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November 6, 2008

British Columbia Utilities Commission
6th Floor, 900 Howe Street
Vancouver, B.C. V6Z 2N3

Attention: Ms. Erica Hamilton, Commission Secretary

Dear Ms. Hamilton:

**RE: Terasen Gas Inc. ("TGI" or the “Company”)
Application (“Application”) for a Certificate of Public Convenience and Necessity ("CPCN") Fraser River South Arm Crossing Upgrade Project**

Pursuant to Section 45 of the *Utilities Commission Act*, TGI hereby requests approval from the British Columbia Utilities Commission (the “Commission”) for a CPCN for the Fraser River South Arm Crossing Upgrade (the “Application”).

TGI currently crosses the South Arm of the Fraser River with two parallel transmission pressure pipelines with outside diameters of 508 mm and 610 mm (nominal pipe size (“NPS”) 20 and NPS 24). The pipelines were installed in 1958 and 1974, respectively. They provide gas supply to the municipalities of Richmond, Vancouver, North Vancouver City and District, West Vancouver and parts of Burnaby. The proposed project is required in order to address integrity concerns with respect to seismic events, river erosion, and future dike improvements. TGI has concluded that the risk associated with these crossings is unacceptable and remedial action is required.

The Company’s current 2004-2007 Performance Based Rates (“PBR) Settlement Agreement requires that the Company submit CPCN applications for capital investments in excess of $5 million.

Twenty hardcopies of this Application will be submitted to Commission in accordance with the Commission’s Document Filing Protocols. The Application and all subsequent exhibits will be made available on the Terasen Gas website under the Regulatory Submissions section for the Lower Mainland at the following link:
http://www.terasengas.com/_Publications/Regulatory/Submissions/LowerMainlandInterior/default.htm

If there are any questions regarding this Application, please contact the undersigned.

Yours very truly,

TERASEN GAS INC.

Original signed:

Tom Loski

Attachments

cc (e-mail only): Parties to the TGI PBR Settlement
Stakeholder Contacts from Appendix 11 for whom e-mail information is listed

TERASEN GAS INC.

Application for a
Certificate of Public Convenience and Necessity
for the

Fraser River South Arm Crossing Upgrade

VOLUME 1

November 6, 2008

TABLE OF CONTENTS

LIST OF APPENDICES

IN THE MATTER OF THE UTILITIES COMMISSION ACT
R.S.B.C. 1996, CHAPTER 473

AND IN THE MATTER OF AN APPLICATION BY TERASEN GAS INC. FOR THE FRASER RIVER SOUTH ARM CROSSING UPGRADE

To: The Secretary
British Columbia Utilities Commission
Sixth Floor, 900 Howe Street
Vancouver, British Columbia V6Z 2N3

1 APPLICATION

Terasen Gas Inc. ("TGI" or the "Company") hereby applies to the British Columbia Utilities Commission (the "BCUC" or the "Commission") pursuant to Section 45 of the Utilities Commission Act, R.S.B.C. 1996, Chapter 473, (the "Act") for approval of a Certificate of Public Convenience and Necessity ("CPCN") to upgrade the transmission pipeline system crossing the south arm of the Fraser River (the "Project" or "Application"). TGI seeks approval of the following:

> Replacement of approximately 1400 m of existing NPS 20 (508 mm) and 1400 m of existing NPS 24 (610 mm) outside diameter ("OD") transmission pressure pipelines, both to be installed across the Fraser River using Horizontal Directionally Drilled ("HDD") technology.

1.1 Applicant

1.1.1 Name, Address, and Nature of Business

TGI is a company incorporated under the laws of the Province of British Columbia and is a wholly-owned subsidiary of Terasen Inc., which in turn is a wholly-owned subsidiary of Fortis Inc. TGI maintains an office and place of business at 16705 Fraser Highway, Surrey, British Columbia, V4N 0E8.

TGI is the largest natural gas distribution utility in British Columbia, providing sales and transportation services to residential, commercial, and industrial customers in more than 100 communities throughout British Columbia, with approximately 840,000 customers served on the mainland including the Inland, Columbia, and Lower Mainland service areas. TGI's distribution network delivers gas to more than eighty percent of the natural gas customers in British Columbia.

1.1.2 Financial Capability of Applicant

TGI is regulated by the BCUC. TGI is capable of financing the Project either directly or through its parent, Terasen Inc. TGI has credit ratings for senior unsecured debentures from Dominion Bond Rating Service and Moody's Investors Service of A and A3 respectively. Terasen Inc. has credit ratings for senior unsecured debentures from Dominion Bond Rating Service and Moody's Investors Service of BBB (High) and Baa2 respectively.

1.1.3 Technical Capability of Applicant

TGI has designed and constructed a system of integrated high, intermediate and low-pressure pipelines and operates more than 38,000 kilometres of natural gas transmission and natural gas distribution mains and service lines in British Columbia. This transmission and distribution infrastructure serves approximately 840,000 customers on the mainland.

1.1.4 Name, Title, and Address of Company Contact

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1.1.5 Name, Title, and Address of Legal Counsel

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1.2 Executive Summary

The Company seeks a CPCN for the Fraser River South Arm Crossing Upgrade Project.

As part of the TGI transmission pipeline infrastructure serving the Lower Mainland, two pipelines with outside diameters of 508 mm and 610 mm (nominal pipe size (“NPS”) 20 and NPS 24) cross the South Arm of the Fraser River between Delta and Richmond approximately 5 km east of the George Massey Tunnel. These two pipelines provide gas supply to the municipalities of Richmond, Vancouver, North Vancouver City and District, West Vancouver and parts of Burnaby.

As described in Section 4, the Fraser River South Arm Crossing Upgrade Project consists of the replacement of approximately 1400 meters of NPS 20 and approximately 1400 meters of NPS 24 pipelines using the Horizontal Directional Drill (“HDD”) construction method. The replacement crossings will be constructed within the existing Right-Of-Way (“ROW”), both on land and across the river. The construction will require temporary shut down of each line while it is being replaced; however, the other line will have sufficient capacity to ensure gas supply during the construction period.

Project justification is addressed in Section 5. The proposed project is required in order to address integrity concerns with respect to seismic events, river erosion, and future dike improvements. Both pipelines are vulnerable to ground movement from seismic induced soil liquefaction and lateral spread. The pipelines do not currently meet TGI’s seismic criteria. River erosion is also a concern, particularly for the NPS 20. Dike improvement works planned at the crossings in the near future will exacerbate the stresses which exist on both pipelines from previous and ongoing settlement of the dike. This project will help ensure reliable gas supply following a strong earthquake, will also address river erosion concerns, and will avoid the further stress on the pipelines that will result from the dike upgrades. For these reasons, TGI believes that the Project is in the public convenience and necessity.

Project alternatives are discussed in Section 6. As a crossing methodology, HDD is more advantageous than open trenching, aerial crossings, or ground consolidation with partial pipe replacement. The Company considered four alternatives for HDD:

Alternative 1	Replacement of both the NPS 20 and NPS 24 crossings
Alternative 2	Replacement of the NPS 24 crossing with a new NPS 24
Alternative 3	Replacement of the NPS 20 crossing with a new NPS 20

Alternative 4 Replacement of the NPS 20 from Tilbury Gate to Nelson Gate with a new NPS 30

The preferred HDD alternative is Alternative 1, as it is the only one which addresses all of the seismic, erosion, and dike settlement risks identified in this Application that could result in the pipelines being compromised.

As described in Section 6, at this stage of project development, the cost of the project based on the preferred alternative is estimated at $27.3 million with an accuracy of -15/+20%. The project duration from receipt of approval for the CPCN Application until the new crossing is in-service is expected to be approximately 8 – 11 months, as shown in Table 6.2.

The recommended alternative includes efficiencies resulting from replacing both crossings utilizing one HDD equipment mobilization. Analysis of tenders is required to better understand the impact of schedule on those efficiencies. The current schedule assumes that construction will occur in 2009, however the project team has allowed for 2010 construction if following evaluation of tenders for the HDD work it is determined to be more cost effective.

Consultations with landowners, local and regional governments, federal and provincial agencies and authorities are in progress, with preliminary discussions already completed. In addition, First Nations have been consulted and continue to be involved in the review of the project. To date, no significant objections to the project have been identified and further input from stakeholders will be incorporated into all phases of the project through to completion.

Primary risks to cost and schedule for this project include: project management, stakeholder impacts, construction schedule, engineering / construction resources, material cost / delivery, HDD / pipeline contract cost, and HDD / pipeline contractor capability. The Application describes how TGI is seeking to manage these risks.

In light of the public safety issues and significant public interest in ensuring reliable service to hundreds of thousands of customers in the Lower Mainland, TGI believes this Project is in the public convenience and necessity and a CPCN should be granted as sought. TGI is committed to minimizing the rate impact associated with this non-discretionary Project. Therefore, TGI proposes to: (i) structure the HDD contract as being conditional upon Commission review and approval; (ii) at the same time, file a revised control budget accounting for new information; and (iii) file with the Commission quarterly project progress reports and a project completion report in a form developed in conjunction with Commission staff.

1.3 Regulatory Review of CPCN Application

Under the Company's current 2004-2007 Performance Based Rates ("PBR") Settlement Agreement, and 2008-2009 Settlement Agreement Extension, a CPCN is necessary for this project as it is in excess of $5 million.

Given the estimated capital cost for the project, and because it involves the integrity of existing assets, does not require new ROW acquisition, and has to date identified no significant stakeholder concerns, TGI believes that a written review and approval process is appropriate for this Application.

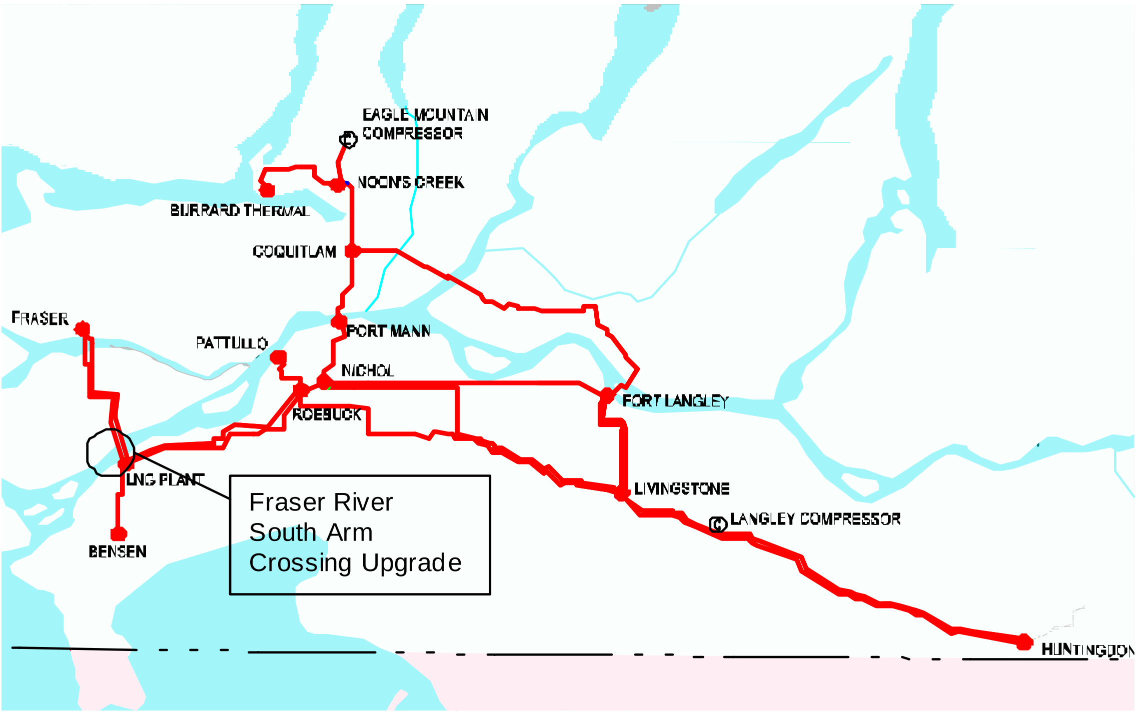
TGI requests that the Commission complete its process to review this Application and reach a decision by early March 2009 in order to meet the proposed construction schedule outlined herein.

2 Background

The Fraser River South Arm crossings consist of two parallel natural gas transmission pipelines which cross beneath the South Arm of the Fraser River between Delta and Richmond approximately 5 km east of the George Massey Tunnel. The original NPS 20 crossing was installed in 1958 as part of the program to bring natural gas to the Lower Mainland in the late 1950's and early 1960's. Subsequent demand growth resulted in the need for system reinforcement, so a parallel NPS 24 crossing was installed in 1974. Both crossings are welded steel, weighted with a concrete outer coating, and were installed in trenches dredged across the river bed. These two pipelines provide gas supply to the cities and municipalities of Richmond, Vancouver, North Vancouver City and District, West Vancouver, and parts of Burnaby.

Figure 1 provides an overview of TGI's Coastal Transmission System in the Lower Mainland. A more detailed map of the system is attached as Appendix 1.

Figure 2.1 – Coastal Transmission System



3 Project Description

TGI is applying to replace the existing NPS 20 and NPS 24 transmission pipelines across the south arm of the Fraser River with new NPS 20 and NPS 24 lines installed using HDD. The two new crossings, each approximately 1400 m in length, will be constructed within the existing ROW, both on land and across the river at depths significantly below the existing crossings. The construction will require the temporary shut down of each pipeline while it is being replaced; however, the other pipeline will have sufficient capacity during the construction period to supply downstream customers.

4 Project Justification

This section discusses how the proposed Fraser River South Arm Crossing Upgrade Project will mitigate three major threats to the integrity of the existing crossings:

Seismic Vulnerability – Recent analyses have confirmed that both pipelines crossing the Fraser River South Arm will likely fail beneath the river in a strong earthquake.

Erosion Vulnerability – The NPS 20 pipeline is at risk of becoming uncovered in the river at the north bank, where prevailing currents have and will likely continue to erode both the north bank and the river-bed at the base of the north bank.

Dike Settlement Vulnerability – The height of the north dike must soon be raised for municipal flood protection. This remediation work will exacerbate the stresses which exist on both pipelines from previous and ongoing settlement of the dike.

4.1 Seismic Vulnerability

4.1.1 TGI Design Practice

The Canadian Pipeline System Standard CSA Z662 requires that anticipated seismic loading be part of the design criteria for any oil or gas pipeline. In accordance with this standard and consistent with industry practice, the TGI seismic design guideline, which is attached as Appendix 2, requires an assessment of potential seismic risks and that the pipeline design be sufficient to withstand anticipated seismic loadings for a seismic event with a return period of 2000 years (2.5% probability of exceedance over 50 years). This design criterion is commonly used by other utilities and, has been the basis for seismic upgrades undertaken by TGI from 1996 to date.

4.1.2 Background Studies

In the early 1990s, TGI initiated a major review of its Lower Mainland pipeline systems in order to address increased seismic concerns. A 1994 report by Golder Associates Ltd (“Golder”) identified the potential for long-term disruption of the gas supply to large portions of the system, including the Fraser River South Arm Crossing, based on soil liquefaction and lateral spread ground displacement in a major seismic event.

Site-specific follow-up studies by Golder in 1996 and 1997 identified a number of transmission pipeline facilities as requiring further study and mitigation. Since 1996, a number of these facilities have been upgraded and all of the remaining facilities have either been deemed acceptable or have been the subject of further study.

The initial evaluation in 1996 of both of the Fraser River South Arm crossings by Golder indicated that with some on-shore improvements, the crossings may very nearly meet TGI's seismic criterion. Therefore, given the uncertainty about meeting the criterion, and because the crossings serve a significant number of Lower Mainland customers, TGI engaged Golder to undertake further field studies and seismic analyses during the period from 1996 and 2006 to better define the seismic vulnerability and potential options to address any concerns. A summary of the findings from the previous analyses can be found in Appendix 3, Appendix II, page 7, Table 1 "A Summary of Findings from Analyses at South Arm Crossings".

4.1.3 Recent Studies

In 2007, as a result of additional geotechnical information and the availability to geotechnical consultants of more sophisticated seismic modeling, and because the NPS 20 and NPS 24 crossings pass through soil layers which are susceptible to liquefaction, TGI commissioned Golder to update the seismic vulnerability of these crossings.

