical Sequential Blasting**

The method of detonation is critical to the success of the project, both in the terms of safety and the ability to control blast-induced overpressures and limit marine life mortality.

***Electric sequential blasting techniques must be employed for two reasons:***

**Safety:** Due to the high powder factor required to blast permafrost, blasting mats must be used to contain fly rock. Nonel or shock tube type detonators are subject to damage when blasting mats are placed over the tubes, resulting in cutoffs, the blast firing out of sequence, excessive fly rock and extremely high overpressures at the water. Overpressure limitations will be exceeded if the designed delay sequence is not achieved due to damaged shock tubes. The safety of personnel and equipment are also at risk from fly rock as a result of a violent, uncontrolled blast caused by damaged shock tubes.

**Accuracy:** All shock tube type detonators contain +/- delay scatter time because of the inaccuracy of the pyrotechnic delay elements in the blasting caps. In order to control overpressure generated by blasting, tight control must be placed on the delay timing sequence. The multi-deck holes require accurate delay times between explosive decks and from hole-to-hole to limit the blast-induced overpressure to 100kPa. The only methods available for the accuracy required for this project are through the use of electronic detonators or electrical sequential blasting. Electronic detonators are not commonly used at present and are costly. Experienced blasting contractors commonly perform electric sequential blasting.

**Polaris Mine**
**Decommissioning Sheet Pile Cell Dock**

**Charge Weight vs Distance**
**(Charge Wt. Per Delay to Meet Fisheries Guideline of 100kPa)**

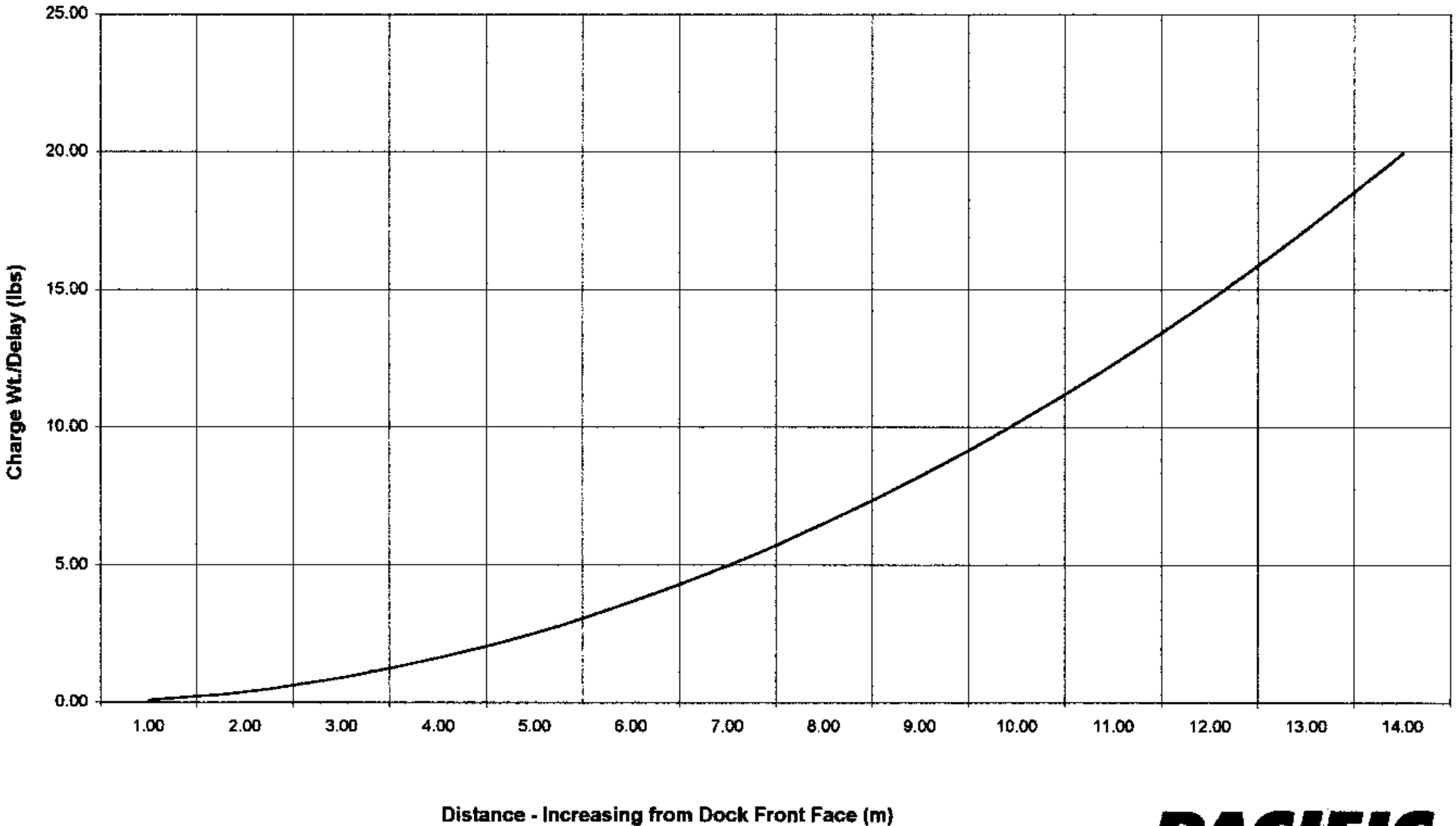



Figure 1

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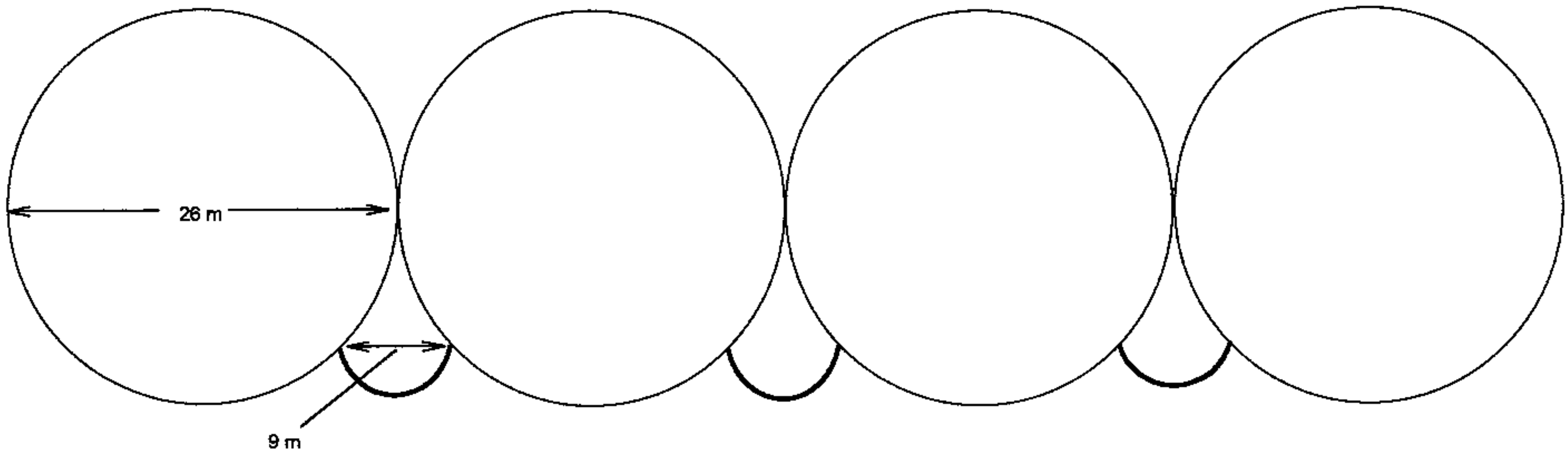
BLASTING & DEMOLITION LTD.

## Polaris Mine DecommissioningSheet Pile Cell Dock

### Cell Layout




| | | TOTAL | |
|---|---|---|---|
| Volume per Cell | 3716.5 | 14866 | cu.m |
| Volume per Tie Cell | 445 | 1336 | cu.m |
| TOTAL Cell Volume | | 16202 | cu.m |
| Volume beyond Cells | | 12500 | cu.m |
| **TOTAL VOLUME** | | **28702** | cu.m |
| Powder Factor | | **1.2** | kg/bcm |
| **Explosives Required** | | **34442** | kg |

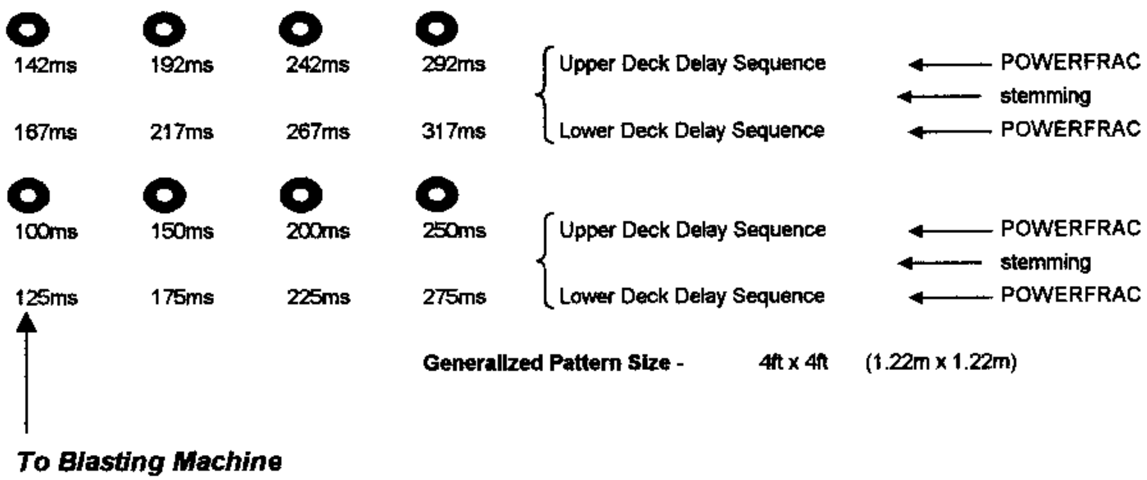
PACIFIC

Figure 2

# Polaris Mine
# Decommissioning Sheet Pile Dock

## Generalized Blast Design
## Electrical Sequential Tie-in : Delay Sequence Decked Holes

**2- Decks per hole**




**Note - Leg wires omitted for sake of clarity**
**- Not to scale**
**- Only 2-row shot shown. Additional rows may be required depending on size of blast**

| PATTERN | EXPLOSIVES |
|---|---|
| 4'x4' (1.22mx1.22m) | 2x16 Powerfrac Cartridges |
| 4'x4' (1.22mx1.22m) | 2x16 Powerfrac Cartridges |

PACIFIC BLASTING & DEMOLITION LTD.

**Figure 3**

PACIFIC BLASTING & DEMOLITION LTD.

SAFETY QUALITY PRODUCTIVITY PROFESSIONALISM

**Design Criteria**
**for**
**Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters**

**Table No. 2**

**Charge Weight Calculations for a 1.0 m Setback**

**Table 1** - *From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998*
Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"

| | Substrate | Dr ($g \cdot cm^{-3}$) | Cr ($cm \cdot s^{-1}$) | Cw ($cm \cdot s^{-1}$) | K | Dw ($g \cdot cm^{-3}$) | Pw (kPa) | PPV ($mm \cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 1 | Rock | 2.64 | 457200 | 146300 | 5.03 | 1.00 | 100.00 | 13.00 |
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.20 | 1.00 | 100.00 | 13.00 |
| 3 | Ice | 0.98 | 304800 | 146300 | 2.10 | 1.00 | 100.00 | 13.00 |
| 4 | Saturated Soil | 2.08 | 146300 | 146300 | 2.13 | 1.00 | 100.00 | 13.00 |
| 5 | Unsaturated Soil | 1.92 | 45700 | 146300 | 0.98 | 1.00 | 100.00 | 13.00 |

**PROJECT DESIGN CRITERIA**

| | | |
|---|---|---|
| **Project Location:** | Polaris Mine - Little Cornwallis Island, Nunavut | |
| **Water Course:** | Crozier Strait | |
| **Substrate:** | Quarry Fill | Frozen Soil ( Fisheries Substrate Classification ) |
| **Nature of Jointing/Fractures:** | N/A | |
| **Overburden:** | N/A | |
| **Hole Depth:** | 2 m | |
| **Explosive Type:** | Orica Powerfrac (Gelatin Dynamite) | |
| **Method of Detonation:** | Electric, blasting cap | |
| **Bubble Curtain Required:** | Yes | |

Table 2 - Calculations for : **Polaris Mine - Little Cornwallis Island, Nunavut**

| | Project Substrate | Dr ($g \cdot cm^{-3}$) | Cr ($cm \cdot s^{-1}$) | Cw ($cm \cdot s^{-1}$) | K | Dw ($g \cdot cm^{-3}$) | Pw (kPa) | Vr ($mm \cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.2 | 1.00 | 100.00 | 13.00 |
| 0.05 | Charge Weight (kg) | 0.05 | 0.11 Lbs/delay | | | | | |
| 1 | No. of Delays/Charge | 1.0 | | | | | | |
| | Charge Weight/Delay | 0.05 | | | | | | |
| 1.0 | Distance to Detonation | 1.00 | | | | | | |
| | Zw = DwCw / Zr = DrCr | 0.2500 | | | | | | |
| | Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr) or Pr = Pw(1+(Zw/Zr)) / 2(Zw/Zr) | 250.0 | 2.50 kPa or | 2.50E+06 dynes - *to limit Pw to 100 kPa* | | | | |
| | Vr = 2Pr / DrCr | 8.54 $cm \cdot s^{-1}$ - *to limit Pw to 100kPa* | | | | | | |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | 1.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa* | | | | | | |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | 3.4 m *Minimum setback distance from a spawning area to maintain PPV @ 13 $mm \cdot sec^{-1}$* | | | | | | |
| | $Vr=100(R/W^{.5})^{-1.6}$ | 9.10 $cm \cdot s^{-1}$ Calculated PPV at Design Criteria | | | | | | |
| | Vr = 2Pr / DrCr or Pr = (DrCrVr)/2 | 2.66E+06 Dynes Calculated Pressure in Substrate at Design Criteria | | | | | | |
| | Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr) | 106.54 kPa Calculated Pressure in Water at Design Criteria | | | | | | |

| PROJECT SUMMARY | Fisheries Limit | Project Design |
|---|---|---|
| | | |
| Pressure in Water (Pw) kPa | 100.0 | 106.54 |
| **Peak Particle Velocity (Vr) cm•s-1 | 13.0 | 91.03 |
| | | |

** Limit for spawning bed during period of egg incubation

PACIFIC BLASTING & DEMOLITION LTD. — SAFETY QUALITY PRODUCTIVITY PROFESSIONALISM

# Design Criteria
## for
## Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters
## Table No. 3
## Charge Weight Calculations for a 2.0 m Setback

**Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998**
**Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"**

| | Substrate | Dr ($g\cdot cm^{-3}$) | Cr ($cm\cdot s^{-1}$) | Cw ($cm\cdot s^{-1}$) | K | Dw ($g\cdot cm^{-3}$) | Pw (kPa) | PPV ($mm\cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 1 | Rock | 2.64 | 457200 | 146300 | 5.03 | 1.00 | 100.00 | 13.00 |
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.20 | 1.00 | 100.00 | 13.00 |
| 3 | Ice | 0.98 | 304800 | 146300 | 2.10 | 1.00 | 100.00 | 13.00 |
| 4 | Saturated Soil | 2.08 | 146300 | 146300 | 2.13 | 1.00 | 100.00 | 13.00 |
| 5 | Unsaturated Soil | 1.92 | 45700 | 146300 | 0.98 | 1.00 | 100.00 | 13.00 |

**PROJECT DESIGN CRITERIA**

| | | |
|---|---|---|
| **Project Location:** | Polaris Mine - Little Cornwallis Island, Nunavut | |
| **Water Course:** | Crozier Strait | |
| **Substrate:** | Quarry Fill | Frozen Soil ( Fisheries Substrate Classification ) |
| **Nature of Jointing/Fractures:** | N/A | |
| **Overburden:** | N/A | |
| **Hole Depth:** | 2 m | |
| **Explosive Type:** | Orica Powerfrac (Gelatin Dynamite) | |
| **Method of Detonation:** | Electric, blasting cap | |
| **Bubble Curtain Required:** | Yes | |

**Table 3 - Calculations for :** **Polaris Mine - Little Cornwallis Island, Nunavut**

| | Project Substrate | Dr ($g\cdot cm^{-3}$) | Cr ($cm\cdot s^{-1}$) | Cw ($cm\cdot s^{-1}$) | K | Dw ($g\cdot cm^{-3}$) | Pw (kPa) | Vr ($mm\cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.2 | 1.00 | 100.00 | 13.00 |

| | | | |
|---|---|---|---|
| 0.18 | Charge Weight (kg) | 0.18 | 0.40 Lbs/delay |
| 1 | No. of Delays/Charge | 1.0 | |
| | Charge Weight/Delay | 0.18 | |
| 2.0 | Distance to Detonation | 2.00 | |
| | $\frac{Zw}{Zr} = \frac{DwCw}{DrCr}$ | 0.2500 | |
| | $Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ or $Pr = \frac{Pw(1+(Zw/Zr))}{2(Zw/Zr)}$ | 250.0 | 2.50 kPa or 2.50E+06 dynes - *to limit Pw to 100 kPa* |
| | $Vr = \frac{2Pr}{DrCr}$ | | 8.54 $cm\cdot s^{-1}$ - *to limit Pw to 100kPa* |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | | 2.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa* |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | | 6.4 m *Minimum setback distance from a spawning area to maintain PPV @ 13 $mm\cdot sec^{-1}$* |
| | $Vr=100(R/W^{.5})^{-1.6}$ | | 8.37 $cm\cdot s^{-1}$ Calculated PPV at Design Criteria |
| | $Vr = \frac{2Pr}{DrCr}$ or $Pr = (DrCrVr)/2$ | | 2.45E+06 Dynes Calculated Pressure in Substrate at Design Criteria |
| | $Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ | | 97.93 kPa Calculated Pressure in Water at Design Criteria |

| PROJECT SUMMARY | Fisheries Limit | Project Design |
|---|---|---|
| Pressure in Water (Pw) kPa | 100.0 | 97.93 |
| **Peak Particle Velocity (Vr) cm-s-1 | 13.0 | 83.67 |

** Limit for spawning bed during period of egg incubation

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# Design Criteria
for
## Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters
## Table No. 4
## Charge Weight Calculations for a 3.0 m Setback

**Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998**
**Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"**

| | Substrate | Dr ($g \cdot cm^{-3}$) | Cr ($cm \cdot s^{-1}$) | Cw ($cm \cdot s^{-1}$) | K | Dw ($g \cdot cm^{-3}$) | Pw (kPa) | PPV ($mm \cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 1 | Rock | 2.64 | 457200 | 146300 | 5.03 | 1.00 | 100.00 | 13.00 |
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.20 | 1.00 | 100.00 | 13.00 |
| 3 | Ice | 0.98 | 304800 | 146300 | 2.10 | 1.00 | 100.00 | 13.00 |
| 4 | Saturated Soil | 2.08 | 146300 | 146300 | 2.13 | 1.00 | 100.00 | 13.00 |
| 5 | Unsaturated Soil | 1.92 | 45700 | 146300 | 0.98 | 1.00 | 100.00 | 13.00 |

**PROJECT DESIGN CRITERIA**

| | | |
|---|---|---|
| **Project Location:** | Polaris Mine - Little Cornwallis Island, Nunavut | |
| **Water Course:** | Crozier Strait | |
| **Substrate:** | Quarry Fill | Frozen Soil ( Fisheries Substrate Classification ) |
| **Nature of Jointing/Fractures:** | N/A | |
| **Overburden:** | N/A | |
| **Hole Depth:** | 2 m | |
| **Explosive Type:** | Orica Powerfrac (Gelatin Dynamite) | |
| **Method of Detonation:** | Electric, blasting cap | |
| **Bubble Curtain Required:** | Yes | |

**Table 4 - Calculations for :** **Polaris Mine - Little Cornwallis Island, Nunavut**

| | Project Substrate | Dr ($g \cdot cm^{-3}$) | Cr ($cm \cdot s^{-1}$) | Cw ($cm \cdot s^{-1}$) | K | Dw ($g \cdot cm^{-3}$) | Pw (kPa) | Vr ($mm \cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.2 | 1.00 | 100.00 | 13.00 |

| | | | |
|---|---|---|---|
| 0.42 | Charge Weight (kg) | 0.42 | 0.93 Lbs/delay |
| 1 | No. of Delays/Charge | 1.0 | |
| | Charge Weight/Delay | 0.42 | |
| 3.0 | Distance to Detonation | 3.00 | |
| | $\frac{Zw}{Zr} = \frac{DwCw}{DrCr}$ | 0.2500 | |
| | $Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ or $Pr = \frac{Pw(1+(Zw/Zr))}{2(Zw/Zr)}$ | 250.0 | 2.50 kPa or 2.50E+06 dynes - *to limit Pw to 100 kPa* |
| | $Vr = \frac{2Pr}{DrCr}$ | 8.64 $cm \cdot s^{-1}$ - *to limit Pw to 100kPa* | |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | 3.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa* | |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | 9.8 m *Minimum setback distance from a spawning area to maintain PPV @ 13 mm•sec*$^{-1}$ | |
| | $Vr=100(R/W^{.5})^{-1.6}$ | 8.61 $cm \cdot s^{-1}$ Calculated PPV at Design Criteria | |
| | $Vr = \frac{2Pr}{DrCr}$ or $Pr = (DrCrVr)/2$ | 2.52E+06 Dynes Calculated Pressure in Substrate at Design Criteria | |
| | $Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ | 100.82 kPa Calculated Pressure in Water at Design Criteria | |

| PROJECT SUMMARY | Fisheries Limit | Project Design | |
|---|---|---|---|
| Pressure in Water (Pw) kPa | 100.0 | 100.82 | |
| **Peak Particle Velocity (Vr) cm•s-1 | 13.0 | 86.14 | ** Limit for spawning bed during period of egg incubation |

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# Design Criteria
for
Guidelines for the Use of Explosives In or
Near Canadian Fisheries Waters
## Table No. 5
## Charge Weight Calculations for a 4.0 m Setback

Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998
Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"

| | Substrate | Dr (g•cm$^{-3}$) | Cr (cm•s$^{-1}$) | Cw (cm•s$^{-1}$) | K | Dw (g•cm$^{-3}$) | Pw (kPa) | PPV (mm•sec$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 1 | Rock | 2.64 | 457200 | 146300 | 5.03 | 1.00 | 100.00 | 13.00 |
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.20 | 1.00 | 100.00 | 13.00 |
| 3 | Ice | 0.98 | 304800 | 146300 | 2.10 | 1.00 | 100.00 | 13.00 |
| 4 | Saturated Soil | 2.08 | 146300 | 146300 | 2.13 | 1.00 | 100.00 | 13.00 |
| 5 | Unsaturated Soil | 1.92 | 45700 | 146300 | 0.98 | 1.00 | 100.00 | 13.00 |

PROJECT DESIGN CRITERIA

**Project Location:** Polaris Mine - Little Cornwallis Island, Nunavut
**Water Course:** Crozier Strait
**Substrate:** Quarry Fill — Frozen Soil ( Fisheries Substrate Classification )
**Nature of Jointing/Fractures:** N/A
**Overburden:** N/A
**Hole Depth:** 2 m
**Explosive Type:** Orica Powerfrac (Gelatin Dynamite)
**Method of Detonation:** Electric, blasting cap
**Bubble Curtain Required:** Yes