A 2007 seismic assessment by Golder concluded that a strong earthquake will cause liquefaction underneath the river bed, leaving the pipelines unsupported and subject to compressive (buckling) stresses which would likely result in failure of the pipelines in the middle of the river. A copy of this study is attached in Appendix 3.

Because of the high consequence from the failure of these crossings, TGI commissioned an independent review of the 2007 Golder assessment by a second geotechnical firm, BGC Engineering Ltd. ("BGC"). BGC examined the procedures and assumptions used to calculate ground deformations and concluded the methodology used was reasonable and in accordance with current standards for professional geotechnical practice. BGC's report is attached as Appendix 4.

In 2008, TGI requested an update to the 2007 analysis utilizing recently published updates to seismic data and modeling from the Geological Survey of Canada ("GSC"), and to collect and incorporate additional soils information collected from within the river channel. The 2008 Golder study determined that both pipelines will fail in seismic events far less severe than the TGI seismic risk criterion of a return period of 2000 years (2.5% probability of exceedance over 50 years). This study determined that the NPS 20 and NPS 24 pipelines are vulnerable to loss of pressure integrity in seismic events which have the following return periods (probabilities of occurrence):

- NPS 20 pipeline - 300 to 500 year return period event (15% - 9% in the next 50 years) and,
- NPS 24 pipeline - 500 to 800 year return period event (9% – 6% in the next 50 years).

In summary, neither pipeline meets the Terasen seismic risk criterion, with the NPS 20 being more vulnerable that the NPS 24. This study is attached as Appendix 5.

4.2 River Erosion Vulnerability

As part of its on-going operation and maintenance activities, TGI routinely surveys and evaluates its major river crossings with respect to hydrotechnical concerns including river scour, channel degradation, and bank erosion. Aside from a strong earthquake, the greatest risk at these crossing locations is the potential exposure of the pipeline resulting in excessive stresses and failure.

Since 1974, TGI has been performing bathymetric surveys of the South Arm crossings at regular intervals and following high flow events. The survey results have identified a gradual degradation of the river bed at the base of the north bank as well as transient local scouring between the pipelines to a depth of 4.0 m. In addition, aerial photographic records show that the north bank of the NPS 20 pipeline crossing has experienced erosion which has significantly degraded the bank armouring.

The depth of cover over the NPS 20 has been recorded as low as 1.7 m, yet river bed scour could reach depths of 5.7 m based on TGI’s 1 in 200 year design flood criterion. A 2002 bathymetric report identified that as much as 335 m of the NPS 20 crossing was at risk of undermining. Consequently, Terasen installed scour protection blankets over both pipelines at the base of the north bank in 2002 in order to reduce immediate operating risk. Notwithstanding that work, if the NPS 20 is not replaced, it is evident that on-going monitoring, analysis and mitigation measures will be required in order to reduce the risk of failure due to erosion. These measures will not reduce the vulnerability due to seismic risk.

The NPS 24 crossing was constructed at a greater depth and at the present time is less vulnerable to excessive stress and failure due to river erosion.

4.3 Dike Settlement Vulnerability

The dike located on the north bank of the Fraser River South Arm crossing was constructed as a sea-dike to protect farm lands from high tides and river floods. The dike was constructed after the 1894 flood using mineral fill materials placed onto unexcavated weak and highly compressible sub-soils that include both organic peat and fine-grained sediments. Over time, the weight of the dike has compressed the underlying soils resulting in a gradual, long-term settlement.

The NPS 20 and the NPS 24 pipelines cross the dikes on both the north and south sides of the river. Since construction, the pipelines have experienced some differential settlement resulting in increased, but acceptable stress levels. However, in order to meet the provincial flood protection standard (1 in 200 year flood event) the dike crest on the north bank must be raised by an additional 0.65 m above its present elevation. Should this be accomplished by placement of additional fill, TGI predicts an increase in differential settlement which would cause pipeline operating stresses to exceed the level allowed by TGI operating policies and the CSA Pipeline Standard.

4.4 Consequences of Pipeline Failure

Failure of both crossings would leave approximately 117,000 TGI customers isolated for a prolonged period with no alternative gas supply. This figure is based on typical, above-freezing winter weather, representing approximately 50% of system design load. A high-level breakdown of customer accounts affected by such an outage is as follows:

- 500 plus health-care and related facilities (space heating, sanitation, cooking);
- 400 schools and educational institutions (space heating, cooking);
- 7,000 plus commercial businesses (space heating);
- 1,000 plus large commercial / industrial businesses (space heating, manufacturing processes);
- 3,000 retail stores and restaurants (space heating, cooking);

- 105,000 residential customers (including apartment complexes), leaving approximately 300,000 residents without gas service for their space & water heating.

Under design conditions, the number of customers impacted would approach 200,000.

It is evident that a prolonged loss of gas supply would not only impact a large number of businesses, industries and residents, but it would particularly impact facilities providing food services, accommodation and care to those most in need following an earthquake.

TGI anticipates that if both crossings failed, restoration could be expected to take from six months to a year at best, assuming extraordinary levels of assistance are available. Installation of a new crossing under post earthquake circumstances would also be considerably more costly. Re-light costs would be in the order of $12 Million and would take an additional number of months, the actual time depending on the number of technicians that could be mobilized.

Unlike the potential failures of other more accessible and repairable parts of the TGI transmission and distribution systems, the integrity of underwater crossings is critical to minimizing the duration and extent of any gas supply interruption to a significant part of the Lower Mainland.

In addition to the capacity constraints, it is also possible that there could be serious safety consequences related to a high pressure pipeline failure at this location. This would not be in compliance with TGI's seismic standard. This is a risk to public safety and would necessitate emergency response efforts.

4.5 Justification Summary

Given the potential for the two crossings to fail, in particular the probability of failure in the event of a seismic event, and the consequences of such a failure discussed above, TGI has concluded that the risk associated with these crossings is unacceptable and remedial action is required.

5 Upgrade Alternatives

TGI has considered a number of alternatives both in terms of methodology and location to address the concerns with the two crossings.

5.1 Methodology

TGI identified five potential methodologies to remediate the crossing of the Fraser River: reinforcement of system back-feeds, ground consolidation and replacement with higher strength pipe, aerial crossing, open trenching, and HDD.

The first methodology considered was reinforcement of existing back-feeds. This would involve looping of the transmission system from Surrey to Coquitlam, the addition of large-diameter intermediate pressure pipelines across Coquitlam and Burnaby, and the abandonment of major existing assets. This option is judged to be significantly more costly than replacing the Fraser River South Arm crossings, and was therefore rejected and detailed cost estimates were not completed.

Improvement of the existing crossings could be achieved using ground consolidation, combined with higher strength pipe replacement. However, this methodology will not adequately reduce the vulnerability of both crossings to failure caused by seismically induced soil liquefaction, subsequent pipe movement, and failure under the river bed, nor will it mitigate the on-going river erosion or dike settlement concerns. It was ruled out on this basis and cost assessments were not completed.

An aerial crossing replacing one or both river crossings was also considered. This methodology would address concerns associated with seismic events, erosion and dike improvements, and avoid environmental concerns associated with trenching. However, such a crossing would have to span the entire distance impacted by any potential soil liquefaction and consequently would require a massive structure spanning over 1400m and built sufficiently high to permit ocean-going ships to pass beneath. This option involves substantial land use impacts at both ends, including construction of the north bridge tower within an existing industrial park, new ROW, and conflicts with existing pipelines. This would have significant permitting and implementation difficulties with adverse stakeholder impacts. This option is judged to be significantly more costly than pipeline replacement, and was therefore rejected and cost assessments were not completed.

New crossings underneath the river can be constructed either by means of open cutting of the river bed (trenching), or by means of HDD. Open cut trenching in a large river such as the Fraser is a significant logistical undertaking and is now generally considered unacceptable to federal and provincial agencies, given the availability of HDD technology. As well, trenching is considered impractical to reach the soil depth needed to address the seismic design requirements, and therefore cost assessments of this option were not completed.

In sum, utilizing HDD for new pipeline installation was determined to be the best upgrade choice on the basis of cost, low environmental impact and the ability to mitigate all seismic, river scour, and dike improvement concerns.

5.2 Location

For a new HDD pipeline crossing or crossings, use of the existing right-of-way (“ROW”) offers significant advantages. Other alignments in the vicinity of the existing crossings were considered, but due to the need for significant new ROW and associated environmental and land use concerns, public impact and cost, these other options were considered significantly less attractive.

5.3 HDD Alternatives Considered

5.3.1 Evaluation Criteria

The following criteria were used to further analyze and compare the alternatives for HDD pipeline replacement within the existing right of way:

- Vulnerability (safety risks)
    - Compliance with TGI seismic standard, including acceptability of predicted likelihood and consequences of pipeline failure
    - Vulnerability to on-going river bank erosion and river bed scour
- Project Considerations
    - Capital cost
    - Environmental and stakeholder impacts
    - Dike work mitigation requirement

- Operational flexibility
    - Availability of a second pipeline crossing for O&M or emergency requirements
- Post Earthquake Considerations
    - Emergency response to failed pipeline
    - Capacity of the remaining facilities within the 20-year long range planning period
    - The need to replace a failed line for capacity reasons immediately following a strong earthquake

Where applicable, the evaluations consider costs related to dike improvements, as well as on-going activities to address potential river bank erosion and river bed scour. All alternatives incorporate the requirement to utilize internal pipeline inspection tools at a future date.

5.3.2 Evaluation of Alternatives

Four HDD replacement alternatives were considered in detail:

Alternative 1	Replacement of both the NPS 20 and NPS 24 crossings
Alternative 2	Replacement of the NPS 24 crossing with a new NPS 24
Alternative 3	Replacement of the NPS 20 crossing with a new NPS 20
Alternative 4	Replacement of the NPS 20 from Tilbury Gate to Nelson Gate with a new NPS 30

Advantages and disadvantages of the four alternatives are described below, followed by Table 5.1 which summarizes the evaluation criteria.

Alternative 1 – Replacement of both the NPS 20 and NPS 24 Crossings with new NPS 20 and NPS 24 Crossings

<u>Description</u>

Install new NPS 20 and NPS 24 crossings using HDD's, at an estimated cost of $27.3 million and tie into the existing pipelines on either side of the river. The contemporaneous installation of two new crossings is considerably less costly than would be the case with separate mobilizations.

<u>Advantages</u>

- Fully complies with all TGI standards; current and future seismic and river erosion issues are fully mitigated.
- System reliability is improved: full capacity of the crossing will survive a strong earthquake.

- Avoids future emergency response and pipeline reconstruction in potentially adverse conditions and difficult terrain. TGI's post-earthquake public safety and recovery efforts can be focused on other response and recovery issues, which can be expected in such events.
- Mitigates effect of dike improvement work and ongoing dike settlement.
- Minimizes construction impacts on environment and landowners relative to Alternative 4.
- Full operating flexibility is retained.
- Efficiencies of at least $6 million by constructing both crossings at once, compared with replacing one now and the second at some later date.

Disadvantages

- Higher initial cost than Alternatives 2 and 3

Alternative 2 – Replacement of the NPS 24 Crossing only with a new NPS 24 Crossing

Description

Install a new NPS 24 crossing using an HDD and tie into the existing NPS 24 pipeline on either side of the river at an estimated cost of $17 million. The existing NPS 24 crossing would be abandoned. This Alternative does not contemplate any changes being made to the NPS 20; rather, it anticipates this pipeline being operated and maintained as per current practice until it either reaches the end of its life or fails in a seismic event and is then replaced.

Advantages

- Second lowest initial cost.
- Relative to Alternative 3, Alternative 2 will support more regional post-earthquake recovery before replacement of the failed NPS 20 is needed. However, TGI recognizes that NPS 24 capacity alone will not be sufficient to meet design loads for the 20 year planning period.

Disadvantages

- Reduced crossing capacity following a strong earthquake. Towards the end of the planning period, downstream system capacity would be reduced below design loads.
- The existing NPS 20 will continue to operate in non-compliance with Terasen's seismic standard, with ongoing public safety risk from failure due to an earthquake. This is a potentially significant addition to initial earthquake emergency assessment and public safety response.

- The existing NPS 20 will continue to operate in non-compliance with Terasen's underwater crossing design standard, with ongoing risk of failure due to river scour.
- Need for future replacement of the existing NPS 20 under unfavourable, post earthquake conditions. This would entail additional costs for the replacement and potential diversion of Terasen and other resources from other recovery work.
- Dike improvement work will require mitigation of stress on NPS 20, and long-term dike settlement concerns will remain.
- On-going O&M costs associated with monitoring the NPS 20 and potential mitigation required due to bank erosion and river bed scour, which would not be required under Alternative 1.
- Operating flexibility is lost following a strong earthquake (including the period of aftershocks), until the failed NPS 20 is replaced.

Alternative 3 – Replacement of the NPS 20 Crossing only with a new NPS 20 Crossing

Description

Install a new NPS 20 crossing using an HDD and tie into the existing NPS 20 pipeline on either side of the river at an estimated cost of $16 million. The existing NPS 20 crossing would be abandoned. This Alternative does not contemplate any changes being made to NPS 24; rather, it anticipates this pipeline being operated and maintained as per current practice until it either reaches the end of its life or fails in a seismic event and is then replaced.

Advantages

- Lowest initial cost alternative.
- Relative to Alternative 2, lower on-going O&M costs for monitoring of the NPS 24 for bank erosion and river bed scour and less potential for related mitigation work.

Disadvantages

- The existing NPS 24 will continue to operate in non-compliance with TGI's standards, with ongoing risk of failure due to an earthquake. Although slightly less seismically vulnerable than the NPS 20, and less at risk from river scour, this remains a potentially significant emergency assessment and public safety response issue.
- Insufficient crossing capacity following a strong earthquake. In the last half of the planning period, downstream system capacity would be reduced below design loads, potentially limiting post-earthquake recovery of the region. Urgent replacement of the failed NPS 24 would be needed to avoid significant and prolonged customer outages, putting a major additional strain on TGI and regional resources in extremely unfavourable circumstances.

- Dike improvement work will require mitigation of stress on NPS 24, and long-term dike settlement concerns will remain.
- Operating flexibility is lost following a strong earthquake (including the period of aftershocks), until the failed NPS 24 is replaced.

Alternative 4 – Replacement of the NPS 20 Crossing with a new NPS 30 Crossing Extending from Tilbury Gate Station to Nelson Gate Station

Description

Install a new NPS 30 crossing using an HDD, and abandon the existing NPS 20 crossing in place. As well, remove the existing on-land NPS 20 pipeline segments which extend from the crossing to existing facilities at Tilbury Gate Station to the south and Nelson Gate Station to the north, replacing those segments with NPS 30. There are additional complexities with this alternative, as both existing gate stations at Tilbury and Nelson require reconfigurations in order to accommodate the NPS 30 pipeline and abandonment of the NPS 20. The total length of transmission system replacement in this alternative is 2.8 km, including 1.3 km of additional open trench pipeline installation. Tie-ins would include addition of facilities for internal inspection of the NPS 30, some of which already exist at Tilbury Gate Station. Existing NPS 24 pipeline and crossing would remain in service to provide operating flexibility. The estimated cost of this alternative is $27 million. It does not contemplate any changes being made to NPS 24; rather, it anticipates the NPS 24 either reaching its end of life or rupturing upon the occurrence of a seismic event and subsequently being replaced.

Advantages

- New NPS 30 fully complies with all TGI standards.
- The crossing can meet gas demand requirements for the planning period after a strong earthquake in the event the NPS 24 fails.

Disadvantages

- Higher cost than Alternatives 2 and 3; equivalent cost to Alternative 1, but with increased cost uncertainty.
- Significant increase in scope, number and duration of landowner, tenant, and environmental/land restoration impacts from open trench construction activities, which would extend on either side of the crossing, to Tilbury Gate Station and to Nelson Gate Station, a total length of 2.8 km.

- Retention of NPS 24 for operating flexibility requires assumption of public safety risk from seismic events, and some river scour risk, which add to emergency response and public safety concerns.
- Dike improvement work will require mitigation of stress on NPS 24.
- Operating flexibility is lost after the NPS 24 fails in a strong earthquake. Parallel pipelines for critical underwater crossings provide better long-term reliability.

Table 5.1 summarizes the evaluation of the four alternatives, and cost estimates are attached as Appendix 13.