Table 5 - Calculations for : Polaris Mine - Little Cornwallis Island, Nunavut

| | Project Substrate | Dr (g•cm$^{-3}$) | Cr (cm•s$^{-1}$) | Cw (cm•s$^{-1}$) | K | Dw (g•cm$^{-3}$) | Pw (kPa) | Vr (mm•sec$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.2 | 1.00 | 100.00 | 13.00 |

| | | | |
|---|---|---|---|
| 0.74 | Charge Weight (kg) | 0.74 | 1.63 Lbs/delay |
| 1 | No. of Delays/Charge | 1.0 | |
| | Charge Weight/Delay | 0.74 | |
| 4.0 | Distance to Detonation | 4.00 | |
| | $Zw/Zr = DwCw/DrCr$ | 0.2500 | |
| | $Pw = 2(Zw/Zr)Pr / (1+(Zw/Zr))$ or $Pr = Pw(1+(Zw/Zr)) / 2(Zw/Zr)$ | 250.0 | 2.50 kPa or 2.50E+06 dynes - *to limit Pw to 100 kPa* |
| | $Vr = 2Pr/DrCr$ | 8.54 cm•s$^{-1}$ - *to limit Pw to 100kPa* | |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | 4.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa* | |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | 13.0 m *Minimum setback distance from a spawning area to maintain PPV @ 13 mm•sec$^{-1}$* | |
| | $Vr=100(R/W^{.5})^{-1.6}$ | 8.55 cm•s$^{-1}$ Calculated PPV at Design Criteria | |
| | $Vr = 2Pr/DrCr$ or $Pr = (DrCrVr)/2$ | 2.50E+06 Dynes Calculated Pressure in Substrate at Design Criteria | |
| | $Pw = 2(Zw/Zr)Pr / (1+(Zw/Zr))$ | 100.10 kPa Calculated Pressure in Water at Design Criteria | |

| PROJECT SUMMARY | Fisheries Limit | Project Design |
|---|---|---|
| Pressure in Water (Pw) kPa | 100.0 | 100.10 |
| **Peak Particle Velocity (Vr) cm•s-1 | 13.0 | 85.52 |

** Limit for spawning bed during period of egg incubation

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**Design Criteria**
**for**
**Guidelines for the Use of Explosives In or**
**Near Canadian Fisheries Waters**
**Table No. 6**
**Charge Weight Calculations for a 5.0 m Setback**

**Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998**
**Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"**

| | Substrate | Dr ($g\cdot cm^{-3}$) | Cr ($cm\cdot s^{-1}$) | Cw ($cm\cdot s^{-1}$) | K | Dw ($g\cdot cm^{-3}$) | Pw (kPa) | PPV ($mm\cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 1 | Rock | 2.64 | 457200 | 146300 | 5.03 | 1.00 | 100.00 | 13.00 |
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.20 | 1.00 | 100.00 | 13.00 |
| 3 | Ice | 0.98 | 304800 | 146300 | 2.10 | 1.00 | 100.00 | 13.00 |
| 4 | Saturated Soil | 2.08 | 146300 | 146300 | 2.13 | 1.00 | 100.00 | 13.00 |
| 5 | Unsaturated Soil | 1.92 | 45700 | 146300 | 0.98 | 1.00 | 100.00 | 13.00 |

**PROJECT DESIGN CRITERIA**

| | | |
|---|---|---|
| **Project Location:** | Polaris Mine - Little Cornwallis Island, Nunavut | |
| **Water Course:** | Crozier Strait | |
| **Substrate:** | Quarry Fill | Frozen Soil ( Fisheries Substrate Classification ) |
| **Nature of Jointing/Fractures:** | N/A | |
| **Overburden:** | N/A | |
| **Hole Depth:** | 2 m | |
| **Explosive Type:** | Orica Powerfrac (Gelatin Dynamite) | |
| **Method of Detonation:** | Electric, blasting cap | |
| **Bubble Curtain Required:** | Yes | |

**Table 6 - Calculations for :** Polaris Mine - Little Cornwallis Island, Nunavut

| | Project Substrate | Dr ($g\cdot cm^{-3}$) | Cr ($cm\cdot s^{-1}$) | Cw ($cm\cdot s^{-1}$) | K | Dw ($g\cdot cm^{-3}$) | Pw (kPa) | Vr ($mm\cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.2 | 1.00 | 100.00 | 13.00 |
| 1.15 | Charge Weight (kg) | 1.15 | 2.54 Lbs/delay | | | | | |
| 1 | No. of Delays/Charge | 1.0 | | | | | | |
| | Charge Weight/Delay | 1.15 | | | | | | |
| 5.0 | Distance to Detonation | 5.00 | | | | | | |
| | $\frac{Zw}{Zr} = \frac{DwCw}{DrCr}$ | 0.2500 | | | | | | |
| | $Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ or $Pr = \frac{Pw(1+(Zw/Zr))}{2(Zw/Zr)}$ | 250.0 | 2.50 kPa or | 2.50E+06 dynes - *to limit Pw to 100 kPa* | | | | |
| | $Vr = \frac{2Pr}{DrCr}$ | 8.54 $cm\cdot s^{-1}$ - *to limit Pw to 100kPa* | | | | | | |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | 5.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa* | | | | | | |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | 16.2 m *Minimum setback distance from a spawning area to maintain PPV @ 13 $mm\cdot sec^{-1}$* | | | | | | |
| | $Vr=100(R/W^{.5})^{-1.6}$ | 8.52 $cm\cdot s^{-1}$ Calculated PPV at Design Criteria | | | | | | |
| | $Vr = \frac{2Pr}{DrCr}$ or $Pr = (DrCrVr)/2$ | 2.49E+06 Dynes Calculated Pressure in Substrate at Design Criteria | | | | | | |
| | $Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ | 99.67 kPa Calculated Pressure in Water at Design Criteria | | | | | | |

| PROJECT SUMMARY | Fisheries Limit | Project Design | |
|---|---|---|---|
| Pressure in Water (Pw) kPa | 100.0 | 99.67 | |
| **Peak Particle Velocity (Vr) cm•s-1 | 13.0 | 85.15 | ** Limit for spawning bed during period of egg incubation |

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**Design Criteria**
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**Table No. 7**
## Charge Weight Calculations for a 6.0 m Setback

**Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998**
**Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"**

| | Substrate | Dr ($g\cdot cm^{-3}$) | Cr ($cm\cdot s^{-1}$) | Cw ($cm\cdot s^{-1}$) | K | Dw ($g\cdot cm^{-3}$) | Pw (kPa) | PPV ($mm\cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 1 | Rock | 2.64 | 457200 | 146300 | 5.03 | 1.00 | 100.00 | 13.00 |
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.20 | 1.00 | 100.00 | 13.00 |
| 3 | Ice | 0.98 | 304800 | 146300 | 2.10 | 1.00 | 100.00 | 13.00 |
| 4 | Saturated Soil | 2.08 | 146300 | 146300 | 2.13 | 1.00 | 100.00 | 13.00 |
| 5 | Unsaturated Soil | 1.92 | 45700 | 146300 | 0.98 | 1.00 | 100.00 | 13.00 |

**PROJECT DESIGN CRITERIA**

| | | |
|---|---|---|
| **Project Location:** | Polaris Mine - Little Cornwallis Island, Nunavut | |
| **Water Course:** | Crozier Strait | |
| **Substrate:** | Quarry Fill | Frozen Soil ( Fisheries Substrate Classification ) |
| **Nature of Jointing/Fractures:** | N/A | |
| **Overburden:** | N/A | |
| **Hole Depth:** | 2 m | |
| **Explosive Type:** | Orica Powerfrac (Gelatin Dynamite) | |
| **Method of Detonation:** | Electric, blasting cap | |
| **Bubble Curtain Required:** | Yes | |

**Table 7 - Calculations for :** **Polaris Mine - Little Cornwallis Island, Nunavut**

| | Project Substrate | Dr ($g\cdot cm^{-3}$) | Cr ($cm\cdot s^{-1}$) | Cw ($cm\cdot s^{-1}$) | K | Dw ($g\cdot cm^{-3}$) | Pw (kPa) | Vr ($mm\cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.2 | 1.00 | 100.00 | 13.00 |

| | | | |
|---|---|---|---|
| 1.66 | Charge Weight (kg) | 1.66 | 3.66 Lbs/delay |
| 1 | No. of Delays/Charge | 1.0 | |
| | Charge Weight/Delay | 1.66 | |
| 6.0 | Distance to Detonation | 6.00 | |
| | $\frac{Zw}{Zr} = \frac{DwCw}{DrCr}$ | 0.2500 | |
| | $Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ or $Pr = \frac{Pw(1+(Zw/Zr))}{2(Zw/Zr)}$ | 250.0 | 2.50 kPa or 2.50E+06 dynes - *to limit Pw to 100 kPa* |
| | $Vr = \frac{2Pr}{DrCr}$ | | 8.54 $cm\cdot s^{-1}$ - *to limit Pw to 100kPa* |
| | $R = (w^{.5})(Vr/100)^{-0.626}$ | | 6.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa* |
| | $R = (w^{.5})(Vr/100)^{-0.626}$ | | 19.4 m *Minimum setback distance from a spawning area to maintain PPV @ 13 mm·sec$^{-1}$* |
| | $Vr=100(R/W^{.5})^{-1.6}$ | | 8.53 $cm\cdot s^{-1}$ Calculated PPV at Design Criteria |
| | $Vr = \frac{2Pr}{DrCr}$ or $Pr = (DrCrVr)/2$ | | 2.50E+06 Dynes Calculated Pressure in Substrate at Design Criteria |
| | $Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ | | 99.86 kPa Calculated Pressure in Water at Design Criteria |

| PROJECT SUMMARY | Fisheries Limit | Project Design |
|---|---|---|
| Pressure in Water (Pw) kPa | 100.0 | 99.86 |
| **Peak Particle Velocity (Vr) cm·s-1 | 13.0 | 85.32 |

** Limit for spawning bed during period of egg incubation

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**Design Criteria**
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**Table No. 8**
**Charge Weight Calculations for a 7.0 m Setback**

**Table 1** - *From* " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998
Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"

| | Substrate | Dr (g•cm$^{-3}$) | Cr (cm•s$^{-1}$) | Cw (cm•s$^{-1}$) | K | Dw (g•cm$^{-3}$) | Pw (kPa) | PPV (mm•sec$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 1 | Rock | 2.64 | 457200 | 146300 | 5.03 | 1.00 | 100.00 | 13.00 |
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.20 | 1.00 | 100.00 | 13.00 |
| 3 | Ice | 0.98 | 304800 | 146300 | 2.10 | 1.00 | 100.00 | 13.00 |
| 4 | Saturated Soil | 2.08 | 146300 | 146300 | 2.13 | 1.00 | 100.00 | 13.00 |
| 5 | Unsaturated Soil | 1.92 | 45700 | 146300 | 0.98 | 1.00 | 100.00 | 13.00 |

**PROJECT DESIGN CRITERIA**

| | |
|---|---|
| **Project Location:** | Polaris Mine - Little Cornwallis Island, Nunavut |
| **Water Course:** | Crozier Strait |
| **Substrate:** | Quarry Fill — Frozen Soil ( Fisheries Substrate Classification ) |
| **Nature of Jointing/Fractures:** | N/A |
| **Overburden:** | N/A |
| **Hole Depth:** | 2 m |
| **Explosive Type:** | Orica Powerfrac (Gelatin Dynamite) |
| **Method of Detonation:** | Electric, blasting cap |
| **Bubble Curtain Required:** | Yes |

**Table 8** - Calculations for : **Polaris Mine - Little Cornwallis Island, Nunavut**

| | Project Substrate | Dr (g•cm$^{-3}$) | Cr (cm•s$^{-1}$) | Cw (cm•s$^{-1}$) | K | Dw (g•cm$^{-3}$) | Pw (kPa) | Vr (mm•sec$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.2 | 1.00 | 100.00 | 13.00 |

| | | | |
|---|---|---|---|
| 2.26 | Charge Weight (kg) | 2.26 | 4.98 Lbs/delay |
| 1 | No. of Delays/Charge | 1.0 | |
| | Charge Weight/Delay | 2.26 | |
| 7.0 | Distance to Detonation | 7.00 | |
| | $\frac{Zw}{Zr} = \frac{DwCw}{DrCr}$ | 0.2500 | |
| | $Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ or $Pr = \frac{Pw(1+(Zw/Zr))}{2(Zw/Zr)}$ | 250.0 | 2.50 kPa or 2.50E+06 dynes - *to limit Pw to 100 kPa* |
| | $Vr = \frac{2Pr}{DrCr}$ | | 8.54 cm•s$^{-1}$ - *to limit Pw to 100kPa* |
| | $R = (w^{.5})(Vr/100)^{-0.626}$ | | 7.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa* |
| | $R = (w^{.5})(Vr/100)^{-0.626}$ | | 22.7 m *Minimum setback distance from a spawning area to maintain PPV @ 13 mm•sec$^{-1}$* |
| | $Vr=100(R/W^{.5})^{-1.6}$ | | 8.53 cm•s$^{-1}$ Calculated PPV at Design Criteria |
| | $Vr = \frac{2Pr}{DrCr}$ or $Pr = (DrCrVr)/2$ | | 2.50E+06 Dynes Calculated Pressure in Substrate at Design Criteria |
| | $Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ | | 99.88 kPa Calculated Pressure in Water at Design Criteria |

| PROJECT SUMMARY | Fisheries Limit | Project Design |
|---|---|---|
| | | |
| Pressure in Water (Pw) kPa | 100.0 | 99.88 |
| **Peak Particle Velocity (Vr) cm•s-1 | 13.0 | 85.34 |
| | | |

** Limit for spawning bed during period of egg incubation

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**Design Criteria**
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**Table No. 9**
## Charge Weight Calculations for a 8.0 m Setback

**Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998**
**Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"**

| | Substrate | Dr ($g{\cdot}cm^{-3}$) | Cr ($cm{\cdot}s^{-1}$) | Cw ($cm{\cdot}s^{-1}$) | K | Dw ($g{\cdot}cm^{-3}$) | Pw (kPa) | PPV ($mm{\cdot}sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 1 | Rock | 2.64 | 457200 | 146300 | 5.03 | 1.00 | 100.00 | 13.00 |
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.20 | 1.00 | 100.00 | 13.00 |
| 3 | Ice | 0.98 | 304800 | 146300 | 2.10 | 1.00 | 100.00 | 13.00 |
| 4 | Saturated Soil | 2.08 | 146300 | 146300 | 2.13 | 1.00 | 100.00 | 13.00 |
| 5 | Unsaturated Soil | 1.92 | 45700 | 146300 | 0.98 | 1.00 | 100.00 | 13.00 |

**PROJECT DESIGN CRITERIA**

| | | |
|---|---|---|
| **Project Location:** | Polaris Mine - Little Cornwallis Island, Nunavut | |
| **Water Course:** | Crozier Strait | |
| **Substrate:** | Quarry Fill | Frozen Soil ( Fisheries Substrate Classification ) |
| **Nature of Jointing/Fractures:** | N/A | |
| **Overburden:** | N/A | |
| **Hole Depth:** | 2 m | |
| **Explosive Type:** | Orica Powerfrac (Gelatin Dynamite) | |
| **Method of Detonation:** | Electric, blasting cap | |
| **Bubble Curtain Required:** | Yes | |

**Table 9 - Calculations for :** **Polaris Mine - Little Cornwallis Island, Nunavut**

| | Project Substrate | Dr ($g{\cdot}cm^{-3}$) | Cr ($cm{\cdot}s^{-1}$) | Cw ($cm{\cdot}s^{-1}$) | K | Dw ($g{\cdot}cm^{-3}$) | Pw (kPa) | Vr ($mm{\cdot}sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.2 | 1.00 | 100.00 | 13.00 |

| | | | |
|---|---|---|---|
| 2.96 | Charge Weight (kg) | 2.96 | 6.53 Lbs/delay |
| 1 | No. of Delays/Charge | 1.0 | |
| | Charge Weight/Delay | 2.96 | |
| 8.0 | Distance to Detonation | 8.00 | |
| | $\frac{Zw}{Zr} = \frac{DwCw}{DrCr}$ | 0.2500 | |
| | $Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ or $Pr = \frac{Pw(1+(Zw/Zr))}{2(Zw/Zr)}$ | 250.0 | 2.50 kPa or 2.50E+06 dynes - *to limit Pw to 100 kPa* |
| | $Vr = \frac{2Pr}{DrCr}$ | | 8.64 $cm{\cdot}s^{-1}$ - *to limit Pw to 100kPa* |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | | 8.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa* |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | | 26.0 m *Minimum setback distance from a spawning area to maintain PPV @ 13 mm•sec$^{-1}$* |
| | $Vr = 100(R/W^{.5})^{-1.6}$ | | 8.55 $cm{\cdot}s^{-1}$ Calculated PPV at Design Criteria |
| | $Vr = \frac{2Pr}{DrCr}$ or $Pr = (DrCrVr)/2$ | | 2.50E+06 Dynes Calculated Pressure in Substrate at Design Criteria |
| | $Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ | | 100.10 kPa Calculated Pressure in Water at Design Criteria |

| PROJECT SUMMARY | Fisheries Limit | Project Design |
|---|---|---|
| | | |
| Pressure in Water (Pw) kPa | 100.0 | 100.10 |
| **Peak Particle Velocity (Vr) cm•s-1 | 13.0 | 85.52 |
| | | |

** Limit for spawning bed during period of egg incubation

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# Design Criteria
# for
# Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters
## Table No. 10
## Charge Weight Calculations for a 9.0 m Setback

**Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998**
**Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"**

| | Substrate | Dr ($g \cdot cm^{-3}$) | Cr ($cm \cdot s^{-1}$) | Cw ($cm \cdot s^{-1}$) | K | Dw ($g \cdot cm^{-3}$) | Pw (kPa) | PPV ($mm \cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 1 | Rock | 2.64 | 457200 | 146300 | 5.03 | 1.00 | 100.00 | 13.00 |
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.20 | 1.00 | 100.00 | 13.00 |
| 3 | Ice | 0.98 | 304800 | 146300 | 2.10 | 1.00 | 100.00 | 13.00 |
| 4 | Saturated Soil | 2.08 | 146300 | 146300 | 2.13 | 1.00 | 100.00 | 13.00 |
| 5 | Unsaturated Soil | 1.92 | 45700 | 146300 | 0.98 | 1.00 | 100.00 | 13.00 |

**PROJECT DESIGN CRITERIA**

| | | |
|---|---|---|
| **Project Location:** | Polaris Mine - Little Cornwallis Island, Nunavut | |
| **Water Course:** | Crozier Strait | |
| **Substrate:** | Quarry Fill | Frozen Soil ( Fisheries Substrate Classification ) |
| **Nature of Jointing/Fractures:** | N/A | |
| **Overburden:** | N/A | |
| **Hole Depth:** | 2 m | |
| **Explosive Type:** | Orica Powerfrac (Gelatin Dynamite) | |
| **Method of Detonation:** | Electric, blasting cap | |
| **Bubble Curtain Required:** | Yes | |

**Table 10 - Calculations for :** **Polaris Mine - Little Cornwallis Island, Nunavut**

| | Project Substrate | Dr ($g \cdot cm^{-3}$) | Cr ($cm \cdot s^{-1}$) | Cw ($cm \cdot s^{-1}$) | K | Dw ($g \cdot cm^{-3}$) | Pw (kPa) | Vr ($mm \cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.2 | 1.00 | 100.00 | 13.00 |

| | | | |
|---|---|---|---|
| 3.74 | Charge Weight (kg) | 3.74 | 8.25 Lbs/delay |
| 1 | No. of Delays/Charge | 1.0 | |
| | Charge Weight/Delay | 3.74 | |
| 9.0 | Distance to Detonation | 9.00 | |
| | Zw = DwCw / Zr DrCr | 0.2500 | |
| | Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr) or Pr = Pw(1+(Zw/Zr)) / 2(Zw/Zr) | 250.0 | 2.50 kPa or 2.50E+06 dynes - *to limit Pw to 100 kPa* |
| | Vr = 2Pr / DrCr | | 8.54 $cm \cdot s^{-1}$ - *to limit Pw to 100kPa* |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | | 9.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa* |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | | 29.2 m *Minimum setback distance from a spawning area to maintain PPV @ 13 mm•sec*$^{-1}$ |
| | $Vr=100(R/W^{.5})^{-1.6}$ | | 8.54 $cm \cdot s^{-1}$ Calculated PPV at Design Criteria |
| | Vr = 2Pr / DrCr or Pr = (DrCrVr)/2 | | 2.50E+06 Dynes Calculated Pressure in Substrate at Design Criteria |
| | Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr) | | 99.96 kPa Calculated Pressure in Water at Design Criteria |

| PROJECT SUMMARY | Fisheries Limit | Project Design | |
|---|---|---|---|
| | | | |
| Pressure in Water (Pw) kPa | 100.0 | 99.96 | |
| **Peak Particle Velocity (Vr) cm•s-1 | 13.0 | 85.41 | ** Limit for spawning bed during period of egg incubation |
| | | | |

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## Design Criteria
## for
## Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters
## Table No. 11
## Charge Weight Calculations for a 10.0 m Setback

**Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998**
**Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"**

| | Substrate | Dr ($g \cdot cm^{-3}$) | Cr ($cm \cdot s^{-1}$) | Cw ($cm \cdot s^{-1}$) | K | Dw ($g \cdot cm^{-3}$) | Pw (kPa) | PPV ($mm \cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 1 | Rock | 2.64 | 457200 | 146300 | 5.03 | 1.00 | 100.00 | 13.00 |
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.20 | 1.00 | 100.00 | 13.00 |
| 3 | Ice | 0.98 | 304800 | 146300 | 2.10 | 1.00 | 100.00 | 13.00 |
| 4 | Saturated Soil | 2.08 | 146300 | 146300 | 2.13 | 1.00 | 100.00 | 13.00 |
| 5 | Unsaturated Soil | 1.92 | 45700 | 146300 | 0.98 | 1.00 | 100.00 | 13.00 |

**PROJECT DESIGN CRITERIA**

| | | |
|---|---|---|
| **Project Location:** | Polaris Mine - Little Cornwallis Island, Nunavut | |
| **Water Course:** | Crozier Strait | |
| **Substrate:** | Quarry Fill | Frozen Soil ( Fisheries Substrate Classification ) |
| **Nature of Jointing/Fractures:** | N/A | |
| **Overburden:** | N/A | |
| **Hole Depth:** | 2 m | |
| **Explosive Type:** | Orica Powerfrac (Gelatin Dynamite) | |
| **Method of Detonation:** | Electric, blasting cap | |
| **Bubble Curtain Required:** | Yes | |

Table 11 - Calculations for : **Polaris Mine - Little Cornwallis Island, Nunavut**

| | Project Substrate | Dr ($g \cdot cm^{-3}$) | Cr ($cm \cdot s^{-1}$) | Cw ($cm \cdot s^{-1}$) | K | Dw ($g \cdot cm^{-3}$) | Pw (kPa) | Vr ($mm \cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.2 | 1.00 | 100.00 | 13.00 |
| 4.62 | Charge Weight (kg) | 4.62 | 10.19 Lbs/delay | | | | | |
| 1 | No. of Delays/Charge | 1.0 | | | | | | |
| | Charge Weight/Delay | 4.62 | | | | | | |
| 10.0 | Distance to Detonation | 10.00 | | | | | | |
| | $\frac{Zw}{Zr} = \frac{DwCw}{DrCr}$ | 0.2500 | | | | | | |
| | $Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ or $Pr = \frac{Pw(1+(Zw/Zr))}{2(Zw/Zr)}$ | 250.0 | 2.50 kPa or | 2.50E+06 dynes - *to limit Pw to 100 kPa* | | | | |
| | $Vr = \frac{2Pr}{DrCr}$ | 8.54 $cm \cdot s^{-1}$ - *to limit Pw to 100kPa* | | | | | | |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | 10.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa* | | | | | | |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | 32.4 m *Minimum setback distance from a spawning area to maintain PPV @ 13 $mm \cdot sec^{-1}$* | | | | | | |
| | $Vr = 100(R/W^{.5})^{-1.6}$ | 8.55 $cm \cdot s^{-1}$ Calculated PPV at Design Criteria | | | | | | |
| | $Vr = \frac{2Pr}{DrCr}$ or $Pr = (DrCrVr)/2$ | 2.50E+06 Dynes Calculated Pressure in Substrate at Design Criteria | | | | | | |
| | $Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ | 100.01 kPa Calculated Pressure in Water at Design Criteria | | | | | | |

| PROJECT SUMMARY | Fisheries Limit | Project Design | |
|---|---|---|---|
| Pressure in Water (Pw) kPa | 100.0 | 100.01 | |
| **Peak Particle Velocity (Vr) cm•s-1 | 13.0 | 85.45 | ** Limit for spawning bed during period of egg incubation |