Table 5.1 - Evaluation of HDD Alternatives

Alternative		Current Issues				Operating Flexibility	Post Earthquake Issues		
		Project Cost ($ millions) (1)	Vulnerabilities						
No.	Replacement Scenario		Seismic	River Scour	Dike Mitigation Needed		Emergency Response Needed	Capacity Shortfall	Replace Failed Pipeline
1	Both crossings: NPS 20 + NPS 24	27	No	No	No (2)	Yes	No	No	No
2	One crossing: NPS 24 with NPS 24	17	Yes - NPS 20	High - NPS 20	Yes - NPS 20	Not until failed pipeline is replaced	Yes	Yes	Yes - NPS 20
3	One crossing: NPS 20 with NPS 20	16	Yes - NPS 24	Med - NPS 24	Yes - NPS 24		Yes	Yes - large	Yes - NPS 24
4	Entire pipeline from Tilbury to Nelson NPS 20 with NPS 30	27	Yes - NPS 24	Med - NPS 24	Yes - NPS 24	No(3)	Yes	No	No(3)

NOTES:

(1) 2008 dollars, incl. AFUDC; accuracy of cost estimates is -15% +20% (dike improvement cost included)
(2) Requires delay of dike improvements until after pipeline construction
(3) Unless failed pipeline is replaced for operating flexibility only

5.4 Conclusions and Recommendation

Alternative 1, replacing both existing pipelines, has a greater initial cost than Alternatives 2 or 3. However, it is the only alternative which fully resolves all issues, both current and future (post-earthquake). This dual HDD replacement resolves seismic and river scour issues, and mitigates current and future problems related to dike improvement and ongoing settlement. Pipeline capacity and operating flexibility are maintained. This alternative improves system reliability and avoids additional maintenance associated with other alternatives, such as bathymetric surveys and possible requirement to install rock blanket scour protection. It also avoids future emergency response and pipeline reconstruction in potentially adverse post-earthquake conditions and difficult terrain. These latter issues, which would arise if both lines are not replaced, potentially create substantial extra burdens on both TGI and the region in the event of a strong earthquake.

In addition, replacing both crossings during one contractor mobilization will reduce future siting and permitting risk and result in cost efficiencies. TGI anticipates cost savings of at least $6 million can be realised under today's conditions with one mobilization versus staging of the replacements of the second crossing to some time in the future or after an event that causes the crossing to fail. TGI also recognises that there will continued development in the area on both sides of the river and therefore gaining approvals and access to the ROW and temporary construction space in the future will become increasing more difficult and could add significantly to costs of doing the second replacement.

Alternative 2, replacing the NPS 24 with a new NPS 24 crossing, is considered unacceptable due to the significant vulnerability of the remaining NPS 20 to river scour, greater seismic vulnerability of the NPS 20, and the added requirement to mitigate the effects of dike improvements and ongoing dike settlement on the remaining NPS 20. The NPS 20 pipeline does not meet TGI seismic or flood design criteria. In addition, a new NPS 24 alone will not fully meet winter capacity requirements throughout the planning period. TGI therefore considers Alternative 2 to carry an unacceptable level of long-term risk.

Alternative 3, replacing the NPS 20 with a new NPS 20 crossing, is the option with lowest initial cost, and would replace the one pipeline most vulnerable to erosion and earthquakes. However the NPS 20 alone is well short of capacity to meet future winter loads. TGI believes that prolonged loss of the NPS 24 capacity following a strong earthquake will be unacceptable at a time when the Lower Mainland will depend on natural gas supply for regional economic recovery. That situation would necessitate immediate replacement of the failed NPS 24 pipeline during the most adverse of circumstances, which would greatly compound the other challenges that TGI will face in the aftermath of a strong earthquake.

Importantly, this alternative will not address the seismic vulnerability of the NPS 24 pipeline, which does not meet the TGI seismic design criterion. As well, it will not mitigate the effects of dike improvements and ongoing dike settlement on the remaining NPS 24. TGI therefore considers Alternative 3 to carry an unacceptable level of long-term risk.

Alternative 4, replacing the entire NPS 20 pipeline segment from Tilbury Gate Station to Nelson Gate Station with NPS 30 would ensure capacity and security of supply following a strong earthquake. However, this alternative has greater potential for disruption to stakeholders due to the greater physical length of the project work. Furthermore, Alternative 4 requires that the vulnerabilities, mitigation and emergency response issues associated with the existing NPS 24 be accepted in return for retaining a second pipeline at this critical crossing to retain operating security and flexibility. Finally, there are no cost or operating advantages for choosing this approach over Alternative 1.

TGI therefore believes that Alternative 1, the replacement of both the NPS 20 and NPS 24 crossings, is the most appropriate alternative.

6 Project Construction

6.1 Replacement of the NPS 20 and NPS 24 Using HDD

Horizontal Directional Drilling is a common method for replacing river crossings. TGI has utilized HDD's on numerous occasions to avoid both technical and environmental concerns associated with other construction methods.

The methodology requires temporary "set-up" areas on both sides of the proposed crossing. On the entry side, a drilling machine is positioned. This machine, using GPS guidance technology, first drills a small diameter pilot hole between the entry and exit points. This is followed by a second drilling process which enlarges the pilot hole to a diameter larger than the pipeline to be installed.

On the opposite side of the proposed crossing (the exit point) a pipe "lay-up" area is required. The space requirements on this side are considerably larger since this area is used to weld together the pipe for the eventual crossing. The drilling machine is then used to pull the pipe through the previously enlarged hole.

The final step involves "tie-ins" to the existing pipeline upstream and downstream of the entry and exit points.

6.2 Design and Construction Considerations

This section describes considerations which impact the design and/or construction of the HDD crossings. An aerial photograph of the proposed crossing site is attached in Appendix 6.

6.2.1 Use of TGI ROW

The pipe lay down area will be located on the north (Richmond) side of the river. The lay down area will utilize existing TGI ROW as much as possible, with additional workspace requirement as identified through the HDD tendering process.

The drill entry points will be located on the existing TGI ROW, to the south of Blundell Road in Richmond and some additional working space will be required at this site.

The drill exit points will be located on existing TGI ROW, to the north of Berg Rd, in Delta, B.C. with some additional access and working space required at this site as well.

Preliminary discussions with impacted businesses and landowners have taken place. Additional detail regarding communication with stakeholders can be found in Section 6.6 of this application.

The drill paths will utilize existing TGI ROW between the entry and exit points, and no new additional ROW will be required. It will be necessary to remove a short section of each existing pipeline at the drill entry and exit locations prior to drilling. The proposed HDD path for both pipelines is generally underneath the existing NPS 20 pipeline alignment.

6.2.2 Other Utilities

The HDD paths involve crossing Metro Vancouver's NPS 48 Tilbury water main on the south side of the river. The expected vertical separation between the HDD paths and the water main is approximately 25 m and no impacts to this important water main are foreseen. TGI will provide sufficient monitoring to ensure that there are no detrimental effects.

Pipeline assembly will be on the ground above and adjacent to the existing TGI pipelines, and there will be no need for excavation of utility lines crossing the ROW. TGI will utilize its existing protocols to assess and mitigate any impact of construction activities on buried utilities, and will implement site-specific construction practices and precautions that may be required to prevent damage from construction equipment. Pipe assembly may also occur in proximity to overhead electrical power lines and all appropriate safe work practices will be followed.

6.2.3 Roads, Highways, Railways

The project will be carried out entirely within the existing TGI ROW and acquired temporary workspace. Construction of new roads or permanent impacts to municipal roads is not anticipated. Minor temporary road closures may be required for transporting pipe, equipment and assembling the pipe strings however these closures will conform to municipal traffic management plans as required. In addition, the selected contractor will be required to comply with all municipal requirements when utilizing city roads.

6.2.4 Private Land and ROW Issues

Noise Control – The drill entry sites are located within an industrial park. Noise monitoring and control of construction activities will comply with municipal guidelines. Noise control methods will include temporary walls and screening to deflect sound away from occupied buildings. Noise control at the drill exit locations is not anticipated as there are no immediate neighbours.

Vehicle Access – Preliminary consultation with property owners to coordinate construction vehicle access have taken place. No significant impacts or disruptions to existing businesses are expected.

ROW Restoration – Preliminary discussions with property owners regarding restoration have taken place and all impacted properties will be restored to pre-construction conditions or equivalent.

6.2.5 Safety Plan

Considering the proximity of the proposed work to industrial areas, farmland, rail lines, roadways, a water pipeline and the existing NPS 20 and NPS 24 transmission lines, an important consideration will be the safety of public and site personnel during construction. A comprehensive safety plan will be developed by the HDD contractor in compliance with TGI standards, WorkSafeBC regulations and the requirements of other impacted stakeholders.

6.3 Capital Cost

The total capital cost of the project is estimated to be approximately $27.3 million in 2008 dollars. This cost estimate is based on preliminary project definition and design and the individual cost elements consist of historical costs, non-binding quotations and projections. The expected accuracy of the cost estimate is -15 to +20%.

Table 6.1 Capital Cost

	Alternative 1; NPS 20 and NPS 24 HDD Replacement	Estimate ($2008 millions)
1	Project Management, Engineering, Consultation, Inspection	$ 4.9
2	Land Utilization, Temporary Workspace	$ 1.8
3	Pipe & Coating Materials	$ 3.6
4	River Crossing HDD Installation & Pipeline Construction	$ 11.6
5	Tie In Construction	$ 2.5
6	North Bank Dike Improvements Allowance	$ 1.0
7	Operations & Commissioning	$ 0.6
8	Sub- Total	$ 26.0
9	Retirement Costs (existing NPS 20 and NPS 24)	$ 0.4
10	AFUDC	$ 0.9
	Total Project	**$ 27.3**

Notes

- All capital cost estimates are based on an in-service date of November 2009.
- Cost estimates include all engineering, procurement and construction costs, regulatory and environmental costs, and workspace acquisition costs.
- Steel pipe costs based on July 2008 quotation and subject to market variation.

Cost estimates are based on the most recent studies and information available to TGI. Relative to previous studies, recent geotechnical information collected at the site along with detailed seismic analysis has resulted in an increase in both the length and depth of the crossing replacements. As well, the north side of the river has undergone significant industrial development over the last few years which has complicated the logistics of the HDD based on pipe layout and impact on businesses. Current market prices have been used for the expected contracted construction services, materials, and heavy-wall line pipe. In particular, the HDD contract estimate is based on construction during the spring, summer or fall seasons. Construction during the winter is typically 5-15% more costly. Allowances have also been included for the rental of workspace and procedures to minimize impacts to local businesses.

TGI is committed to minimizing the rate impact associated with this non-discretionary Project; therefore, TGI proposes to: (i) structure the HDD contract as being conditional upon Commission review and approval; (ii) schedule the project to avoid higher winter prices for HDD, (iii) file a revised control budget accounting for new information; and (iv) file with the Commission quarterly project progress reports and a project completion report in a form developed in conjunction with Commission staff.

6.4 Schedule

The proposed Fraser River Crossing Upgrade will be undertaken from 2008 to early 2010 with specific activities and durations as follows:

Table 6.2: Schedule Milestones

Activity	Duration
Concept Development	January – September 2008
Detailed Engineering	August 2008 – May 2009
CPCN Preparation and Approval	July 2008 – March 2009
Tendering (Materials)	November 2008 – February 2009
Tendering (HDD)	November 2008 – March 2009
Construction	June 2009 – October 2009
In Service	November 2009
Site Restoration	September 2009 – May 2010

A more detailed schedule is attached as Appendix 7.

The recommended alternative includes efficiencies resulting from replacing both crossings utilizing one HDD equipment mobilization. Analysis of tenders is required to better understand the impact of schedule on those efficiencies. The current schedule assumes that construction will occur in 2009, however the project team has allowed for 2010 construction if following evaluation of tenders for the HDD work it is determined to be more cost effective.

6.5 Cost & Schedule Risks

The primary risks to cost and schedule, and the control / mitigation strategies for this Project are identified in Table 6.3.

Table 6.3 - Project Execution - Risk Control Summary

KEY RISK	CONTROL / MITIGATION
Project Management	Upon approval of the Project, a Project Execution Plan will be issued to detail risks and mitigation strategies, including a Control Budget based on material and HDD/Pipeline construction tenders.
Stakeholder Impacts	Regular collaborative communication with all internal and external stakeholders throughout duration of the Project.
Construction Schedule	Analyze requirements and the feedback from tenders to determine whether 2009 In-service Target is reasonably achievable, or that 2010 completion target is better.
Engineering / Construction Resources	Use Terasen internal resources combined with consultants who have proven skills, HDD experience and availability.
Material Cost / Delivery	Tender to known vendors and award to the lowest qualified bidder.
HDD / Pipeline Contract Cost	Optimize Total Contract Price via: 1) Lump Sum cost components for surface activities that can be best managed by the contractor; and 2) Unit Rates for unforeseen or variable subsurface risks to be shared between the contractor and Terasen (e.g. mud fractures or extreme weather).
HDD / Pipeline Contractor Capability	Tender to known contractors with proven experience; award to the lowest qualified bidder.

In the case of an HDD contract, there will always remain some uncertainty with respect to subsurface conditions. TGI has conducted detailed geotechnical investigations along the drill path and it is expected that the geotechnical baseline report produced for the HDD contractors will reduce the uncertainty regarding subsurface conditions. In designing procurement documents, it is possible to trade off risk for cost. TGI will seek to structure the tender documents for the HDD contract in such a way as to arrive at an appropriate balance between price and the retention of some risk.

TGI plans to schedule the HDD construction work for the summer or fall, when contractors are more available and pricing will be more competitive.

6.6 Environment and Socio-Economic Assessments

6.6.1 Environmental Assessment

TGI has retained a team of environmental professionals from Dillon Consulting Ltd. (“Dillon”) and sub-consultants, Madrone Environmental Consulting, and Altamira Consulting Ltd. to complete a preliminary screening assessment of environmental issues including fisheries, aquatic and terrestrial habitat, agricultural and archaeological resources. In addition, introductory discussions with relevant environmental regulators have been initiated for this project. Based on the results of the environmental screening and agency liaison completed to date, TGI expects that all potential environmental, agricultural, and archaeological impacts associated with this project can be mitigated through standard mitigation protocols.

An environmental screening-level assessment of the project was completed in September 2008 and a copy of the report prepared by Dillon has been attached as Appendix 8. The objective of the environmental screening assessment is to:

- describe the pre-construction conditions of the project site and its attributes (e.g., fish and wildlife habitat, riparian vegetation, upland conditions, surface water drainage patterns, and agricultural, archaeological, and cultural resources);
- predict and evaluate potential temporal and residual project-related impacts and/or interactions with environmentally sensitive areas;
- identify other potential issues of concern in the study area; and
- determine and identify construction constraints (e.g., appropriate timing windows), regulatory permits and approvals and summarize the environmental regulatory process.

The Dillon environmental assessment report has been supplemented with two additional detailed assessments.

First a screening level archaeological overview has confirmed that there are no known archaeological sites or areas of archaeological potential within or immediately adjacent to the Project area. As such, there exists little to no possibility that the project could adversely affect any known or unknown archaeological sites. A copy of the report prepared by Altamira Consulting Ltd. has been attached as Appendix 9.

Second, a preliminary agricultural assessment of the potentially affected Agricultural Land Reserve (ALR) regulated property (i.e., the Gilmour Farm property) in Richmond has been completed. Any agricultural impacts associated with construction can be mitigated by means of standard topsoil stripping and ground pressure reduction measures. Preliminary negotiations for any required temporary work space and access have been initiated with the land owners and applications will be submitted for all required permits post-CPCN approval. A report from Madrone Environmental Services is attached as Appendix 10

In summary, all potential environmental impacts associated with the project will be temporary and mitigated through the implementation of standard mitigation protocols during construction and site restoration.

TGI has completed its initial environmental screening for the project. A more detailed Environmental Impact Assessment (EIA) will be undertaken during the design phase of the project to identify the nature and magnitude of potential impacts and associated risks to the environment. The EIA will focus on the use of matrices to show issues scoping and pathway analysis plus potential effects on valued components and recommended mitigation measures as per appropriate provincial and federal legislation and guidelines. Coinciding with the completion of the EIA, individual permit and approval applications will be submitted to the environmental regulatory agencies for review. Consultation with local and regional governments and federal and provincial agencies and authorities have been initiated and will continue through to completion of the project.

The table below outlines the proposed completion dates for the environmental activities.