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# Design Criteria
# for
# Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters
# Table No. 12
# Charge Weight Calculations for a 11.0 m Setback

**Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998**
**Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"**

| | Substrate | Dr ($g \cdot cm^{-3}$) | Cr ($cm \cdot s^{-1}$) | Cw ($cm \cdot s^{-1}$) | K | Dw ($g \cdot cm^{-3}$) | Pw (kPa) | PPV ($mm \cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 1 | Rock | 2.64 | 457200 | 146300 | 5.03 | 1.00 | 100.00 | 13.00 |
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.20 | 1.00 | 100.00 | 13.00 |
| 3 | Ice | 0.98 | 304800 | 146300 | 2.10 | 1.00 | 100.00 | 13.00 |
| 4 | Saturated Soil | 2.08 | 146300 | 146300 | 2.13 | 1.00 | 100.00 | 13.00 |
| 5 | Unsaturated Soil | 1.92 | 45700 | 146300 | 0.98 | 1.00 | 100.00 | 13.00 |

**PROJECT DESIGN CRITERIA**

| | | |
|---|---|---|
| **Project Location:** | Polaris Mine - Little Cornwallis Island, Nunavut | |
| **Water Course:** | Crozier Strait | |
| **Substrate:** | Quarry Fill | Frozen Soil ( Fisheries Substrate Classification ) |
| **Nature of Jointing/Fractures:** | N/A | |
| **Overburden:** | N/A | |
| **Hole Depth:** | 2 m | |
| **Explosive Type:** | Orica Powerfrac (Gelatin Dynamite) | |
| **Method of Detonation:** | Electric, blasting cap | |
| **Bubble Curtain Required:** | Yes | |

Table 12 - Calculations for : **Polaris Mine - Little Cornwallis Island, Nunavut**

| | Project Substrate | Dr ($g \cdot cm^{-3}$) | Cr ($cm \cdot s^{-1}$) | Cw ($cm \cdot s^{-1}$) | K | Dw ($g \cdot cm^{-3}$) | Pw (kPa) | Vr ($mm \cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.2 | 1.00 | 100.00 | 13.00 |

| | | | |
|---|---|---|---|
| 5.59 | Charge Weight (kg) | 5.59 | 12.32 Lbs/delay |
| 1 | No. of Delays/Charge | 1.0 | |
| | Charge Weight/Delay | 5.59 | |
| 11.0 | Distance to Detonation | 11.00 | |
| | Zw = DwCw / Zr DrCr | 0.2500 | |
| | Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr) or | | |
| | Pr = Pw(1+(Zw/Zr)) / 2(Zw/Zr) | 250.0 | 2.50 kPa or 2.50E+06 dynes - *to limit Pw to 100 kPa* |
| | Vr = 2Pr / DrCr | | 8.54 $cm \cdot s^{-1}$ - *to limit Pw to 100kPa* |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | | **11.0 m** *Minimum setback distance required to reduce overpressure to less than 100 kPa* |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | | **36.7 m** *Minimum setback distance from a spawning area to maintain PPV @ 13 $mm \cdot sec^{-1}$* |
| | $Vr=100(R/W^{.5})^{-1.6}$ | | 8.54 $cm \cdot s^{-1}$ Calculated PPV at Design Criteria |
| | Vr = 2Pr / DrCr or Pr = (DrCrVr)/2 | | 2.50E+06 Dynes Calculated Pressure in Substrate at Design Criteria |
| | Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr) | | 100.01 kPa Calculated Pressure in Water at Design Criteria |

| PROJECT SUMMARY | Fisheries Limit | Project Design |
|---|---|---|
| | | |
| Pressure in Water (Pw) kPa | 100.0 | 100.01 |
| **Peak Particle Velocity (Vr) cm•s-1 | 13.0 | 85.45 |
| | | |

** Limit for spawning bed during period of egg incubation

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# Design Criteria
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## Table No. 13

## Charge Weight Calculations for a 12.0 m Setback

**Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998**
**Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"**

| | Substrate | Dr ($g\cdot cm^{-3}$) | Cr ($cm\cdot s^{-1}$) | Cw ($cm\cdot s^{-1}$) | K | Dw ($g\cdot cm^{-3}$) | Pw (kPa) | PPV ($mm\cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 1 | Rock | 2.64 | 457200 | 146300 | 5.03 | 1.00 | 100.00 | 13.00 |
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.20 | 1.00 | 100.00 | 13.00 |
| 3 | Ice | 0.98 | 304800 | 146300 | 2.10 | 1.00 | 100.00 | 13.00 |
| 4 | Saturated Soil | 2.08 | 146300 | 146300 | 2.13 | 1.00 | 100.00 | 13.00 |
| 5 | Unsaturated Soil | 1.92 | 45700 | 146300 | 0.98 | 1.00 | 100.00 | 13.00 |

**PROJECT DESIGN CRITERIA**

| | | |
|---|---|---|
| **Project Location:** | Polaris Mine - Little Cornwallis Island, Nunavut | |
| **Water Course:** | Crozier Strait | |
| **Substrate:** | Quarry Fill | Frozen Soil ( Fisheries Substrate Classification ) |
| **Nature of Jointing/Fractures:** | N/A | |
| **Overburden:** | N/A | |
| **Hole Depth:** | 2 m | |
| **Explosive Type:** | Orica Powerfrac (Gelatin Dynamite) | |
| **Method of Detonation:** | Electric, blasting cap | |
| **Bubble Curtain Required:** | Yes | |

**Table 13 - Calculations for :** **Polaris Mine - Little Cornwallis Island, Nunavut**

| | Project Substrate | Dr ($g\cdot cm^{-3}$) | Cr ($cm\cdot s^{-1}$) | Cw ($cm\cdot s^{-1}$) | K | Dw ($g\cdot cm^{-3}$) | Pw (kPa) | Vr ($mm\cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.2 | 1.00 | 100.00 | 13.00 |

| | | | |
|---|---|---|---|
| 6.65 | Charge Weight (kg) | 6.65 | 14.66 Lbs/delay |
| 1 | No. of Delays/Charge | 1.0 | |
| | Charge Weight/Delay | 6.65 | |
| 12.0 | Distance to Detonation | 12.00 | |
| | Zw/Zr = DwCw/DrCr | 0.2500 | |
| | Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr) or Pr = Pw(1+(Zw/Zr)) / 2(Zw/Zr) | 250.0 | 2.50 kPa or 2.50E+06 dynes - *to limit Pw to 100 kPa* |
| | Vr = 2Pr / DrCr | | 8.54 $cm\cdot s^{-1}$ - *to limit Pw to 100kPa* |
| | R = $(w^{.5})(Vr/100)^{-0.626}$ | | 12.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa* |
| | R = $(w^{.5})(Vr/100)^{-0.626}$ | | 38.9 m *Minimum setback distance from a spawning area to maintain PPV @ 13 mm•sec$^{-1}$* |
| | Vr=100$(R/W^{.5})^{-1.6}$ | | 8.54 $cm\cdot s^{-1}$ Calculated PPV at Design Criteria |
| | Vr = 2Pr / DrCr or Pr = (DrCrVr)/2 | | 2.50E+06 Dynes Calculated Pressure in Substrate at Design Criteria |
| | Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr) | | 99.98 kPa Calculated Pressure in Water at Design Criteria |

| PROJECT SUMMARY | Fisheries Limit | Project Design | |
|---|---|---|---|
| | | | |
| Pressure in Water (Pw) kPa | 100.0 | 99.98 | |
| **Peak Particle Velocity (Vr) cm•s-1 | 13.0 | 85.42 | ** Limit for spawning bed during period of egg incubation |
| | | | |

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## Table No. 14
## Charge Weight Calculations for a 13.0 m Setback

**Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998**
**Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"**

| | Substrate | Dr ($g \cdot cm^{-3}$) | Cr ($cm \cdot s^{-1}$) | Cw ($cm \cdot s^{-1}$) | K | Dw ($g \cdot cm^{-3}$) | Pw (kPa) | PPV ($mm \cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 1 | Rock | 2.64 | 457200 | 146300 | 5.03 | 1.00 | 100.00 | 13.00 |
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.20 | 1.00 | 100.00 | 13.00 |
| 3 | Ice | 0.98 | 304800 | 146300 | 2.10 | 1.00 | 100.00 | 13.00 |
| 4 | Saturated Soil | 2.08 | 146300 | 146300 | 2.13 | 1.00 | 100.00 | 13.00 |
| 5 | Unsaturated Soil | 1.92 | 45700 | 146300 | 0.98 | 1.00 | 100.00 | 13.00 |

**PROJECT DESIGN CRITERIA**

| | | |
|---|---|---|
| **Project Location:** | Polaris Mine - Little Cornwallis Island, Nunavut | |
| **Water Course:** | Crozier Strait | |
| **Substrate:** | Quarry Fill | Frozen Soil ( Fisheries Substrate Classification ) |
| **Nature of Jointing/Fractures:** | N/A | |
| **Overburden:** | N/A | |
| **Hole Depth:** | 2 m | |
| **Explosive Type:** | Orica Powerfrac (Gelatin Dynamite) | |
| **Method of Detonation:** | Electric, blasting cap | |
| **Bubble Curtain Required:** | Yes | |

**Table 14 - Calculations for :** **Polaris Mine - Little Cornwallis Island, Nunavut**

| | Project Substrate | Dr ($g \cdot cm^{-3}$) | Cr ($cm \cdot s^{-1}$) | Cw ($cm \cdot s^{-1}$) | K | Dw ($g \cdot cm^{-3}$) | Pw (kPa) | Vr ($mm \cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.2 | 1.00 | 100.00 | 13.00 |

| | | | |
|---|---|---|---|
| 7.81 | Charge Weight (kg) | 7.81 | 17.22 Lbs/delay |
| 1 | No. of Delays/Charge | 1.0 | |
| | Charge Weight/Delay | 7.81 | |
| 13.0 | Distance to Detonation | 13.00 | |
| | $\frac{Zw}{Zr} = \frac{DwCw}{DrCr}$ | 0.2500 | |
| | $Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ or $Pr = \frac{Pw(1+(Zw/Zr))}{2(Zw/Zr)}$ | 250.0 | 2.50 kPa or 2.50E+06 dynes - *to limit Pw to 100 kPa* |
| | $Vr = \frac{2Pr}{DrCr}$ | | 8.54 $cm \cdot s^{-1}$ - *to limit Pw to 100kPa* |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | | 13.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa* |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | | 42.2 m *Minimum setback distance from a spawning area to maintain PPV @ 13 mm·sec* $^{-1}$ |
| | $Vr=100(R/W^{.5})^{-1.6}$ | | 8.55 $cm \cdot s^{-1}$ Calculated PPV at Design Criteria |
| | $Vr = \frac{2Pr}{DrCr}$ or $Pr = (DrCrVr)/2$ | | 2.50E+06 Dynes Calculated Pressure in Substrate at Design Criteria |
| | $Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ | | 100.03 kPa Calculated Pressure in Water at Design Criteria |

| PROJECT SUMMARY | Fisheries Limit | Project Design | |
|---|---|---|---|
| | | | |
| Pressure in Water (Pw) kPa | 100.0 | 100.03 | |
| **Peak Particle Velocity (Vr) cm·s-1 | 13.0 | 85.47 | ** Limit for spawning bed during period of egg incubation |
| | | | |

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# Design Criteria
# for
# Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters
## Table No. 15
## Charge Weight Calculations for a 14.0 m Setback

**Table 1** - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998
Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"

| | Substrate | Dr ($g \cdot cm^{-3}$) | Cr ($cm \cdot s^{-1}$) | Cw ($cm \cdot s^{-1}$) | K | Dw ($g \cdot cm^{-3}$) | Pw (kPa) | PPV ($mm \cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 1 | Rock | 2.64 | 457200 | 146300 | 5.03 | 1.00 | 100.00 | 13.00 |
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.20 | 1.00 | 100.00 | 13.00 |
| 3 | Ice | 0.98 | 304800 | 146300 | 2.10 | 1.00 | 100.00 | 13.00 |
| 4 | Saturated Soil | 2.08 | 146300 | 146300 | 2.13 | 1.00 | 100.00 | 13.00 |
| 5 | Unsaturated Soil | 1.92 | 45700 | 146300 | 0.98 | 1.00 | 100.00 | 13.00 |