Table 6.4 Environmental Activities Schedule

Activity	Completed by
Environmental Screening-level Assessment	Sept 2008 - complete
Environmental Impact Assessment	March 2009
Regulatory Approvals/permitting Submission	March 2009

6.6.2 Socio-Economic Assessment

The economic impact of the Project to the regional area is expected to be limited. The HDD contractor and the major materials, such as pipe and valves, will be procured from out-of-province sources since these resources are not available in B.C. Most of the professional services, such as geotechnical engineering and environmental assessments will be provided by personnel based in B.C as will some of the HDD personnel. Expenditure by the small workforce can be expected to benefit local restaurants and hotels.

The Project's greatest impact, however, is the prevention of major social and economic consequences to the region that would be associated with a failure of these pipelines. These issues and impacts are addressed in Section 4 Project Justification.

The majority of the project work will be carried out within the existing TGI ROW. However, the project will have some minor impact on the operations of a few industrial properties, farms and owners on both sides of the Fraser River. Preliminary discussions with property owners and lessees have included the use of temporary working space, noise control, vehicular access, ROW restoration, and compensation for business or crop losses.

The City of Richmond and the Corporation of Delta have been informed of the project and will be consulted on traffic patterns, removal and replacement of vegetation, grading, and the supply and disposal of water for drilling and testing purposes. The Vancouver Fraser Port Authority has also been informed as the proposed works will extend beneath the Fraser River.

6.7 Communication and Consultation Program

Through its communication and consultation program, TGI has currently undertaken through initial stakeholder discussions to:

- identify key community stakeholders in order to appropriately communicate project intent;
- respond to public interest and potential issues; and
- gather information that will assist TGI in its plans to construct, schedule and operate the pipeline crossings.

TGI has held initial meetings with key stakeholders in Richmond, Delta and Metro Vancouver and has been in contact with government bodies and landowners that would be affected by the project. These meetings have gone well. No "show-stoppers" have been identified, and key stakeholders have voiced their support of the potential project.

6.7.1 Project Stakeholders

TGI has completed preliminary discussions with each of the following project stakeholders:

- Affected property owners or lessees that include:
    - Lantic (Belkorp Industries Inc)
    - Lehigh Cement Dynacor Coatings
    - Stork Craft Manufacturing Inc
    - Kingswood Industrial Park Property Management
    - Emerson Real Estate Group
    - Gilmour Farms
- City of Richmond
    - Director of Engineering
    - Director of Parks & Operations
    - Mayor & Council
- Richmond Chamber of Commerce
    - Executive Director
- Delta Chamber of Commerce
    - Executive Director

- Corporation of Delta
    - Chief Administrative Officer
    - Director of Engineering
    - Mayor & Council
- Canadian National Railway / Burlington Northern Santa Fe Railway / CP Railway
- Metro Vancouver (formerly Greater Vancouver Regional District)
- Provincial Dike Authority
- Fraser River Port Authority (“FRPA” - replaces Fraser River Harbour Commission),
- Fraser River Estuary Management Program (“FREMP”)
- Ministry of Environment (“MoE”)
- Dept of Fisheries and Oceans (“DFO”)
- First Nations
    - Musqueam Indian Band
    - Katzie First Nation
    - Tsawwassen First Nation
- Oil and Gas Commission (“OGC”)
- Agricultural Land Commission
- Transport Canada (Navigable Water Protection Division)

6.7.2 First Nations

The Fraser River Crossing South Arm Crossing Upgrade Project will be impacting private fee simple land that contains the TGI statutory ROW on both sides of the Fraser River. It will not be impacting Crown or Indian Reserve land. Studies have not identified any archaeological sites within the project area. All land has been previously disturbed. Nonetheless, TGI has contacted three First Nations who have archaeological interests in the area - Tsawwassen First Nation, Katzie First Nation and Musqueam First Nation - and provided information on the proposed project. To date none of the three First Nations have identified any issues with the project.

6.7.3 Summary of Stakeholder Concerns

To the point of filing this CPCN application, all feedback on the project has been positive and encouraging. TGI believes all identified issues can be mitigated. Stakeholder comments have included typical concerns such as:

- temporary loss of parking;
- stakeholder vehicular access;
- site restoration / remediation;
- access or utility disruption associated with possible road closures and traffic detours, and
- noise impacts associated with construction equipment and movement of support vehicles.

TGI expects to develop reasonable resolutions that mitigate the concerns that have been raised. A more detailed summary of stakeholder communications is attached as Appendix 11.

6.7.4 Communications Plan

TGI's approach with stakeholders will remain inclusive and proactive. A summary of TGI's communications plans is presented in Table 6.4 below.

Table 6.5 Project Communications Plan Summary

Activity	Completed By
Informational meetings regarding the project held with key stakeholders and property owners	Summer 2008 - Complete
A local TGI employee has been designated as the spokesperson and contact for project inquiries	Summer 2008 - Complete
A project fact sheet has been assembled that includes details on the pipeline replacement rationale, methodology, project schedule, costs and the regulatory approval process	Summer 2008 - Complete
Presentations will be made to Mayor & Council of City of Richmond and the Corporation of Delta	Fall 2008
Key property owners, First Nations and other stakeholders will receive project updates and reports	As needed basis
TGI will continue to work directly with stakeholders	Throughout the project

6.7.5 Conclusions - Communication and Consultation Program

TGI believes that the public consultation and communication plan at the time of filing has been appropriate and has met the expectations of landowners and interested stakeholders alike. In particular, initial meetings with the City of Richmond, the Corporation of Delta, Metro Vancouver, Belkorp, Lantic and Stork Craft have been both useful and instructive. TGI will continue to consult with property owners and lessees regarding public safety, schedule, ROW, temporary construction space, access and accommodation issues.

With respect to First Nations, in light of the limited impact to previously disturbed fee simple land, TGI believes that the consultation conducted to date has been appropriate and adequate.

It is TGI's intent that good relationships with property owners, First Nations and other stakeholders will be maintained through all phases of the project. TGI has every expectation that the public consultation and communication process will help diminish potential impacts, ensure the project remains on schedule, and mitigate unexpected project issues.

6.8 Applications and Approvals

6.8.1 Design, Construction and Operations

The design, construction and operation of the Fraser River South Arm Crossing transmission pipelines are subject to the *British Columbia Pipeline Act and Regulations,* which fall under the jurisdiction of the OGC. Design & construction and operating approvals for the Fraser River South Arm Crossing Upgrade Project have been discussed with the OGC, and these will be obtained as required.

6.8.2 Site Rezoning and Land Rights Purchase

Site rezoning is not required for this Project. The new pipelines will be wholly installed within the existing TGI ROW, and additional temporary working space will be negotiated as required with the land owners. TGI has completed preliminary discussions with land owners regarding temporary working space.

6.8.3 Private Land Rights and Access Road Use

Access to private lands and access road use will be in accordance with established or new agreements with property owners and lessees. TGI has completed preliminary discussions with land owners regarding temporary road access.

6.8.4 Water Crossing

All waters classified as fish habitat are protected by the federal *Fisheries Act*, which is administered by DFO. TGI will make application to DFO which will determine whether the activities associated with the Project should also be referred to the Fraser River Estuary Management Program (FREMP) for project review. TGI has had preliminary discussions with DFO and FREMP, and expects the Project will receive a favorable review, given that no work is expected to occur within fish habitat; i.e. “no-net loss” of fish habitat can be achieved.

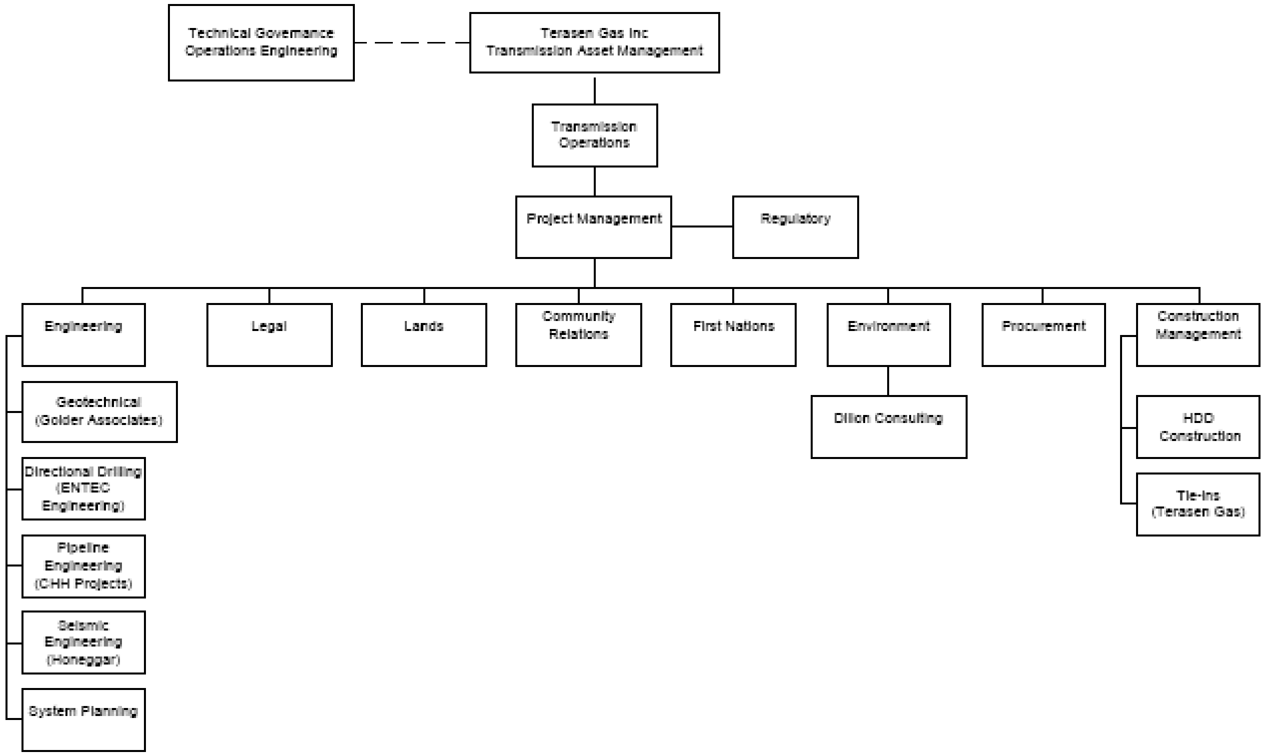
Notification to the Fraser River Port Authority (FRPA) will be required for the project. TGI expects that the FRPA will process the notification via their “Track 1” process given that the project activities are of a predictable nature with little or no impact. An approval submission to Transport Canada (Navigable Waters Protection Division) will likewise be required for this project as will an application for approval to the OGC under Section 9 of the *Provincial Water Act.*

7 Resource Requirements

7.1 Project Management

A TGI project manager will manage the Project and implement the execution plan for each phase of the Project. Figure 7.1 below outlines the functional organization chart for management of this Project.

Figure 7.1: Project Functional Organization Chart



7.2 Design and Quality Control

TGI engineering resources will be utilized for the design of the land-based pipelines and tie-ins. However, the specialized services required for environmental management, geotechnical investigation and analysis, HDD pipe and profile design, and construction inspection will be contracted to individuals and companies possessing the demonstrated skills and experience to complete the work. These individuals and companies will be expected to ensure that public and worker safety, quality workmanship and environmental compliance are maintained throughout this Project.

TGI operating personnel will ensure all facilities are efficiently placed into operation upon completion of construction and conform to TGI standards and industry practices.

7.3 Construction Services

Potential prime construction contractors will be pre-qualified prior to the release of the tender documents. For the HDD Crossing, the prime contractor will be responsible for the drilling and installation of the pipeline across the Fraser River. The lowest cost qualified contractor will be selected by TGI at the close of the procurement process.

7.4 Materials

All owner-supplied materials will be purchased by TGI from the lowest-cost qualified bidder.

8 Cost of Service Impact

TGI estimates the annual incremental cost of service for the $27.3 million investment in the new crossing assets to be approximately $2.2 million starting 2010. The incremental cost of service estimates are based on the TGI current approved capital structure, cost of capital and tax treatment. TGI does not anticipate any incremental operating or maintenance costs, and modest potential maintenance savings have not been included.

Based on forecasted volumes for sales and applicable transportation customers the unit cost of service impact is estimated to be 1.4 cents per GJ starting 2010.

The estimated 20 year incremental cost of service for the new crossing is attached as Appendix 12.

9 Conclusion

As described in this Application, TGI’s concerns regarding seismic events, river erosion and the negative effects of future dike improvements on the NPS 20 and 24 are founded on a series of studies commissioned over the last decade. In light of the public safety issues and significant public interest in ensuring reliable service to hundreds of thousands of customers in the Lower Mainland, TGI believes this Project is in the public convenience and necessity and a CPCN should be granted as sought. TGI has evaluated a number of alternatives to mitigate unacceptable seismic and erosion risks to the existing Fraser River South Arm crossings. TGI has concluded that the most appropriate alternative is the replacement of both the NPS 20 and NPS 24 crossings in 2009, at an estimated cost of $27.3 million. Consultations with stakeholders and First Nations have been initiated, and no significant issues have been identified.

TGI is committed to minimizing the rate impact associated with this non-discretionary Project; therefore, TGI proposes to: (i) structure the HDD contract as being conditional upon Commission review and approval; (ii) at the same time, file a revised control budget accounting for new information; and (iii) file with the Commission quarterly project progress reports and a project completion report in a form developed in conjunction with Commission staff.

Appendix 1

LOWER MAINLAND NATURAL GAS SYSTEM

AS OF JANUARY 1, 2003
KILOMETRES OF MAIN - 10,119
No. OF CUSTOMERS - 538,753

TERASEN GAS TRANSMISSION PIPELINES

- 1067mm OD (NPS 42)
- 914mm OD (NPS 36)
- 762mm OD (NPS 30)
- 610mm OD (NPS 24)
- 508mm OD (NPS 20)
- 457mm OD (NPS 18)
- 406mm OD (NPS 16)
- 323mm OD (NPS 12)
- 273mm OD (NPS 10)
- 219mm OD (NPS 8)
- 168mm OD (NPS 6)
- 114mm OD (NPS 4)
- 88mm OD (NPS 3)
- 60mm OD (NPS 2)

- TERASEN GAS (VANCOUVER ISLAND) INC. PIPELINE
- DUKE ENERGY PIPELINES
- TERASEN GAS HUNTINGDON INC. PIPELINE
- TERASEN GAS SUMAS INC. PIPELINE
- TERASEN GAS INC. INTERMEDIATE PIPELINES
- TERASEN GAS INC. DISTRIBUTION AREA
- ■ FLOW CONTROL STATION
- ◉ GATE STATION OR PIPELINE TAP
- ● DISTRICT REGULATOR STATION
- ▲ VALVE STATION
- Ⓒ COMPRESSOR
- ■ MUSTERSTATION

0 1 2 3 4 5
KILOMETRES

ENGINEERING SERVICES	6	GENERAL REVISIONS. ADDED HORNBY REG STN.	F. SEDLAR			03/11/28
ENGINEERING SERVICES	7	STATIONS NAME CHANGE	W KUMPULA			07/07/10
BY	No.	REVISION	DRAWN	DESIGNED	CHECKED	DATE(YY-MM-DD)
			MICROFILMED			SCALE- AS SHOWN

REF.- XXXXXXX
SAP ID: XXXXXXXXXX
DRAWING No. 99000-P-000-024-R7

Appendix 2

DES 09-02
27 February 2004

GUIDELINE
DESIGN
Seismic Design

Seismic Design Requirements for Buried Pipelines

Replaces: n/a

Overview

This guideline describes factors that need to be considered in determining the need for special seismic design measures. It provides guidance on implementing seismic design measures for buried pipelines.

A screening methodology is provided to assist in the process of deciding whether or not additional expertise is required to quantify specific seismic design issues and design measures. The screening methodology is largely based on judgment and uses a qualitative assessment of damage consequences and general information on surface soil deposits and topography to identify site conditions that could experience permanent ground displacements large enough to pose a hazard to Terasen Gas buried pipelines. It must be recognized that local conditions may be highly variable and there is always the possibility that detailed site investigations will lead to conclusions that differ from the screening methodology.

Audience

This guideline is intended to be used by engineers responsible for the planning and design of projects related to the installation, repair, and replacement of pipelines.

Background

Since 1993, Terasen Gas has implemented several projects to assess the vulnerability of its major transmission and intermediate pressure pipelines to potential hazards related to a significant earthquake affecting the Terasen Gas service area. These assessments were focused on determining whether or not key pipelines critical to the Terasen Gas system had a reasonable likelihood of maintaining pressure following a seismic event with an average return period of 2,000 years (annual exceedance probability of 0.0005).

Past efforts to assess pipeline response to seismic hazards have led to the upgrading of several critical pipelines and modification of design requirements for new pipeline installations and pipeline replacement. This guideline is based on the lessons learned from Terasen Gas experience in assessing expected pipeline performance for earthquake hazards typically found in British Columbia and generally accepted seismic design practices in the natural gas industry.

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Definitions

Annual Exceedance Probability

Probability that a specific level of seismic hazard (ground shaking, liquefaction, ground displacement) will be exceeded in one year; equal to 1/Return Period.

Distribution Pipeline

A pipeline operating at a gauge pressure of 700 kPa or less.

Intermediate Pressure

A pipeline operating at a gauge pressure greater than 700 kPa but less than or equal to 2070 kPa.

Lateral Spread

Ground displacement that generally occurs in a down-slope direction as a result of liquefaction-induced soil strength loss.

Liquefaction

Process by which the strength of granular soil layers below the water table is reduced as a result of an increase in pore water pressure generated by shearing deformation of the soil caused by earthquake ground shaking.

Peak Ground Acceleration

Maximum earthquake acceleration experienced by a perfectly rigid object on the ground surface.

Return Period

Average time interval between earthquake events.

Transmission Pipeline

A pipeline operating at a gauge pressure greater than 2070 kPa.

Responsibilities

The pipeline asset manager is responsible for ensuring that the appropriate level of engineering design is applied to the pipeline system. Where it is determined that special seismic design measures are needed, the asset manager is responsible for obtaining the necessary geotechnical and pipeline design services to define appropriate design and construction recommendations.

Design Objectives

The seismic design objective for Terasen Gas pipelines is to provide a reasonable level of confidence that the pipelines will not pose a hazard to the public significantly greater than other risks the public might face in the event of a major earthquake. An additional benefit of meeting this objective is an increased likelihood that natural gas service can be maintained and enhance earthquake response and recovery to residential customers by providing fuel for heating, cooking, and disinfecting drinking water.

Seismic Hazards Considered

Potential seismic hazards affecting the Terasen Gas service area include the following:

- Ground shaking
- Liquefaction
- Lateral spread displacement
- Slope movement caused by ground shaking

Earthquake-generated permanent ground displacement is considered the only credible hazard to buried pipelines used in the Terasen Gas system. Sources of earthquake-generated permanent ground displacement in the Terasen Gas service area are limited to earthquake-triggered landslides, lateral spread displacement, and settlement related to liquefaction.

In addition, there is a potential for collateral damage from interaction with other structures or systems (limited to pipelines supported on bridges and in close proximity to other utilities damaged as a result of the seismic hazards listed above).

Regulatory Requirements

Existing regulatory requirements do not specifically address mandatory measures for the seismic design of buried pipelines. Section 4.2.4.1 of CSA Z-662-03 explicitly excludes loading related to “(a) occasional extreme loads, such as inertial earthquakes, (b) slope movements, (c) fault movements, and (d) seismic-related earth movements.” Although Appendix C of CSA Z-662-03 addresses limit state design for ground movement, the provisions of Appendix C are generally only applicable when the design requirements are focused on preventing significant permanent deformation of the pipe. This design requirement is generally far too conservative for use in assessing earthquake performance where some pipeline damage can be accepted (see discussion in **Pipeline Deformation Capacity**, below).

Buried Pipeline Response to Ground Displacement

General Behaviour

Permanent ground displacements are an important consideration for buried pipelines, because pipelines crossing zones of ground displacement must deform longitudinally and in flexure to accommodate the ground movements. Loads will be induced in a pipeline when it moves relative to the surrounding soil. This may occur when the soil restricts the free movement of a pipeline or when the pipeline attempts to resist the movement of the surrounding soil.

The axial component of ground displacement is resisted by friction forces at the soil-pipeline interface. For a given pipeline axial force, there is a length of pipeline required to develop opposing soil frictional forces. Beyond this length, the pipeline is not affected by the ground displacement and can be considered anchored. Hence, the frictional resistance provided by soil-pipeline interaction governs the length of pipeline available to undergo axial strain to accommodate ground displacement.

Vertical ground movement is resisted by a pipeline in a different manner. For a shallow buried pipeline, the uplift resistance of the soil is much lower than the downward bearing resistance. Thus, the pipeline may be able to lift upward with relative freedom to accommodate the vertical ground movement, and the maximum pressure between the pipeline and the soil will occur on the upward moving side. The corresponding curvature and bending strains will generally be lower than those caused by purely horizontal ground movements of equal magnitude.

The longitudinal strain (combined axial and bending strain) condition in a buried pipeline subject to ground displacement generally varies directly with soil restraint conditions, i.e., the greater the resistance of the soil to the relative displacement of the pipeline within the soil mass, the more concentrated the loads become at the location of differential ground movement, and the larger the pipe strains must become to conform to the ground at the location of differential ground movement. For typical pipeline trench conditions, loose granular backfills (sand or gravel) will offer less resistance to pipe movement than cohesive backfill materials (clay or silty clay). In cases where the native soil is cohesive, loose to medium dense granular soil can be used to promote additional fault movement capacity.

The strain developed in a buried pipeline from imposed ground displacement is limited by the fact that the maximum pipeline displacement cannot exceed the ground displacement. That is, exceeding the pipeline yield stress does not imply uncontrolled increase in pipeline displacement as might occur if an aboveground span of pipe was overloaded. The behaviour characteristic of buried pipelines responding to ground displacement is commonly called displacement-controlled or displacement-limited and is referred to as a secondary load in the ASME codes. Because exceeding the pipeline yield stress in the longitudinal direction is of little importance to the ability of the pipeline to maintain pressure integrity, strain acceptance criteria are more appropriate for determining pipeline ground displacement capacity.

Pipeline Deformation Capacity

Contemporary pipeline steels generally can accommodate average tensile strains on the order of 3% to 5% or more and local strain concentrations of 15% or more without rupture. Small homogenous test specimens of typical pipe material in a tensile test fail at a total tensile strain on the order of 20% to 25%. However, the strain between first yield and maximum load (onset of necking and plastic instability) is only 5% to 10% and may be even smaller on specimens from large weldments that generally contain some flaws of various sizes.

The ability of pipelines to undergo flexural compressive strains much greater than those associated with the onset of wrinkling without loss of pressure integrity, as demonstrated by full-scale testing, has led to the adoption of flexural compressive strains much greater than those associated with the onset of wrinkling. Flexural compressive strains of the same order of magnitude as tensile strains will generally not result in a rupture condition, although consideration should be given to the potential for wrinkling due to compressive bending strains.

In compression, local instabilities such as wrinkling can develop at strains much less than the achievable tensile strain limits. Wrinkling of the pipeline wall does not, in itself, constitute a failure condition for displacement controlled loading conditions produced by pipeline response to permanent ground displacement. However, under sustained loading, further compressive shortening would be expected to concentrate at points of initial wrinkling. Typically, the initiation of compressive wrinkling occurs in the range of 0.3% to 0.6% strain for most thin-walled large diameter pipes. Loss of pressure boundary integrity is associated with strains far greater, generally at least ten to twenty times greater, than those associated with the initiation of compressive wrinkling.

Pipe and Welding Specifications

The selection and specification of both pipe and welding for a strain-based design pipeline system includes consideration of a number of factors that may not be adequately addressed in current Terasen Gas pipe welding specifications. The level of pipeline strain that can be developed without compromising pressure integrity is influenced primarily by the properties of the pipe steel, welding materials and procedures, and quality control over the welding process.

In addition to strength, fracture toughness, and weldability considerations, the most important pipe property for strain-based design is the yield-to-ultimate strength, Y/U, ratio of the pipe, heat-affected zone (HAZ), and weld deposit. This ratio, together with the shape of the stress-strain curve, determines the amount of plastic strain that can be tolerated without failure of the material in and adjacent to the girth weld. A ratio on the order of 75% is desirable and is common on low yield strength pipe. (The low Y/U ratio should also apply to the longitudinal seam weld of the fabricated pipe.) The Y/U properties of the as-rolled plate for the pipe and the as-welded properties of the weld deposit are both subject to change, almost always in the wrong direction, as the result of straining and aging during the manufacturing, field welding, and/or pipe installation process. Special precautions and quality control testing are needed to minimize this condition (i.e., higher Y/U ratios).

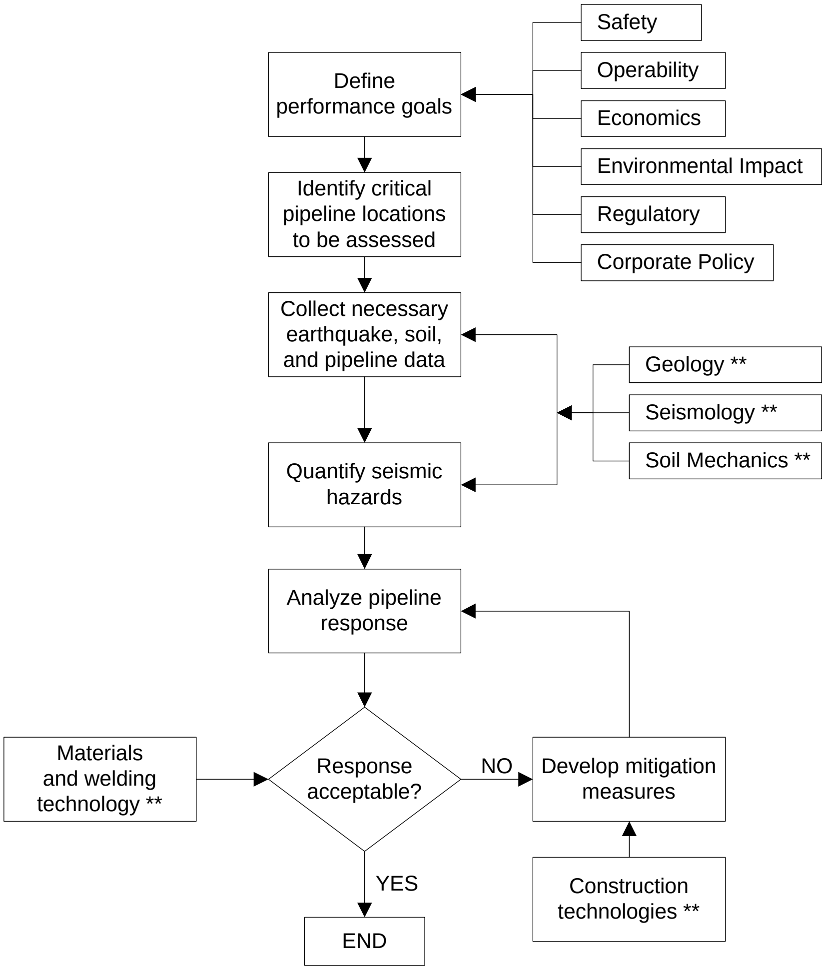
Modern high strength line pipe achieves its strength from thermo-mechanical controlled processing during plate rolling as opposed to the older technology of adding alloying elements to the steel. The newer technology results in a more weldable pipe at a lower cost but sacrifices the Y/U ratio. The high strength grade X70 pipe that would normally be specified to achieve minimum pipe weight and price is likely to have a Y/U ratio of 85-90% or perhaps higher if the high end of the normal distribution is included. It will be difficult to purchase the small quantities of special pipe required for crossing zones of ground displacement. Selection of a lower strength pipe material such as X52 or X60, with a necessarily thicker wall, is suggested whenever practical because of its generally lower Y/U ratios and the higher likelihood that welds will substantially overmatch the lower-strength pipe materials.

The choice of a minimum wall design based upon higher pipe material strength also leads to a higher D/t ratio and a lower compressive strain at which buckling initiates. A higher D/t ratio increases the potential for wrinkling of the pipe wall if the pipe is subjected to permanent ground deformation. Therefore, when economically practical, consideration should be given to selecting a pipe wall thickness larger than what may be required by code for internal pressure loads.

General Design Considerations

Transmission and Intermediate Pressure Pipelines

Figure 1



** Special technical expertise typically required

The general process for performing a design or an assessment of a buried pipeline is illustrated by Figure 1 above. As indicated in the flowchart, seismic pipeline design may require input from experts in specialized technical disciplines, particularly in the areas of seismology, geology, soil mechanics, and materials and welding technology.

Most of the approaches for quantifying seismic hazards are based upon empirical relationships developed from past earthquake observations. As a result, use of the empirical relationships is inherently limited to the particular conditions characteristic of the underlying database, i.e., the earthquake data used to develop the empirical relationship. Understanding the relative importance of these limits and rational approaches for implementing modifications for site-specific conditions is the primary reason for relying on individuals with special technical expertise.

Detailed seismic design of buried pipelines typically requires a site-specific soils investigation, analytical assessment of likely permanent ground displacements along the pipeline alignment and detailed analysis of pipeline response to the estimated ground displacements. Site specific seismic design will require outside contractors with expertise in geotechnical engineering, analytical assessment of buried pipelines and, in some cases, local geology and seismology.

The approach to seismic design is often iterative and requires consideration of modifications to pipeline material or wall thickness, pipeline alignment, and pipeline construction details in order to arrive at an acceptable design. Because of the iterative nature of the process, it is important that the seismic design be considered early in the planning process, preferably before rights-of-way have been secured for the pipeline alignment.

It is not possible to provide general guidance on the likely vulnerability of buried pipelines to permanent ground displacement without the benefit of a detailed analysis. An assessment of the likelihood of damage to buried pipelines involves many factors. Some of the most important factors include the length of pipe traversing an area of potential permanent ground displacement, the direction of ground displacement relative to the pipeline alignment, the presence of significant bends (side bends, sag bends, and over bends greater than about 10°) within or adjacent to the zone of ground displacement, and the pipeline diameter-to-thickness ratio.

Because of the ability of pipelines to withstand higher strains in tension, buried pipeline alignments through zones of permanent ground displacement that result in pipeline being placed in tension or tension and bending are preferred over alignments that result in compression or compression and bending. At river crossings, this will often require crossing perpendicular to the river and maintaining a straight pipeline alignment within 250 m of the river bank.

Buried pipeline response to ground displacement is also improved by increasing the length of pipeline available to undergo axial strain. The length of pipeline available to strain axially is increased when soil friction forces are reduced and the pipeline alignment is relatively straight within 100 m to 300 m of the zone of ground displacement. Reduced soil friction is achieved by minimizing the depth of soil cover, using hard, smooth pipeline coatings (e.g., fusion bonded epoxy, polyethylene) and backfilling the pipeline trench with loose granular soil. Sharp bends (side bends, sag bends and over bends greater than about 10°) can significantly increase the axial soil restraint on buried pipelines and should be avoided within 100 m to 300 m of zones of ground displacement.

Other construction alternatives available to improve pipeline response to permanent ground displacement include aboveground support of the pipeline, placing the pipeline within a soil berm, isolating the pipeline from the soil by placing the pipeline within a culvert or sacrificial casing and using alternate lightweight backfill material such geofoam. Each of these alternatives has certain drawbacks with respect to exposing the pipeline to other non-seismic hazards and is best suited for pipelines in remote, sparsely populated areas.

Distribution Pipelines

By necessity, distribution pipelines are typically installed within a road or street right-of-way and must be installed in well-compacted soils that reduce the potential for ground settlement that can lead to deterioration of the road surface. In addition, the alignment and depth of distribution pipelines beneath streets is often dictated by the need to avoid other services (e.g., water, sewer, telecommunication lines). Distribution pipelines typically have multiple tie-ins for customer gas connections that can be especially susceptible to damage from ground displacement. Finally, the majority of new or replacement distribution pipelines in the Terasen Gas system are constructed of medium density polyethylene (MDPE) While MDPE pipelines can undergo larger strains than steel pipelines without loss of pressure integrity, MDPE has lower stiffness and is susceptible to pinching failures when subjected to ground displacement.

The potentially higher vulnerability of distribution pipelines is offset by the fact that the lower pressure generally leads to lower consequences of failure for a distribution pipeline compared to an intermediate or transmission pressure pipeline.