**PROJECT DESIGN CRITERIA**

| | | |
|---|---|---|
| **Project Location:** | Polaris Mine - Little Cornwallis Island, Nunavut | |
| **Water Course:** | Crozier Strait | |
| **Substrate:** | Quarry Fill | Frozen Soil ( Fisheries Substrate Classification ) |
| **Nature of Jointing/Fractures:** | N/A | |
| **Overburden:** | N/A | |
| **Hole Depth:** | 2 m | |
| **Explosive Type:** | Orica Powerfrac (Gelatin Dynamite) | |
| **Method of Detonation:** | Electric, blasting cap | |
| **Bubble Curtain Required:** | Yes | |

**Table 15** - Calculations for : **Polaris Mine - Little Cornwallis Island, Nunavut**

| | Project Substrate | Dr ($g \cdot cm^{-3}$) | Cr ($cm \cdot s^{-1}$) | Cw ($cm \cdot s^{-1}$) | K | Dw ($g \cdot cm^{-3}$) | Pw (kPa) | Vr ($mm \cdot sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 2 | Frozen Soil | 1.92 | 304800 | 146300 | 3.2 | 1.00 | 100.00 | 13.00 |
| 9.05 | Charge Weight (kg) | 9.05 | 19.95 Lbs/delay | | | | | |
| 1 | No. of Delays/Charge | 1.0 | | | | | | |
| | Charge Weight/Delay | 9.05 | | | | | | |
| 14.0 | Distance to Detonation | 14.00 | | | | | | |
| | $\frac{Zw}{Zr} = \frac{DwCw}{DrCr}$ | 0.2500 | | | | | | |
| | $Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ or $Pr = \frac{Pw(1+(Zw/Zr))}{2(Zw/Zr)}$ | 250.0 | 2.50 kPa or | 2.50E+06 dynes - *to limit Pw to 100 kPa* | | | | |
| | $Vr = \frac{2Pr}{DrCr}$ | 8.54 $cm \cdot s^{-1}$ - *to limit Pw to 100kPa* | | | | | | |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | 14.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa* | | | | | | |
| | $R = (w^{.5})(Vr/100)^{-0.625}$ | 45.4 m *Minimum setback distance from a spawning area to maintain PPV @ 13 $mm \cdot sec^{-1}$* | | | | | | |
| | $Vr=100(R/W^{.5})^{-1.6}$ | 8.54 $cm \cdot s^{-1}$ Calculated PPV at Design Criteria | | | | | | |
| | $Vr = \frac{2Pr}{DrCr}$ or $Pr = (DrCrVr)/2$ | 2.50E+06 Dynes Calculated Pressure in Substrate at Design Criteria | | | | | | |
| | $Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ | 99.97 kPa Calculated Pressure in Water at Design Criteria | | | | | | |

| PROJECT SUMMARY | Fisheries Limit | Project Design |
|---|---|---|
| Pressure in Water (Pw) kPa | 100.0 | 99.97 |
| **Peak Particle Velocity (Vr) cm•s-1 | 13.0 | 85.41 |

** Limit for spawning bed during period of egg incubation

## ATTACHMENT # 16

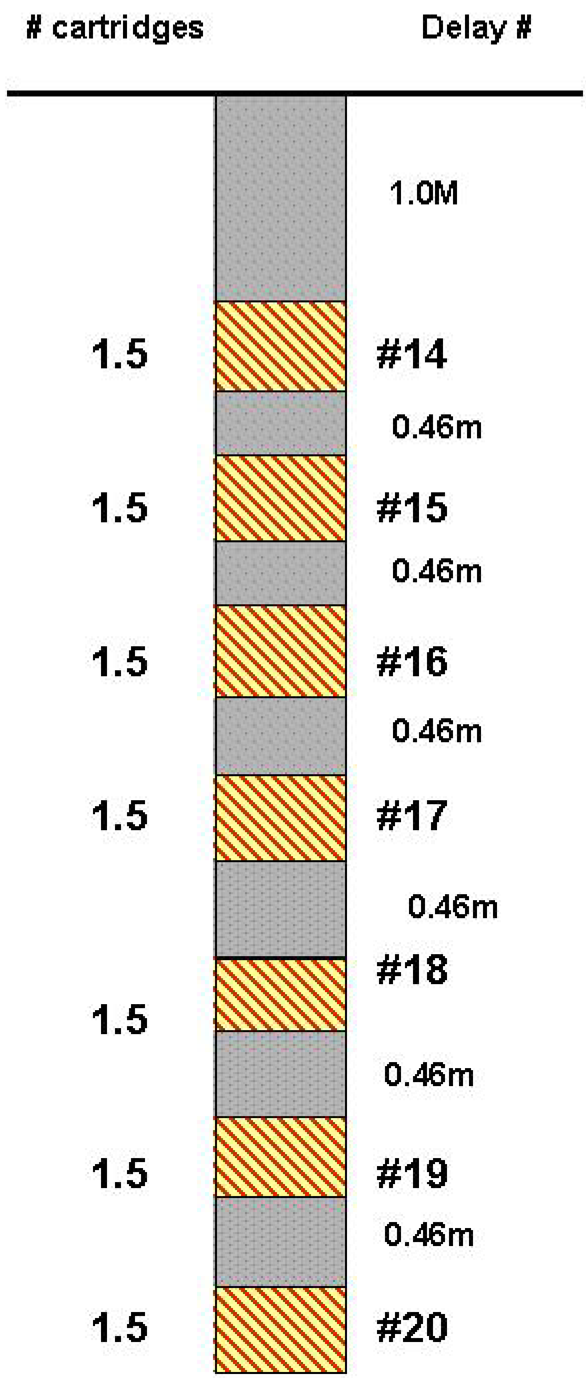
## APPENDIX H FROM REVISION 1 OF

## 'DECOMMISSIONING OF DOCK FACILITIES AT POLARIS MINE LITTLE CORNWALLIS

## ISLAND, NUNAVUT'

## BY WESTMAR CONSULTING ENGINEERS

# Polaris Mine Reclamation Project
# Typical Blasthole Loading Sketch
# Removal of Dock Structure




Hole Depth = 7.9m
Explosive Type = Powerfrac 65x400mm
Explosive loading = 2.27kg (5 lbs.) per deck
Maximum charge weight per delay = 2.27 kg.
Detonator type = Electric MS