The scoring checklist in Appendix A is intended to infrequently identify a need for special seismic design measures for distribution pipelines. When considered necessary, seismic design considerations for distribution pipelines should focus on providing sufficient operational flexibility to isolate areas of potential damage, typically by judicial installation of valves, to limit the duration of gas release and the extent of affected service area. Practical seismic design considerations for a distribution pipeline are often limited to locating the pipeline in the street right-of-way to maximize the distance between the pipeline and buildings to reduce the threat to the public from earthquake damage. Post-earthquake response planning should include procedures for rapidly identifying areas of pipeline damage and getting field crews to the damaged areas to isolate the distribution system. Additional guidance on practical seismic design measures for distribution pipelines can be found in McDounough (1995).

Determining the Need for Special Seismic Design of Buried Pipelines

Determining whether or not detailed seismic design for permanent ground displacement (typically involving contracting with specialists in geotechnical engineering, seismic hazard evaluation, and analytical assessments) is required for a particular buried pipeline installation can be accomplished through the following steps:

1. Assess the potential consequences of pipeline damage on public safety.
2. Assess the potential consequences related to operational integrity of the gas system.
3. Determine that there is a significant likelihood that the project site can experience earthquake-related ground displacement.

Decisions on the level of required seismic design measures should be made on a case-by-case basis with the additional costs of implementing seismic design balanced against the above.

These guidelines provide a multilevel qualitative scoring methodology to assist in determining the need for special seismic design measures. The scoring methodology examines the potential consequences, as measured by potential direct effects (gas release and potential ignition) and indirect effects (number of customers potentially impacted by earthquake damage) to determine if a pipeline segment warrants special seismic design considerations. If the score indicates a significant consequence of pipeline damage, an additional scoring sheet is used to identify the likelihood for earthquake-related permanent ground displacements with a potential to cause pipeline damage.

Assess Impact of Pipeline Damage

A scoring checklist to assist in assessing consequences of pipeline damage is provided in Appendix A. The scoring checklist separately addresses safety consequences (based on location class, diameter, and pressure) and operational consequences (based on potential number of customers impacted). A score greater than 1.0 is representative of unacceptable consequences of earthquake-related pipeline damage and indicates that an assessment of potential for seismic hazards is necessary.

Assess Likelihood for Ground Displacement

Based upon past experience in assessing seismic hazards for the Terasen Gas service area, a scoring checklist to assist in the determination of whether or not a credible seismic hazard exists is also provided in Appendix A. The scoring checklist provides a system for ranking various factors important in determining the likelihood for earthquake-induced permanent ground displacements.

Use of the ground displacement scoring checklist in Appendix A requires information on surficial geology, topography, and seismicity. Information that can be used in conjunction with the scoring checklist in Appendix A includes the following:

1. PGA contour maps from the National Building Code of Canada (map MCR 4171 (1994) available from the Geologic Survey of Canada)
2. Topographic maps (available from Geologic Survey of Canada)
3. Natural hazard map for the lower mainland indicating liquefaction susceptibility (available from Geologic Survey of Canada)
4. Liquefaction susceptibility maps contained in a 1994 EQE/Golder report on the seismic vulnerability of Terasen Gas transmission and intermediate pressure pipelines in the lower mainland.
5. Municipal liquefaction hazard maps. (These are only available for those municipalities that have undertaken detailed studies. It is known that such maps exist for the City of Richmond, the City of Surrey, the City of Coquitlam, and the Greater Saanich District (Vancouver Island). Other municipalities could be contacted as required to determine if detailed maps are available.).

Guidance for Implementing Seismic Design Measures

Specifying special seismic design measures for buried pipelines should be considered when the product of the consequence score and seismic hazard score is greater than 1.0. Note that the overall score can be much greater than 1.0. However, the actual score is not indicative of the relative need to consider special seismic design measures (i.e., a score of 22 does not indicate that seismic issues are 22 times greater than a score of 1.0).

Buried Pipelines

The approach to the seismic design of transmission and intermediate pressure pipelines for Terasen Gas considers conservative estimates of what is likely to occur in defining seismic ground displacements with lesser degrees of conservatism adopted in pipeline strain acceptance criteria. Past approaches for evaluating and upgrading critical Terasen Gas pipelines has equated the likelihood of experiencing a seismic hazard to the acceptable probability of not achieving the performance goals for the pipeline. In other words, the annual exceedance probability of 0.0005 for defining seismic hazards is based on accepting an annual probability of 0.0005 that seismic hazards may lead to loss of pipeline pressure integrity.

Unless a lower level of performance can be justified based on specific project constraints, seismic design of key high pressure pipelines should strive to achieve an annual probability of loss of pressure integrity less than or equal to 0.0005. This can be achieved by using mean permanent ground displacements associated with an exceedance probability of 0.0005 (average annual return period of 2,000 years).

In general, analytical assessment of pipeline performance should focus on strain acceptance criteria consistent with accepting permanent deformation of the pipeline but maintaining pressure integrity. This approach requires post-earthquake investigation of pipeline response and replacing deformed sections of the pipeline.

The following actions will typically be necessary to adequately address potential seismic hazards to buried pipelines:

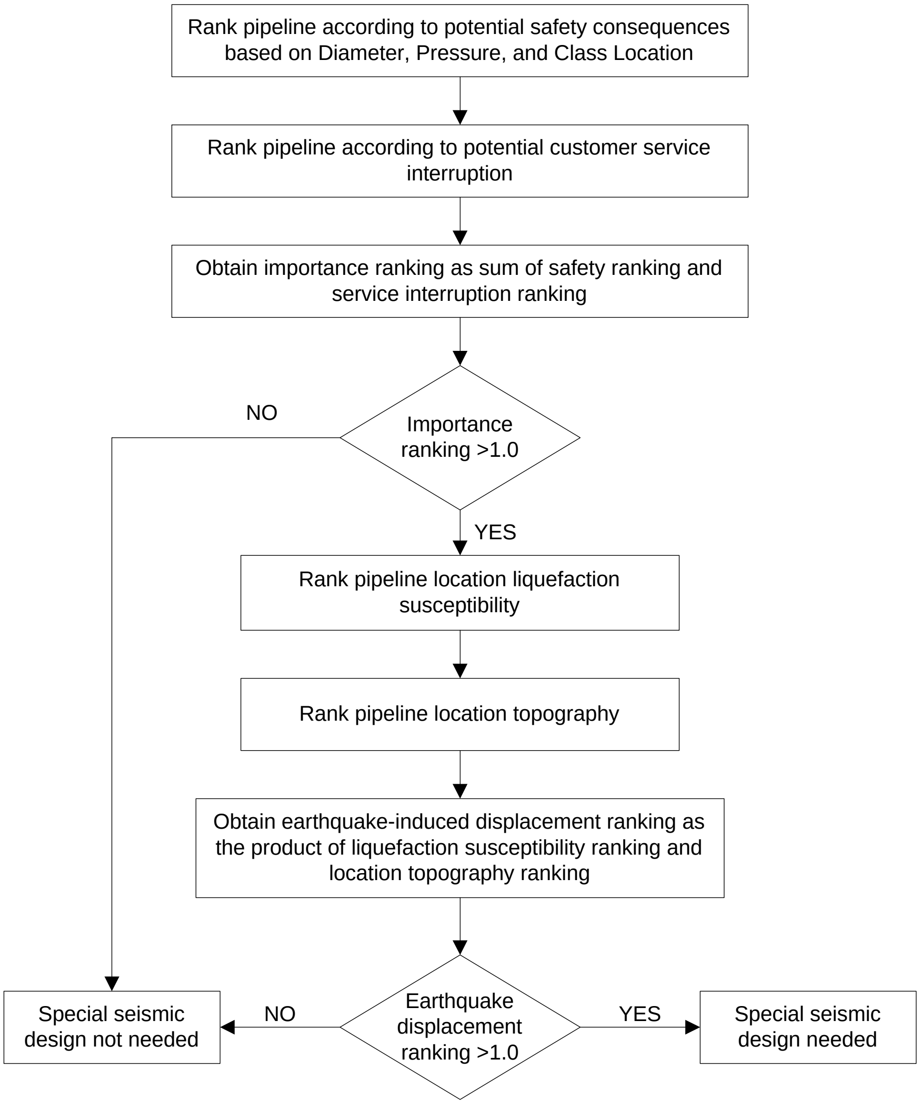
1. Perform a geotechnical assessment to determine the potential for earthquake-generated permanent ground displacement for mean or median estimates of earthquake ground motions. This assessment will typically require subsurface investigations to determine site stratigraphy and analytical studies to assess site stability. Permanent ground displacement estimates should be mean or median estimates and not incorporate additional conservatism.
2. Perform an analytical assessment of pipeline response to earthquake-generated permanent ground displacement. The pipeline assessment should use finite element analysis methods that have the capability to account for geometric, material, and boundary condition nonlinearities. Soil-pipeline interaction can be modeled by discrete nonlinear springs oriented in the axial, horizontal, and vertical directions with respect to the pipeline alignment. Inelastic pipeline behaviour should be simulated by specifying a nonlinear stress-strain curve for the pipeline steel. Guidance on acceptable analysis approaches and strain acceptance criteria can be found in ALA (2001).
3. Establishing specific construction criteria to assure the pipeline installation is consistent with the assumptions used in the analytical assessment. Special construction criteria will typically focus on weld acceptance criteria (number and size of permissible flaws), weld inspection (typically 100% radiographic and/or ultrasonic inspection), pipe material specifications (e.g., limits on maximum yield stress and Y/U ratio), pipe coating (use of hard, smooth external coatings and alternatives to the use of concrete coating), and placement of backfill (e.g., backfill material, degree of compaction).

Appendix A: Scoring Checklists

Use of Scoring Checklists to Assess Need for Special Seismic Design Requirements

The checklists in this Appendix are intended to assist in the determining the need to provide special seismic design measures for buried pipelines. The checklist approach is based on separate qualitative measures of the potential for liquefaction, lateral spread displacement, and consequences of pipeline damage. Use of the checklists follows the flowchart shown in Figure 2 below.

Figure 2



The first step is to rank the potential consequences of pipeline damage. Consideration of potential consequences consists of two steps. The first step is to determine the ranking considering factors that relate to potential safety consequences. Large diameter, high pressure pipelines in populated areas are given a higher ranking than low pressure pipelines in sparsely populated areas. The ranking for safety consequences is the product of the ranking values for pipe diameter, pressure, and class location. The second step is to consider a ranking modifier related to the number of customers that could potentially suffer interruption of service in the event of pipeline damage. The total ranking value for potential consequences is the sum of the safety consequences value and the customer outage value. Special seismic design measures may be warranted if the ranking value for potential consequences is 1.0 or greater.

The second step is to rank the potential for liquefaction-induced displacement. Again, this is a two-phase process. The first phase is to rank the liquefaction susceptibility. The second phase is to rank the site conditions that can lead to liquefaction-induced displacements. Clearly, if the ranking value for liquefaction susceptibility is 0, no ranking is necessary for site conditions and no special seismic considerations are necessary. The ranking for ground displacement is based on proximity to a river or stream or the ground slope in the area with a potential liquefaction hazard. The total ranking for liquefaction-induced displacement is the product of the liquefaction susceptibility ranking value and the site conditions ranking value.

Special seismic design considerations should be considered when the product of the ranking values for potential consequences and liquefaction-induced displacements is greater than or equal to 1.0.

Example:

Consider the extension of an NPS 6 intermediate pressure pipeline in the vicinity of the Dinsmore Bridge in Richmond. Preliminary plans call for the pipeline to generally follow River Road in an area considered to be Class 2. The primary purpose of the pipeline extension is to supply two large industrial customers. The score for potential consequences of pipeline damage is as follows:

Class Location:	1.0
Size:	1.0
Pressure:	1.5
Preliminary Score:	*1.5*
Service Interruption Ranking:	0.2
Total Score:	*1.7*

A consequences score greater than 1 indicates the need to consider the potential for seismic hazards. From a review of surficial geology maps for the Vancouver region, the pipeline location will be in geologic unit Fc, indicating a high liquefaction potential. This is confirmed by reviewing the liquefaction susceptibility maps in the 1994 EQE/Golder report. The pipeline will be located within 100 m of the Middle Arm of the Fraser River. The score for ground displacement potential is computed as follows:

Liquefaction Susceptibility:	2.0
Proximity to River Bank:	1.0
Displacement Score:	*2.0*

The total score from the checklists is 3.4, indicating that consideration should be given to assessing the likelihood of earthquake-induced ground displacement and designing the pipeline to maintain pressure integrity for that displacement. The asset manager has the final decision on what design measures are required and may consider other factors such as the actual maximum operating pressure for the pipeline, the likely impact of pipeline damage at the specific location, and the importance of maintaining service.

Table 1: Screening Checklist to Gauge Potential Consequences of Pipeline Damage

SAFETY RANKING		
Parameter	**Description**	**Value**
CSA Z-662 Class Location	4	2
CSA Z-662 Class Location	3	1.5
CSA Z-662 Class Location	2	1
CSA Z-662 Class Location	1	0.5
Size	greater than NPS 24	2
Size	NPS 14 to NPS 24	1.5
Size	NPS 6 to NPS 12	1
Size	less than NPS 6	0.5
Pressure	transmission (greater than 2070 kPa)	2
Pressure	intermediate (701 kPa to 2070 kPa)	1.5
Pressure	distribution (700 kPa or less)	0.75
Safety Ranking (product of above values)		

SERVICE INTERRUPTION RANKING		
Parameter	**Description**	**Value**
Likely Number of Customers Without Service from Pipeline Damage	more than 5,000	2
Likely Number of Customers Without Service from Pipeline Damage	2,000 to 5,000	1.5
Likely Number of Customers Without Service from Pipeline Damage	500 to 2,000	1
Likely Number of Customers Without Service from Pipeline Damage	50 to 500	0.5
Likely Number of Customers Without Service from Pipeline Damage	less than 50	0.2

Total Importance Ranking **(service interruption value + safety ranking)**

Table 2: Screening Checklist to Gauge Potential for Permanent Ground Displacement

LIQUEFACTION RANKING		
Liquefaction Susceptibility Category*	Surficial Geologic Unit**	Value
high and very high	Fa through Fh	2
high and very high	SAa, SAb, SAd, SAe	2
moderate	SAc	0.5
moderate	SAf through SAj	0.5
moderate	SAr, SAq	0.5
moderate	SA-C	0.5
low to very low	SA, SB, SC	0
low to very low	C, FL, PV, PT, S, T, UPV, V, VC (includes all sub-classes)	0
Za in BCBC 2 or greater***	all soils	1
Za in BCBC less than 2***	all soils	0
Liquefaction Ranking (product of above values)		

LATERAL SPREAD RANKING		
Topographic Considerations	**Topographic Description**	**Value**
Slope (if site is within 250 m from river bank or shoreline, skip this score)	5% or greater	2
Slope (if site is within 250 m from river bank or shoreline, skip this score)	2% to 5%	1.5
Slope (if site is within 250 m from river bank or shoreline, skip this score)	0.5% to 1%	1
Slope (if site is within 250 m from river bank or shoreline, skip this score)	less than 0.5%	0.25
Proximity to river bank or shoreline (only applies if site is within 250 m of river bank or shoreline)	less than 50 m	2
Proximity to river bank or shoreline (only applies if site is within 250 m of river bank or shoreline)	50 m to 100 m	1.5
Proximity to river bank or shoreline (only applies if site is within 250 m of river bank or shoreline)	100 m to 150 m	1
Proximity to river bank or shoreline (only applies if site is within 250 m of river bank or shoreline)	200 m to 250 m	0.5
Lateral Spread Ranking		

Earthquake-Induced Displacement Ranking
(product of liquefaction ranking and lateral spread ranking)

Total Ranking
(product of importance ranking and earthquake-induced displacement ranking)

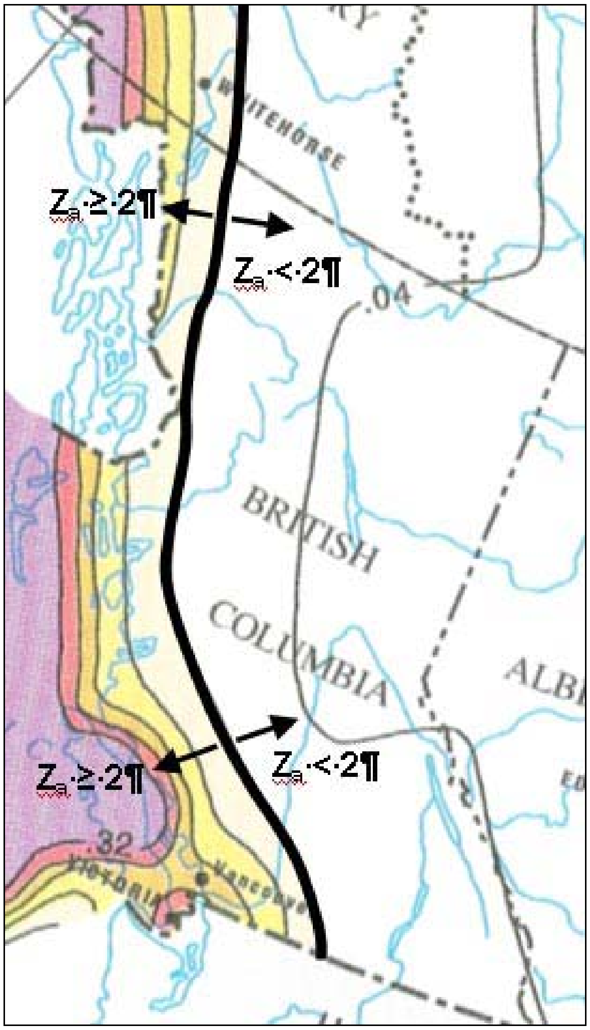
NOTES:
* See Table 3 for soil deposits related to liquefaction susceptibility categories
** Surficial geology units only applicable to Geologic Survey of Canada maps covering the Vancouver region. Surficial geology maps may also be available for specific locations in the province.
*** See Figure 3.