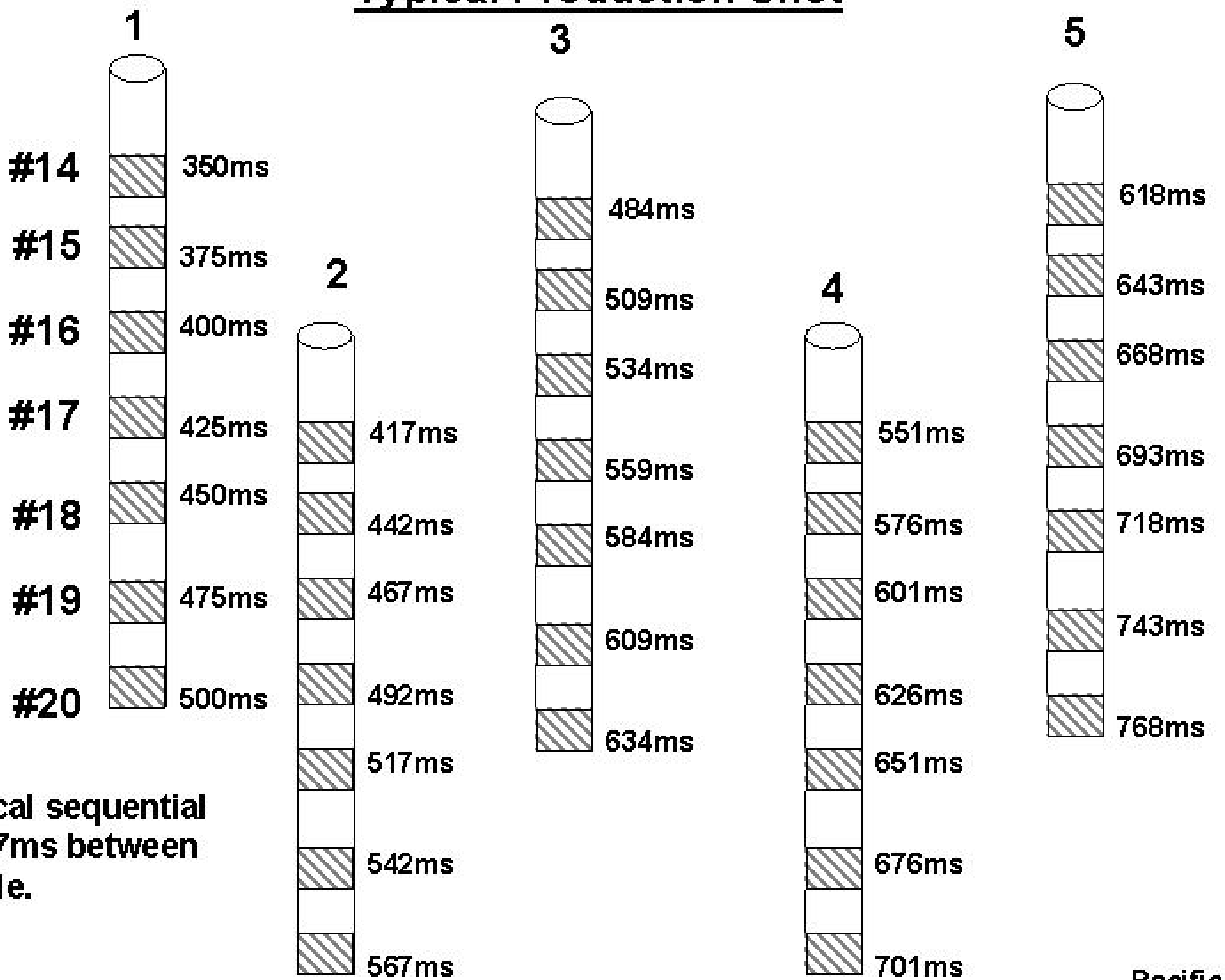
Pacific Blasting

**Polaris Mine Reclamation**

**Dock Structure**

**Electrical Sequential Blast Design**

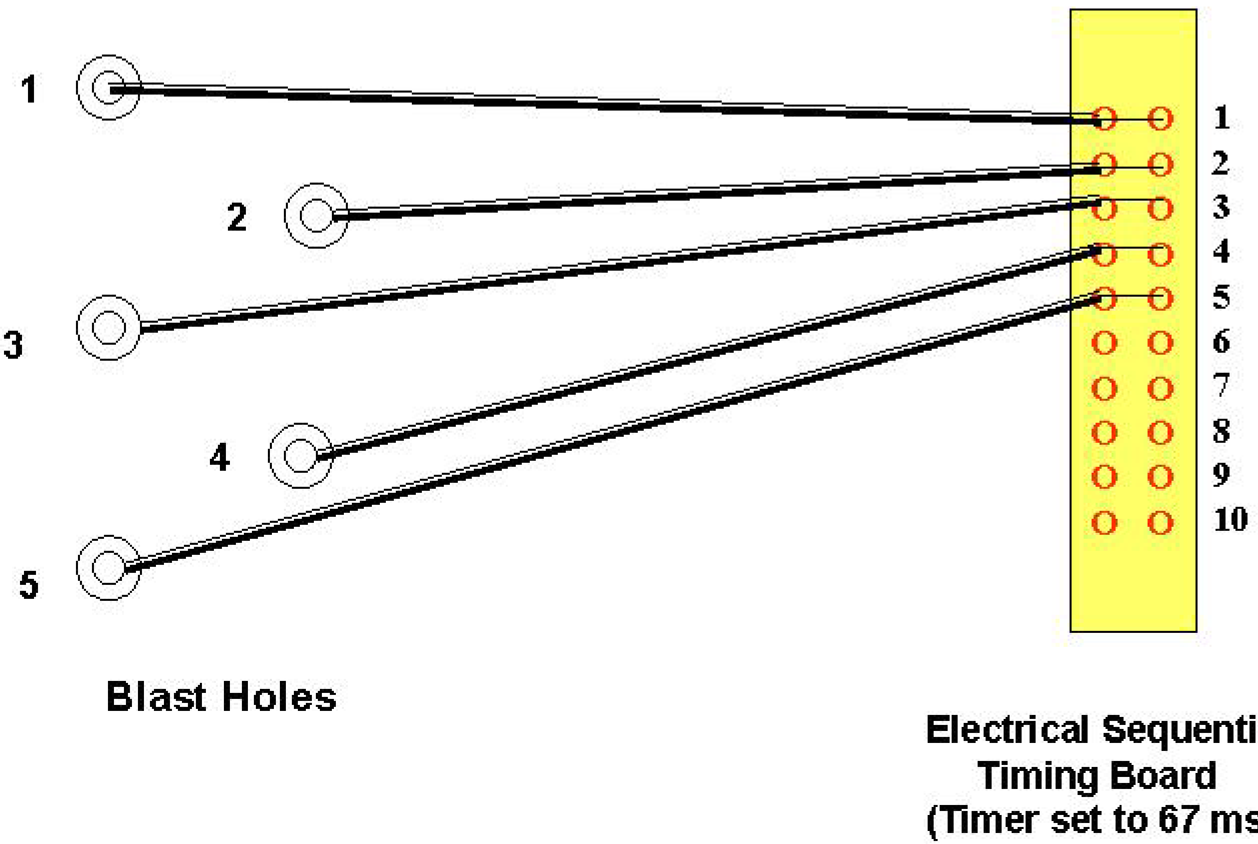
**Typical Production Shot**




**Note**: Electrical sequential timer set to 67ms between each blast hole.

Pacific Blasting

**Polaris Mine Reclamation Project**
**Dock Structure**
**Tie-in Sketch**




Pacific Blasting

# ATTACHMENT # 17

# FAX TO B. DONALD FROM A. EGLAUER OF EBA ENGINEERING CONSULTANTS LTD.

# REGARDING

# 'RESPONSE TO DFO-FHM COMMENTS, GARROW LAKE DAM DECOMMISSIONING, POLARIS MINE OPERATIONS, NUNAVUT'

# dated December 13, 2001.

December 13, 2001 EBA File: 0101-94-11552.002

**VIA FAX: (250) 427-8202 (7 Pages)**
Teck Cominco Metals Ltd.
Bag 2000
Kimberly, BC V1A 3E1

Attention: Mr. Bruce Donald

**Subject: Response to DFO-FHM Comments**
**Garrow Lake Dam Decommissioning**
**Polaris Mine Operations, Nunavut**

## 1.0 INTRODUCTION

This letter addresses comments received by Teck Cominco Metals Ltd. (TCML) from the Department of Fisheries and Oceans – Fish Habitat Management (DFO-FHM) in a letter dated October 26, 2001 pertaining to the Garrow Lake Dam Decommissioning report submitted by EBA Engineering Consultants Ltd. (EBA) to TCML in March 2001.

It is EBA's understanding that decommissioning of Garrow Lake Dam has been scheduled during 2004. The lake elevation will gradually be reduced between now and then by discharging water using the siphon system during open water season.

## 2.0 DFO-FHM COMMENTS

The DFO-FHM letter of October 26, 2001 includes comments from three parties: Mr. Bruce Fallis, Messrs. Rick Gervais and Chris Katopodis, and Mr. Dennis Wright.

A summary of the comments is presented below:

- A cost-benefit analysis should be provided to compare the partial and complete dam removal options.
- Integrity of the remaining portion of the dam after drilling and blasting needs to be addressed.
- Timing of the dam decommissioning is critical to its success.
- Erosion of the now-thawed shoreline of Garrow Lake and the potential increase in total and/or dissolved solids (TSS/TDS) in run-off needs to be addressed.

## 3.0 EBA RESPONSES

### 3.1 Cost-Benefit Analysis

Two options were presented in the EBA report; partial dam removal and complete removal. Partial removal was the preferred option and the design was developed on this basis. The following expands on the complete dam removal and presents a cost-benefit analysis of the two options.

#### 3.1.1 Complete Dam Removal

Complete removal of the dam is a viable option to its decommissioning. This option removes the entire dam structure, allowing Garrow Creek to flow through its historic channel.

The core material used to construct the dam (processed, saturated limestone and shale) will have to be removed from the key trench under the dam core. This material will thaw in the summer months and slump towards or into Garrow Creek unless replaced or covered with stable granular material.

Complete removal of the core and key trench will entail exhaustive blasting of the frozen material. The loose surface materials (shell and rip rap) will require removal prior to drilling and blasting. The estimated volume of the shell and rip rap material is 21,100 $m^3$. Some of this material could be stockpiled for remediation use at the dam site and the balance hauled to Little Red Dog Pit for disposal.

The drilling and blasting of the frozen portion of the dam can proceed following removal of the shell and rip rap. The volume of the frozen shell and core material is estimated to be 27,900 $m^3$. This in-place volume will have to be excavated and hauled to the Little Red Dog Pit for disposal.

Blasting of the core will affect the natural ground to some degree. The native permafrost may experience some minor cracking; however, this is not deemed as problematic because the permafrost will naturally "heal" itself by freezing water that infiltrates the cracks.

Placement of fill material will be required in the channel and in the excavated key trench under the core. The volume of fill to be placed is estimated to be 1500 $m^3$. A small thickness of shell material should be left in place over the remaining dam footprint to cover the disturbed dam footprint.

Table 1 provides the estimated cost for complete removal of the dam. Unit costs have been based on historical northern earthworks, but the actual costs will be a function of the overall decommissioning plan and contract strategy. It does not include any costs for remediation of erosion channels near the dam as this cost is common to all decommissioning options. The complete dam removal would be accomplished at the cost of nearly $1,250,000.

**Table 1**
**Estimate Decommissioning Costs for**
**Complete Removal of Garrow Lake Dam**

| Item | Unit | Unit Cost | Estimated Quantity | Amount |
|---|---|---|---|---|
| Excavate rip rap material | $m^3$ | $ 5.00 | 3,300 | $16,500 |
| Haul excess rip rap to Little Red Dog Pit (8 km) | $m^3$ | $12.00 (1) | 1,800 | $21,600 |
| Excavate unfrozen shell material | $m^3$ | $ 5.00 | 17,800 (2) | $89,000 |
| Haul unfrozen shell to Little Red Dog Pit (8 km) | $m^3$ | $12.00 (1) | 17,800 | $213,600 |
| Drill and blast frozen shell and core material | $m^3$ | $15.00 | 27,900 (2) | $418,500 |
| Excavate blasted shell and core material | $m^3$ | $ 5.00 | 27,900 | $139,500 |
| Haul blasted shell and core to Little Red Dog Pit (8 km) | $m^3$ | $12.00 (1) | 27,900 | $334,800 |
| Place rip rap in creek channel and key trench | $m^3$ | $10.00 | 1,500 | $15,000 |
| | | | Total | $1,248,500 |

(1) Based on a rate of $1.50 per $m^3$-km and an 8 km haul distance
(2) 50% of the shell material volume is estimated to require drill and blast excavation; the actual percentage will vary with degree of material saturation and temperature at the time of excavation.

### 3.1.2 Partial Dam Removal

Partial removal of the dam is detailed in EBA's March 2001 report. The concepts and discussion are presented in the report (Report #4, Volume 2 of the Polaris Decommissioning and Reclamation Plan).

Partial dam removal entails removal of the portion of the dam constructed over the historic Garrow Creek. After removal of this portion of the dam, the two remaining abutments would be sloped at 4H:1V and the exposed frozen core of the dam would be thermally protected by placing a thick layer of shell material on the slopes. The partial dam option is considered a viable option. The estimated costs for this option are presented in Table 2. The partial dam removal would be accomplished at a cost of nearly $450,000.

**Table 2**
**Estimated Decommissioning Costs for**
**Partial Removal of Garrow Lake Dam**

| Item | Unit | Unit Cost | Estimated Quantity | Amount |
|---|---|---|---|---|
| Excavate rip rap material | $m^3$ | $5.00 | 1,500 | $7,500 |
| Haul rip rap to Little Red Dog Pit (8 km) | $m^3$ | $12.00 (1) | 400 | $4,800 |
| Excavate unfrozen shell material | $m^3$ | $5.00 | 9,100 (2) | $45,500 |
| Haul unfrozen shell to Little Red Dog Pit (8 km) | $m^3$ | $12.00 (1) | 2,900 | $34,800 |
| Drill and blast frozen shell and core material | $m^3$ | $15.00 | 8,750 (2) | $131,250 |
| Excavate frozen shell and core material | $m^3$ | $5.00 | 8,750 | $43,750 |
| Haul frozen shell and core to Little Red Dog Pit (8 km) | $m^3$ | $12.00 (1) | 8,750 | $105,000 |
| Place shell material on excavated slope of core | $m^3$ | $10.00 | 6,200 | $62,000 |
| Place rip rap in creek channel | $m^3$ | $10.00 | 1,100 | $11,000 |
| | | | Total | $445,600 |

(1) Based on a rate of $1.50 per $m^3$-km and an 8 km haul distance.
(2) 50% of the shell material volume is estimated to require drill and blast excavation; the actual percentage will vary with degree of material saturation and temperature at the time of excavation.

### 3.1.3 Complete vs. Partial Dam Removal

Both removal options achieve the end result of allowing natural discharge from Garrow Lake through the historic Garrow Creek. There is no difference between the two options with regard to the halocline and the concerns related to it, nor the issue of potential increased erosion and TSS.

Complete dam removal provides the following benefits over the partial dam removal option:

- eliminates risk with potential slope failure of the remaining dam abutments; and
- reduces risk of channel blocking/freezing off which could lead to large flow and erosion downstream of dam location (once the blockage releases).

The risk of slope failure of the dam abutments is low because the slopes are flat (4H:1V) and the core will remain frozen under global warming conditions. The natural ground in the area of the dam also slopes at about 4H:1V so removing the abutments will not necessarily eliminate the risk of slope failures occurring.

The 4H:1V slopes and 15 m wide channel result in a very low risk of blockage. Further, the channel will be protected from erosion by placing rip rap through the bottom of the channel as well as up the slopes of remaining abutments.

The complete dam removal option carries a cost of more than twice that of the partial removal option. Should TCML have to remobilize to site and reconstruct containment of Garrow Lake, the costs would be at least double (or more) if the complete dam is removed as part of the mine closure in 2004. There could be some difficulties in melding a new dam to the remnant abutments of the existing one, but such issues are deemed to be resolvable at limited cost that keeps the partial removal more economical.

It is under all of these considerations that the partial dam removal option is considered to be technically equivalent and economically superior to the complete dam removal option. The risk level associated with the partial dam removal is deemed to be low.

### 3.2 Integrity of Remaining Dam Structure Related to Blasting

The stability of the remaining dam structure is presented in EBA's report. Blasting within the central portion of the dam will have some effect on the remaining portion of the dam, as cracking of the core could result. This is not problematic because the remaining dam abutment need not be impervious. Any water that infiltrates the tiny cracks would freeze because of the cold temperatures within the core (temperatures within the core have not risen above –10˚C over the life of the dam).

The slope of the cut in the core material (frozen) would be 2H:1V. This cut will be stable if it remains frozen. A blanket of shell and/or rip rap material will be placed on the exposed core to thermally protect it. The blanket would be placed with a 4H:1V slope, such that the blanket material itself would also be stable.

The cracked portions of the frozen core are not considered to introduce unstable zones within the final dam geometry. A cracked frozen zone will be outside of the critical stability zone. In addition, the cracked frozen material would have a relatively high friction angle and not introduce a weak zone in the embankment. The frozen core will be covered with a significant amount of granular fill. The granular fill will be placed at a relatively flat slope of 4H:1V, and the thickness of it will vary. The minimum fill thickness required to keep the core frozen has been provided.