Table 3: Liquefaction Susceptibility Based on General Soil Deposit Classification

Type of Deposit	General Distribution of Cohesionless Sediments in Deposits	Likelihood that Cohesionless Sediments (saturated) would be Susceptible to Liquefaction (by age of deposit)			
		Less than 500 years	Holocene	Pleistocene	Pre-Pleistocene
Continental Deposits					
River channel	Locally variable	Very high	High	Low	Very low
Flood plain	Locally variable	High	Moderate	Low	Very low
Alluvial fan and plain	Widespread	Moderate	Low	Low	Very low
Marine terraces and plains	Widespread	N/A	Low	Very low	Very low
Delta and fan-delta	Widespread	High	Moderate	Low	Very low
Lacustrine and playa	Variable	High	Moderate	Low	Very low
Colluvium	Variable	High	Moderate	Low	Very low
Talus	Widespread	Low	Low	Very low	Very low
Dunes	Widespread	High	Moderate	Low	Very low
Loess	Variable	High	High	High	Unknown
Glacial till	Variable	Low	Low	Very low	Very low
Tuff	Rare	Low	Low	Very low	Very low
Tephra	Widespread	High	High	Unknown	Unknown
Residual soils	Rare	Low	Low	Very low	Very low
Selka	Locally variable	High	Moderate	Low	Very low

Type of Deposit	General Distribution of Cohesionless Sediments in Deposits	Likelihood that Cohesionless Sediments (saturated) would be Susceptible to Liquefaction (by age of deposit)			
		Less than 500 years	Holocene	Pleistocene	Pre-Pleistocene
Coastal Zone					
Delta	Widespread	Very high	High	Low	Very low
Estuarine	Locally variable	High	Moderate	Low	Very low
Beach: high wave energy	Widespread	Moderate	Low	Very low	Very low
Beach: low wave energy	Widespread	High	Moderate	Low	Very low
Lagoonal	Locally variable	High	Moderate	Low	Very Low
Foreshore	Locally variable	High	Moderate	Low	Very low
Artificial					
Uncompacted fill	Variable	Very high	N/A	N/A	N/A
Compacted fill	Variable	Low	N/A	N/A	N/A

Figure 3: Seismic Zone Map for BC
(based on MCR 4171, 1994)



Appendix 3

Golder Associates Ltd.

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Burnaby, British Columbia, Canada V5C 6C6
Telephone 604-296-4200
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REPORT ON

ASSESSMENT OF SEISMIC PERFORMANCE TERASEN GAS INC. NPS 20 AND NPS 24 T.P PIPELINES SOUTH ARM OF FRASER RIVER TILBURY ISLAND (DELTA) TO RICHMOND, BC

Submitted to:

Terasen Gas Inc.
16705 Fraser Highway
Surrey, BC
V35 2X7

DISTRIBUTION:

1 Copy - Terasen Gas Inc., Surrey, BC
1 Copy - BGC Engineering Inc., Vancouver, BC
2 Copies - Golder Associates Ltd., Burnaby, BC

August 9, 2007

07-1411-0027

Golder Associates Ltd.

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Golder Associates

August 9, 2007

07-1411-0027

Terasen Gas Inc.
16705 Fraser Highway
Surrey, BC, V35 2X7

Attention: Mr. Dan Ellis

**RE: ASSESSMENT OF SEISMIC PERFORMANCE
TERASEN GAS INC. NPS 20 AND NPS 24 T.P. PIPELINES
SOUTH ARM OF FRASER RIVER
TILBURY ISLAND (DELTA) TO RICHMOND, BC**

Dear Sir:

As requested by Terasen Gas Inc. (Terasen), Golder Associates Ltd. (Golder) and D.G. Honegger Consulting (DGHC) carried out a seismic (earthquake) performance evaluation of the Terasen NPS 20 and NPS 24 transmission pressure pipelines where they cross beneath the South Arm of the Fraser River between Delta and Richmond BC.

This letter report summarizes the results the Golder/DGHC investigations and analyses, which included supplementary subsurface investigations, laboratory testing of soil samples and engineering analyses. Also included is a description of the two-dimensional (2D) ground response analyses carried out as part of the seismic vulnerability assessment, together with brief descriptions of the engineering properties of the overburden soils inferred from the available subsurface data, the methodology followed and the results of analyses.

This report should be read in conjunction with **"Important Information and Limitations of This Report"** which is appended following the text of the letter report. The reader's attention is specifically drawn to this information, as it is essential that it is followed for the proper use and interpretation of this report.

1.0 BACKGROUND

1.1 Site Conditions

Terasen operates dual 20 and 24 inch diameter transmission pressure (T.P.) pipelines to supply natural gas to the cities of Richmond and Vancouver. The configuration of the pipeline crossing of the South Arm of the Fraser River is shown in the Figures that follow the text of this report. Also shown in the Figures is the vertical pipeline profiles determined by pigging (using the "geopig"), superimposed on the interpreted stratigraphic cross-section of the site as determined through geotechnical investigations.

At the northern and southern banks of the Fraser River, the pipelines are located within a single, nominal 15.24 m width right-of-way with approximately 7 m spacing between the pipelines. However, at the Fraser River crossing, the pipelines separate into two parallel rights-of-way with an increased spacing of approximately 90 m. The NPS 20 T.P pipeline, which occupies the eastern portion of the pipeline right-of-way, has a relatively straight alignment in plan throughout the study area. However, the NPS 24 T.P. pipeline was constructed with nominal 90 m length, east-west aligned "offset" pipeline segments adjoining the northern and southern river banks to achieve the pipeline separation within the river crossing. Both pipelines are understood to have been constructed utilizing open trenching methods.

The soil conditions at the river crossing comprise an extensive, layered sequence of Fraser River silt and sand deposits that overlie interlayered silt, sand and clay deposits of marine origin that extend to in excess of 100 m below ground surface. The upper Fraser River silt and sand sequence is considered to be susceptible to soil liquefaction when subject to strong seismic shaking. Soil liquefaction is expected to cause significant horizontal and vertical ground deformations at the site, particularly at the river banks, and result in bank failures and possible flow slides into the river and damage to the transmission pipelines.

1.2 Study Objectives

The purpose of the seismic performance evaluation was to:

- predict the ground response and transmission pipeline performance in response to strong seismic shaking;
- compare the predicted pipeline performance to Terasen's seismic performance criteria for the transmission pipeline system;

- where the predicted pipeline performance did not meet Terasen's performance objectives, mitigation options were identified and evaluated; and
- recommendations were developed to upgrade the vulnerable portions of the pipelines to satisfy Terasen's seismic design and performance criteria.

1.3 Scope of Work

The potential seismic vulnerability of the South Arm pipeline crossings were identified in Terasen's regional seismic hazard risk assessment carried out in 1994. Subsequent to this initial assessment, more detailed geotechnical investigations, ground response analyses and pipeline performance modeling were carried out by Golder and DGHC to better define the ground response and pipeline performance at and adjoining the river crossing site.

Golder provided input to these analyses by:

- carrying out subsurface investigations to define the soil stratigraphy;
- identifying stratigraphic zones where the subgrade soils are potentially susceptible to earthquake-induced soil liquefaction;
- overlaying pipeline geometry data (derived initially by geophysical exploration, then by applying fitted "geopig" profiles and pipeline survey data) on the interpreted soils stratigraphy;
- carrying out numerical modeling and ground response analyses to provide estimates of soil displacements at the pipeline locations, with and without possible ground improvement measures to reduce the extent of seismically-induced soil liquefaction and the magnitude of resulting ground displacements; and
- providing input on the feasibility and order-of-magnitude costs of possible ground improvement and horizontal directionally drilled (HDD) pipeline replacement options.

DGHC performed finite element analyses to compute the response of the pipelines from the soil displacements estimated by Golder with the following goals:

- compute the deformations induced in the pipelines by the estimated soil displacements in their current configuration, and the impact of the pipeline deformations on the ability of the pipeline to retain pressure integrity or long-term safe operation;
- assess and make recommendations for improvements in pipeline response that might result from physical modifications to the pipelines, including replacement of existing pipe with increased wall thickness, induction bends and/or alternate on-shore alignment; and
- assess the improvements in pipeline response from implementing ground improvement measures to reduce the magnitude of soil displacement.

2.0 GEOTECHNICAL FIELD INVESTIGATION AND SOIL STRATIGRAPHY

2.1 Collection of Available Data

A summary of subsurface data sources from previous/current field investigations is shown on Table 2-1. A site plan that shows borehole and cone penetration test locations is shown on Figure 2-1.

TABLE 2-1: Summary of Subsurface Data

Year	Test Hole	Depth (m)	Driller	Consultant
1995	CPT95-0	21.0	ConeTec Investigations Ltd.	Golder
1995	CPT95-1	28.7	ConeTec Investigations Ltd.	Golder
1995	CPT95-2	13.8	ConeTec Investigations Ltd.	Golder
1995	AH/CPT95-3	4.0/12.3	ConeTec Investigations Ltd.	Golder
1995	AH/CPT95-4	13.3/14.7	ConeTec Investigations Ltd.	Golder
1995	CPT95-5	16.3	ConeTec Investigations Ltd.	Golder
1995	AH/SCPT95-6	16.8/35.2	ConeTec Investigations Ltd.	Golder
1996	AH/CPT96-1	15.2/25.8	ConeTec Investigations Ltd.	Golder
1996	AH/SCPT96-2	15.2/32.7	ConeTec Investigations Ltd.	Golder
1996	AH/CPT96-3	15.2/26.0	ConeTec Investigations Ltd.	Golder
2003	CPT03-1	14.6	ConeTec Investigations Ltd.	Golder
2003	CPT03-2	26.7	ConeTec Investigations Ltd.	Golder
2003	BH03-2	25.0	Mud Bay Drilling Co. Ltd.	Golder
2003	BH/CPT03-3	21.3/35.1	Mud Bay Drilling Co. Ltd./ ConeTec Investigations Ltd.	Golder

2.2 Groundwater Conditions

The groundwater conditions along the on-land portions of the pipeline are expected to vary with tidal variations, seasonal precipitation, and drainage conditions. At the time of our most recent field investigation program, the water table was encountered at depth of about 1 m below the existing ground surface on both the north and south sides of the river.

2.3 Laboratory Testing

Water content determination, Atterberg limits, and sieve analyses were carried out on selected soil samples obtained from the boreholes for soil classification purposes. Selected results of the laboratory index tests are presented in Appendix 1.

2.4 Soil Stratigraphy

A profile illustrating the inferred soil stratigraphy at the site in the north-south direction along the Terasen Gas pipelines-South Arm Fraser River is also shown on Figure 2-1. The major soil units identified on the north side of the river (north of the crest of bank), under the river channel, and on the south side of the river (south from the dyke) are summarized in Tables 2-2, 2-3, and 2-4, respectively.

TABLE 2-2: Soil Stratigraphy Summary-North Side of River

Soil Unit	Layer Thickness (m)	Soil Description	Inferred Geologic Origin
A	4.0 to 6.0	Compact Sand, trace to some silt	Fill
C	1.0 to 3.0	Loose to Compact Sand	Fraser River Channel
E	2.5 to 5.0	Peat to Organic Silt	Bog
F	1.5 to 4.0	Soft to Firm Silt	Fraser River Estuary
G	14.0 to 18.0	Compact to Dense Sand	Fraser River Channel
H	~ 120.0	Firm to Stiff Silt	Fraser River Estuary & Marine
I	Unknown	Very dense, Silty Sand to Silty Sand & Gravel	Glaciofluvial Outwash/Glacial Till

TABLE 2-3: Soil Stratigraphy Summary –River Channel

Soil Unit	Layer Thickness (m)	Soil Description	Inferred Geologic Origin
	1.5	Rip-Rap/Filter	
C	2.0 to 10.0	Loose to Compact Sand	Fraser River Channel
D	0.0 to 2.0	Compact Sand	Fraser River Channel
G	7.0 to 14.0	Compact to Dense Sand	Fraser River Channel
H	~ 120.0	Firm to Stiff Silt	Fraser River Estuary & Marine
I	Unknown	Very dense, Sand to Gravel, Silty Sand to Silty Gravel	Glaciofluvial Outwash/Glacial Till

TABLE 2-4: Soil Stratigraphy Summary-South Side of River

Soil Unit	Layer Thickness (m)	Soil Description	Inferred Geologic Origin
A	2.0 to 4.0	Dense Sand	Fill
B	1.5 to 9.0	Very Loose Silty Sand	Fraser River Channel
C	8.0 to 15.0	Loose to Compact Sand	Fraser River Channel
D	0.0 – 6.0	Compact Sand	Fraser River Channel
G	7.0 to 15.0	Compact to Dense Sand	Fraser River Channel
H	~ 120.0	Firm to Stiff Silt	Fraser River Estuary & Marine
I	Unknown	Very dense, Sand to Gravel, Silty Sand to Silty Gravel	Glaciofluvial Outwash/Glacial Till

The depth to Pleistocene (firm-ground) deposits at the site is estimated to be about 150 m based on available information from the Geological Survey of Canada (Hunter et al. 1999).

2.5 Soil Parameters

2.5.1 Strength Parameters

The interpreted soil parameters that characterize the pre-liquefaction behaviour of the different soil units described in Tables 2-2 through 2-4 are listed in Table 2-5.

TABLE 2-5: Soil Parameters (Pre-Liquefaction)

Soil Unit	Unit Description	SPT $(N_1)_{60}$ (blows/0.3 m)	Unit Wt. (kN/m^3)	ϕ' (deg)	S_u (kPa)
	Rip Rap		21	40	
A	Fill (North Bank)	15 (Assumed)	19	32	-
	Fill (South Bank)	24 (from SPT and CPT)	19	36	-
B	Silty Sand	6 (from SPT and CPT)	19	29	-
C	Loose to Compact Sand	9 – 11 (from SPT and CPT)	19	31	-
D	Compact Sand	12 (from SPT and CPT)	19	33	-
E	Peat /Organic Silt	-	17.5	-	0.3 σ'_{vo}
F	Soft to Firm Silt	-	18	-	0.3 σ'_{vo}
G	Compact to Dense Sand	18 (from SPT and CPT)	19	35	-
H	Firm to Stiff Silt	-	18	-	-
I	Glacial Till	-	21	-	-

Notes: ϕ' = internal friction angle
S_u = undrained shear strength
σ'_{vo} = in-situ vertical effective stress

2.5.2 Maximum Shear Modulus

The small-strain shear modulus (G_{max}) is related to the shear wave velocity (Vs) through the following expression:

$G_{max} = \rho\ (Vs)^2$,
where ρ is the material density.

Hence, values of G_{max} within the upper 50 m were estimated using site-specific Vs measurements obtained from seismic cone penetration tests, i.e. SCPT95-6, SCPT96-1, and SCPT96-2. Below 50 m depth, the values of G_{max} were derived from Vs measurements taken at the LNG plant extension project in Tilbury Island.