Sudden failure will not occur given the design slopes. The thermal modelling and stability analyses (as discussed in Volume 2, Report #4 of the Polaris Mine Decommissioning and Reclamation Plan) indicate that under global warming conditions, the core of the dam will remain frozen and stable.

### 3.3 Timing of the Dam Decommissioning

EBA has indicated that the work is least likely to cause erosion and/or sediment transport in the creek if completed during winter months. “Winter months” is better defined as the period where the ground and water around the dam (including the creek) are completely frozen. It is anticipated that "winter months" typically span from November through April, and possibly further into the shoulder months.

The importance of the timing of the decommissioning is the same for both the complete and partial removal options.

### 3.4 Shoreline Erosion

Shoreline erosion potential arises from the fact that during the mine operations, Garrow Lake rose in elevation and submerged the permafrost around its historic perimeter. Some disturbance of the submerged shoreline has likely resulted over the years due to wave erosion and surface slumping. Upon decommissioning of Garrow Lake Dam, the water level will drop and expose the now-thawed soil. Erosion potential of this soil remains constant, regardless of the dam decommissioning option.

The reservoir level has experienced fluctuations over the years due to annual discharges. Garrow Lake is gradually being lowered back to historic levels over the coming years prior to decommissioning. The performance of the shoreline and suspended solids concentrations is to be monitored over this period of time. The thawed banks of the lowered lake could potentially be unstable if the lake is drawn down too quickly. Because the lowering of the lake is scheduled over a long time period, risk of bank failure is drastically reduced.

Shoreline erosion is of concern during freshet (spring thaw or breakup), during or shortly following periods of summer precipitation and at times of high winds. The erosion around Garrow Lake will be most severe during lowering of the lake. There is likely to be less erosion following lowering of the lake, decommissioning of the dam and the return of the original lake level. Once the lake is returned to its original level the fetch distance for wave set up will be 0.5 km shorter than it is presently, and the shoreline will be at the location where it was historically. The historic shoreline will have less fine sediments than the zone above it since the historic shoreline has been subjected to erosion prior to raising the lake.

The reference to TSS issues at Kuhulu Lake was cited by DFO-FHM. Discussions with Mr. Frank Tordon, formerly of Nanisivik Mine, did not reveal any definitive conclusions that can be applied at Polaris and Garrow Lake. Mr. Tordon did indicate the Kuhulu incident may have resulted from a dam being washed away (i.e. catastrophic failure) in the 1950's, as opposed to a gradual drawdown as is planned for Garrow Lake.

Mr. Robert Carreau of Breakwater Resources Ltd. (BRL) was also contacted with regards to this incident. Mr. Carreau received the following information on the Kuhulu Lake incident from Mr. Jim Marshall, Nanisivik Mine Project Manager until 1997:

> "…A dam was built by Texas Gulf before our [BRL] involvement. The dam was built at the discharge which is on the east side to raise the level of the lake and cause it to discharge through an old creek bed at the north-east corner of the lake. The lake rose but the dam failed and washed down the current discharge route with considerable erosion. The net effect was to lower the lake level which was evident at the shallow west end."

This information verifies what Mr. Tordon recalled. The Kuhulu Lake incident was a catastrophic failure resulting in rapid drawdown of the lake and large quantities of water being rapidly discharged. The large volume of and fast velocity of the water most likely caused the vast majority of the erosion and elevated TSS levels. A similar scenario is deliberately being avoided at Garrow Lake by slowly and gradually drawing down the lake prior to removing the dam. Thus, the large water volume and high flow velocities will not be present when Garrow Lake Dam is decommissioned.

## 4.0 CLOSURE

The comments received from DFO-FHM in response to TCML's Mine Closure Plan submission pertaining to the decommissioning of Garrow Lake Dam have been reviewed and considered.

After reconsideration of the technical merits and potential risks associated with partial dam removal and complete dam removal options, there is little technical difference between the two. Economics suggests that the partial dam removal is preferred.

Perimeter erosion and the timing of the decommissioning are independent of the removal options. As discussed herein, the erosion around the perimeter and TSS levels during windy ambient conditions in the open water season are not expected to be significantly greater than historic levels.

We trust that the comments and potential issues raised by DFO-FHM have been satisfactorily addressed. Should you require further clarification or information, please contact EBA's office at your convenience.

Respectfully submitted,
EBA Engineering Consultants Ltd.

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ATE/kfh

# ATTACHMENT # 18

# MEMORANDUM TO B.DONAALD FROM PETER CHAPMAN

# AND

# CATHY McPHERSON OF EVS ENVIRONMENT

# CONSULTANTS

# REGARDING 'REMOVAL OF GARROW LAKE DAM –

# SIGNIFICANCE FOR GARROW BAY MARINE ORGANISMS'

**dated November 29, 2001**

195 Pemberton Avenue
North Vancouver, BC
Fax: (604) 662-8548
Tel: (604) 986-4331
www.evsenvironment.com

# Memo

**To:** Bruce Donald, Teck Cominco

**From:** Peter Chapman and Cathy McPherson, EVS

**Our File:** 03-0302-49

**Date:** November 29, 2001

**Re:** **Removal of Garrow Lake Dam – Significance for Garrow Bay Marine Organisms**

## INTRODUCTION

This memorandum provides our expert opinion regarding the potential effects of Garrow Lake Dam removal on Garrow Bay marine organisms. Note that our opinion is restricted to biological issues; for data on contaminants of potential concern (COPCs) and their concentrations under different scenarios, we rely on Erickson (2001) and Erickson and Bennett (2001).

## BACKGROUND

Teck Cominco (Polaris Operations) have applied for permission to remove Garrow Lake Dam as part of their closure plans for the Polaris Mine. Review of these closure plans by the Department of Fisheries and Oceans (DFO) led to the identification of the following concerns:

1. Stability of Garrow Lake related to concentrations of zinc in surface waters that could discharge to Garrow Creek.
2. Zinc concentrations in the discharge to Garrow Creek.

The only COPC is zinc. Although lead is also present in Garrow Lake, concentrations are presently 10-fold less than the current License Limits and, because there is no longer a maximum present in the halocline, cannot increase. Lead concentrations in water from Garrow Lake discharged to Garrow Bay with removal of the dam will be at pre-mining levels.

Since 1993, the Garrow Lake discharge permit limit has been 0.5 mg/L; maximum “worst case” levels following closure are expected to be 0.31 mg/L and are expected to decrease to pre-mine conditions. The worst case prediction for zinc in Garrow Lake surface waters of 0.31 mg/L could result from the mixing of the present surface maximum in the halocline into the surface layer in the first few years after the surface of the lake is lowered to its pre-dam level. Generally, zinc concentrations will be <0.3 mg/L. Concentrations of zinc in the surface waters of Garrow Lake are expected to decrease due to the annual freeze thaw cycle, which transfers salt and metals to deeper parts of the lake. Concentrations of zinc in the outflow of Garrow Lake will be less than in the surface waters of Garrow Lake due to dilution by melt water.

Erosion of the top 2 m of the halocline containing the zinc maximum in Garrow Lake would only occur under very unusual circumstances, however the stability of the lake is not threatened. Erickson and Bennett (2001) recommend that monitoring of Garrow Lake continue following dam removal for a set period of time to ensure that their predictions are correct. Similar recommendations have been made by DFO. and Teck Cominco have committed to monitoring Garrow Lake on a periodic basis through to 2011 (Polaris Mine Decommissioning and Reclamation Plan, Volume 1, Section 7.1).

**ZINC EXPOSURE AND SENSITIVITY OF ARCTIC MARINE FAUNA**

Discharges from Garrow Lake enter the Arctic marine environment (Garrow Bay) via Garrow Creek. Garrow Bay is an open marine system with tidal flushing. Water in Garrow Creek is less dense than the marine waters of Garrow Bay, and thus will remain on the surface. While there is ice in Garrow Bay, Garrow Creek waters will either move laterally along the shore if constrained by ice or follow leads out into the Bay.

The initial discharge from Garrow Lake will be mostly melt water (ice and snow) since in the early summer the lake will still be ice covered. Zinc concentrations during initial discharges are expected to be less than 0.1 mg/L. Later in the summer season, if the lake clears of ice, zinc concentrations in the discharge waters may be higher, at least for the first few years post-closure. However, based on data prior to dam construction, concentrations of zinc in Garrow Creek are not expected to exceed about a third of concentrations in Garrow Lake surface waters. For example, in 1989 the last year of natural outflow from the Lake, the lake was clear of ice and the surface layer well mixed in August. Zinc concentrations reached 0.34 mg/L in the surface waters of Garrow Lake in August and 0.36 mg/L in September. However, zinc concentrations in Garrow Creek did not exceed 0.12 mg/L, indicating an approximately 3-fold dilution of surface waters.

During periods of discharge when ice remains on Garrow Bay, the marine organisms most directly exposed to the discharge will be those living under ice, which have been shown to be extremely tolerant to zinc (and to lead). During periods of discharge when there is no ice on Garrow Bay, water column organisms will be most directly exposed to this discharge. These organisms have also been shown to be extremely tolerant to zinc.

Under-ice amphipods collected from Garrow Bay in June 1991 showed extremely high tolerances to zinc and lead (Chapman and McPherson, 1992, 1993; Chapman, 1993). Zinc 96-h $LC_{50}$ values were > 11.8mg/L for three species and > 4.9 mg/L for one species.

Lead 96-h $LC_{50}$ values were >3.5 mg/L for two species. Arctic mysids, living in the water column in the absence of ice, were even more tolerant (96-h $LC_{50}$ > 50 mg/L). These findings have been validated for Antarctic amphipods by Ling et al. (1998) and Hickey et al. (1999 – additional details provided in Chapman, 1998). King and Riddle (2001) found that embryonic development of the Antarctic sea urchin *Sterechinus neumayeri* showed a similar high tolerance to lead. $EC_{50}$ values were > 3.2 mg/L. And the chronic (6-8d) response of this sea urchin to zinc was only slightly more sensitive ($EC_{50}$ 2.23 mg/L) than the acute lethal Arctic amphipod responses (96h $LC_{50}$ values > 4.9 mg/L). However, the sea urchin was more sensitive to copper and cadmium. Duquesne et al. (2000) conducted 96-h LC50 tests with the Antarctic amphipod *Paramorea walkeri* exposed to copper and cadmium and found that this amphipod was similarly sensitive to temperate species. Thus it appears that Arctic and Antarctic marine species are relatively tolerant to lead and zinc, but less so to copper and cadmium.

The present Water License for Garrow Lake surface waters (0.5 mg/L zinc) was granted based on the work of Chapman (1993) and Chapman and McPherson (1992, 1993), which indicated that these concentrations of zinc in surface waters discharged to Garrow Creek and thence to Garrow Bay would not harm Arctic marine organisms. Highest concentrations in Garrow Lake surface waters when the dam is removed will be 0.31 mg/L and will decrease. Concentrations reaching Garrow Bay will be a third less (e.g., worst case <0.1 mg/L). These concentrations will not harm Garrow Bay marine fauna most exposed (i.e., to the lowest dilutions in seawater) based on toxicity tests conducted with representative organisms from the Bay and subsequent similar work in Antarctic environments. These fauna include those living under ice and in the water column. Bottom-dwelling organisms will only be exposed to extremely dilute concentrations of zinc, thus will also not be harmed (note that under-ice amphipods, which are very tolerant of zinc, move to the sediments when the ice melts). Note that zinc concentrations in Garrow Bay were measured at oceanic background (0.0001 mg/L) in 1990.

The long-term fate of zinc discharged to Garrow Bay will be removal from the water column and immobilization in the sediments (Di Toro et al., 2001). However, the Arctic marine environment tends to be zinc deficient and the 1990 study of Erickson (1991) indicated that the waters of Garrow Bay were very low in zinc, particularly at the end of summer. Thus, prior its eventual immobilization in the sediments, the zinc discharged from Garrow Lake is expected, as an essential element, to be a positive asset to phytoplankton and other marine biota.

**SUMMARY**

Even assuming that worst case predictions regarding zinc concentrations in Garrow Lake surface waters were to occur, removing the tailings dam to allow surface waters to flow into Garrow Creek and thus into Garrow Bay, will not create any risk of harm to the marine organisms in Garrow Bay.

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