Subsequently, the following relations were established by correlating G_{max} to the inferred values of undrained strength (Su), equivalent SPT $(N_1)_{60}$, and effective overburden stress (σ'_{vo}) in each of the soil units, as applicable:

- $G_{max} = 1000 * Su$ (Units E and F)
- $G_{max} = 21.7 * Pa * 15 * [(N_1)_{60}]^{1/3} * [\sigma'_m / Pa]^{1/2}$ (Units A, B, C, D, and G)
- $G_{max} = 109 * [\sigma'_{vo}]^{1.2}$ (Unit H)

For analysis purposes, profiles of $Vs = (G_{max} / \rho)^{0.5}$ with depth were computed using the above relations. The profiles of computed and measured shear wave velocities at the south and north banks are shown on Figures 2-2 and 2-3, respectively, where good agreement can be noted.

The shear wave velocity at the top of the Pleistocene deposits (Unit I) was assumed to be 700 m/s based on Sy et al. (1991).

2.5.3 Post-liquefaction Strength

The interpreted post-liquefaction strength (S_{ur}) values of the potentially liquefiable soil strata are listed in Table 2-6.

TABLE 2-6: Soil Shear Strength (Post-Liquefaction)

Soil Unit	Unit Description	$(N_1)_{60}$ (blows/0.3 m)	Unit Wt. (kN/m^3)	S_{ur}
A	Fill (North Bank)	15 (Assumed)	19	$0.1 - 0.4\ \sigma'_{vo}$
	Fill (South Bank)	24 (from SPT & CPT)	19	$0.1 - 0.4\ \sigma'_{vo}$
B	Silty Sand	6 (from SPT & CPT)	19	$0.08\ \sigma'_{vo}$
C	Loose to Compact Sand	11 (from CPT)	19	$0.1 - 0.4\ \sigma'_{vo}$
D	Compact Sand	12	19	$0.1 - 0.4\ \sigma'_{vo}$
E	Peat to Organic Silt	-	17.5	Not Liquefiable.
F	Soft to Firm Silt	-	18	Not Liquefiable.
G	Compact to Dense Sand	18 (from SPT & CPT)	19	$0.1 - 0.4\ \sigma'_{vo}$
H	Firm to Stiff Silt	-	18	Not Liquefiable.
I	Glaciofluvial and Glacial Till	-	21	Not Liquefiable.

Notes: S_{ur} = residual undrained shear strength.

The residual undrained shear strength ratio (S_{ur}/σ'_{vo}) of the granular soils following liquefaction was estimated using the median relationship between (S_{ur}/σ'_{vo}) and $(N1)_{60}$ proposed by Olson and Stark (2002).

3.0 SITE-SPECIFIC GROUND MOTIONS

Terasen Gas established a seismic risk level of 1 in 2,000 year to assess the seismic vulnerability of their pipelines. The peak firm-ground horizontal acceleration of 0.37g is predicted for the site based on BC Hydro model (Golder, 1997).

Applicable acceleration time-histories for 2D ground response analyses were established by modifying the acceleration time histories, which have been matched to the Uniform Hazard Response Spectrum (UHRS) for the return period of 2,475 year. Due to time and budget constrains, the time-histories spectrally matched for 1 in 2,475 year return period were scaled down for the applicable time-histories of 1 in 2,000 year return period. The acceleration time-histories used in the 2D ground response analyses are summarized in Table 3-1.

TABLE 3-1: Details of Input Earthquake Time Histories

Event	Station
Landers (EW)	Joshua Tree
Landers (NS)	Joshua Tree
Loma Prieta (EW)	Capitola
Loma Prieta (NS)	Capitola
Chi Chi (EW)	Taichung
Chi Chi (NS)	Taichung

4.0 GROUND RESPONSE ANALYSES

Ground response analyses involving 2-D time-history analyses were carried out to assess the liquefaction potential of overburden soils and the resulting permanent ground deformations along the submarine pipeline crossing. Analyses were carried out for "as-is" ground conditions. Analyses were also carried for "improved" ground conditions with ground improvement at selected critical areas to assess their relative impact on permanent deformations.

4.1 FLAC^{2D} Numerical Models

Two-dimensional ground response analyses were carried out on a soil profile established along the Terasen Gas-South Arm Fraser River crossing and extending about 300 m from each of the river banks using the computer code FLAC (Version 4.0, 2000).

The synthesized approach proposed by Beaty & Byrne (1999) for modeling soil liquefaction and predicting ground displacements was followed in the 2D ground response analyses.

4.2 Selection of Input Ground Motions for 2D Analysis

Due to budget and time constrains, the 2D ground response analyses were carried out for the earthquake ground motions that produce the "upper-bound" of expected response. Figures 4-1 and 4-2 show a typical cyclic stress ratio (CSR) and the maximum ground acceleration profiles with depth, respectively.

As can be seen on the figures, the CSR and the maximum ground acceleration induced by the modified EW component of the 1991 Landers EQ ground motions (LN-EW) is approximately the "upper-bound' of expected response. Hence, the LN-EW ground motions were selected for the 2D ground response analyses.

5.0 RESULTS

5.1 As-Is Ground Conditions

The permanent horizontal and vertical displacements computed with FLAC for the inferred current ground conditions along the pipeline locations are shown on Figures 5-1 through 5-4.

5.2 Densified Ground Conditions

In order to assess the effect of ground improvement on the predicted displacements at the river banks, a practical ground improvement scheme consisting of six seismic dykes on the south bank and one seismic dyke on the north bank of the river was analyzed for the 2000-year ground motions. Figure 5-5 shows the finite difference grid with the proposed seismic dykes.

The permanent horizontal displacements computed with FLAC along the pipeline locations are shown on Figures 5-6 and 5-7.

5.3 Pipeline Structural Assessment

The soil-structure interaction analyses for the pipelines utilizing the predicted ground displacement from the ground response analyses were carried by D.G. Honegger Consulting (DGHC). A brief summary of the soil-structure interaction analyses and the results of the analyses are described in DGHC letter dated September 29, 2005, which included for reference in Appendix 2.

5.4 Recommendations

The analyses outlined above identified potential vulnerabilities to both the NPS 20 and NPS 24 transmission pipelines as they are currently configured, with the NPS 20 T.P. being most at risk of damage. Remedial treatment is required at both pipelines to improve pipeline performance and provide reasonable confidence that the pipelines will maintain pressure integrity for earthquake ground motions having an annual probability of exceedance of less than 0.05 percent (1/2,000). This performance requirement accepts a risk that local damage may occur (such as pipe wall wrinkling), and that some pipeline repair or replacement may be required following the earthquake.

Mitigative treatment alternatives to improve pipeline performance were explored in detail. This included consideration of the following options:

- replacement of the vulnerable on-shore segments of the pipelines using conventional trenching and pipeline replacement techniques. This included assessing the benefits of replacement of the vulnerable east-west aligned pipeline offset adjoining the southern river bank, as well as consideration of replacing more extensive segments of the on-shore portion of the NPS 24 T.P. pipeline to straighten and strengthen the pipe;

- implementation of ground improvement measures to reduce the extent and consequences of seismically-induced soil liquefaction, and thus the magnitude and consequences of predicted soil and pipeline movements. This included evaluation of the potential for construction of multiple rows of ground densification barriers ("seismic dykes") using vibro-replacement techniques within both the on-shore and off-shore areas;

- replacement of the existing pipeline river crossings by new pipelines installed using horizontal directional drilling (HDD) techniques; and

- combinations of the above alternatives.

The combination of measures developed to improve the seismic performance of the pipelines to satisfy Terasen's seismic performance and risk management criteria include the following:

- implementation of limited replacement of the NPS 24 T.P. pipeline at the east-west aligned offset at the southern bank of the river, including replacement of the existing 7.1 mm wall thickness, grade X52 pipe with 13.7 mm X60 pipe at the on-shore segment located north of the river dyke, and replacement of the existing 3D elbows with 12D induction bends; and

- replacement of the NPS 20 T.P. pipeline using HDD techniques at the river crossing and extending approximately 200 m inland from the crest of the river banks at both sides of the river.

Implementation of these measures is considered to provide a reasonable level of assurance that both the NPS 24 and replacement NPS 20 T.P. pipelines will maintain pressure integrity following a severe earthquake. Further, the HDD replacement option of the NPS 20 T.P. pipeline provides a robust mitigation measure that can be designed to provide a relatively high level of confidence of continued safe operation (not just maintaining pressure integrity) following a severe earthquake, which could be a significant added advantage.

6.0 CLOSURE

We trust that the contents of this letter report meets your immediate requirements. If you have any questions or need further information, please do not hesitate to contact the undersigned.

Yours very truly,
GOLDER ASSOCIATES LTD.

Viji Fernando, M.E.Sc., P.Eng.
Geotechnical Engineer

Mark T. Bradshaw, P.Eng.
Geotechnical Engineer, Principal

VF/MTB/nnv
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Attachments
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REFERENCES

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Sy, A., Henderson, P.W., Lo, R.C., Siu, D.Y., Finn, W.D.L., and Heidebrecht, A.C. (1991). "Ground motion response for Fraser Delta, British Columbia," Fourth International Conference on Seismic Zonation, August 26-29, Stanford, California

Attachments

1. Site Specific Seismic Vulnerability Assessment of BC Gas Transmission Pipelines at the North Bank of the South Arm of the Fraser River, Richmond, BC – Report by Golder, February 1997
2. Site Specific Seismic Vulnerability Assessment of BC Gas Transmission Pipelines at the South Bank of the South Arm of the Fraser River, Delta, BC – Report by Golder, March 1997
3. CPT Data (Hard Copy & Electronic Data)
4. Figure 2-1 - Site Plan and Interpreted Stratigraphic Profile (Hard Copy & CAD Drawing)
5. Bathymetry and Pipe Profile for 508 mm Pipe – BC Gas Dwg No: 42012-P-000 -105-1-0 (Hard Copy, CAD Drawing, Digital data - 2002 Geopig data NPS 20*.xls)
6. Bathymetry and Pipe Profile for 610 mm Pipe – BC Gas Dwg No: 42013-P-000-105-1-0 (Hard Copy, CAD Drawing, Digital data – 2004 Geopig data NPS 24*.xls)
7. Plan and Riverbed Contours "As Constructed" – BC Gas File BCGS-003A (Hard Copy & CAD Drawing)
8. Plan of Profiles at Pipelines "As Constructed" – BC Gas File BCGS-003A (Hard Copy & CAD Drawing)
9. Figure 5-5 - Stratigraphic Profile and Finite Difference Grids With Location of Seismic Dykes (Hard Copy & CAD Drawing)
10. Deformation Profile, As-Is Ground Conditions (Hard Copy and Digital Data – Deformation-As-is.xls)
11. Deformation Profile, Densified Ground Conditions (Hard Copy and Digital Data – Deformation-densified.xls)

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practicing under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder can not be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, Golder may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder can not be responsible for use of portions of the report without reference to the entire report.

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT (cont'd)

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. **The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report.** The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT (cont'd)

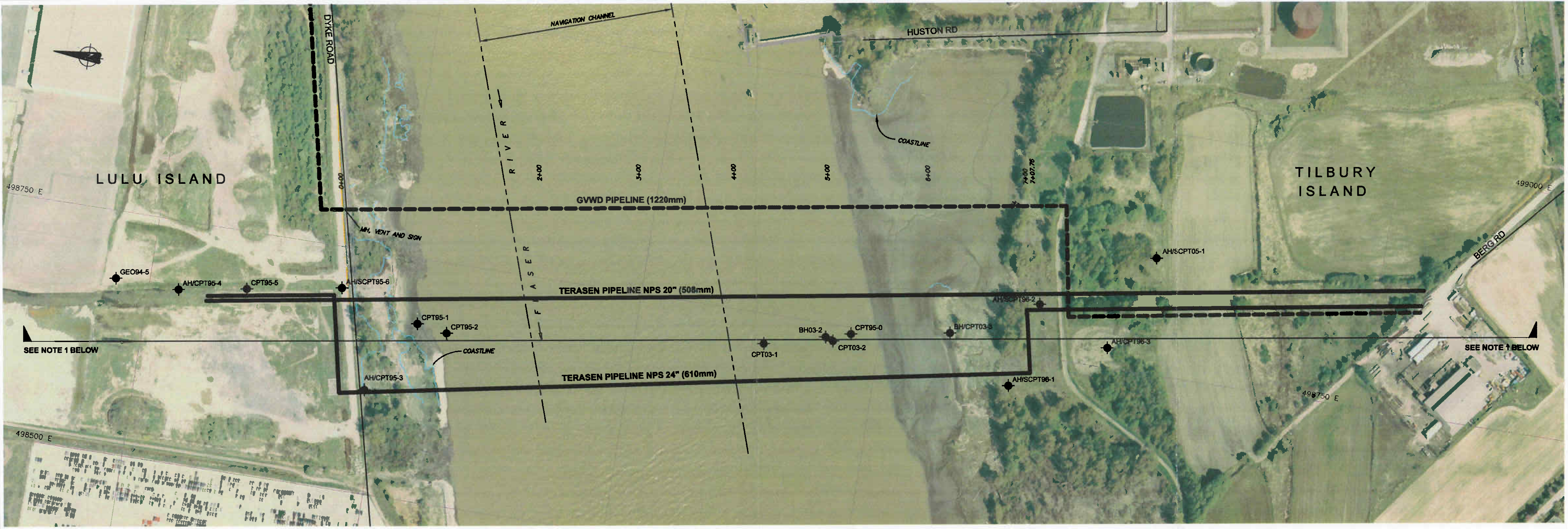
Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

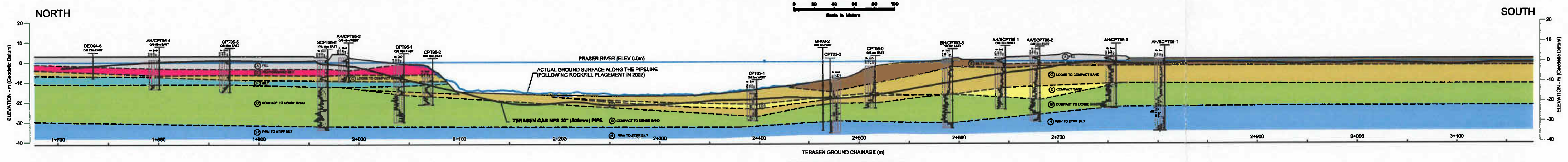
Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

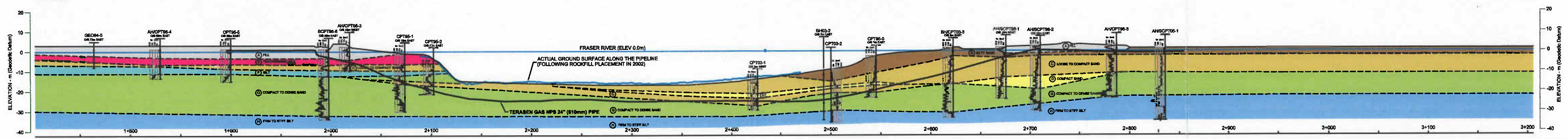


PLAN

0 20 40 60 80 100
Scale in Meters



PROFILE: NPS 20 (508mm) PIPE



PROFILE: NPS 24 (610mm) PIPE

0 20 40 60 80 100
Horizontal Scale in Meters

0 10 20 30 40 50
Vertical Scale in Meters

LEGEND

▨	A - FILL
▨	B - SILTY SAND
🟥	E - PEAT/ORGANIC SILT
▨	F - SILT
▨	C - LOOSE TO COMPACT SAND
🟨	D - COMPACT SAND
🟩	G - COMPACT TO DENSE SAND
🟦	H - FIRM TO STIFF SILT
◆	APPROXIMATE LOCATION OF TEST HOLES

NOTES

1. Interpreted stratigraphic profiles were developed at section line shown in above plan. The actual ground surface profiles above the pipelines within the river (following rip rap placement in 2002) are shown in the profiles.
2. The pipeline profiles shown were derived from GEOPIG pipeline measurements. These profiles are superimposed on the interpreted stratigraphic profiles and are therefore approximate.
3. Data concerning the various strata have been obtained at test hole locations only. The soil stratigraphy between test holes has been inferred from geological evidence and so may vary from that shown.

REFERENCES

1. Hay & Company Consultants Inc. / Fraser River Pile & Dredge Ltd.
   File: BCGS-003A (Rev B)
   Dated: Mar. 2002
2. BC Gas
   Dwg No.: 42012-P-000-105-1-0 (Rev 3)
   Dated: 17 Apr. 2003
3. BC Gas
   Dwg No.: 42013-P-000-105-1-0 (Rev 0)
   Dated: May 1998

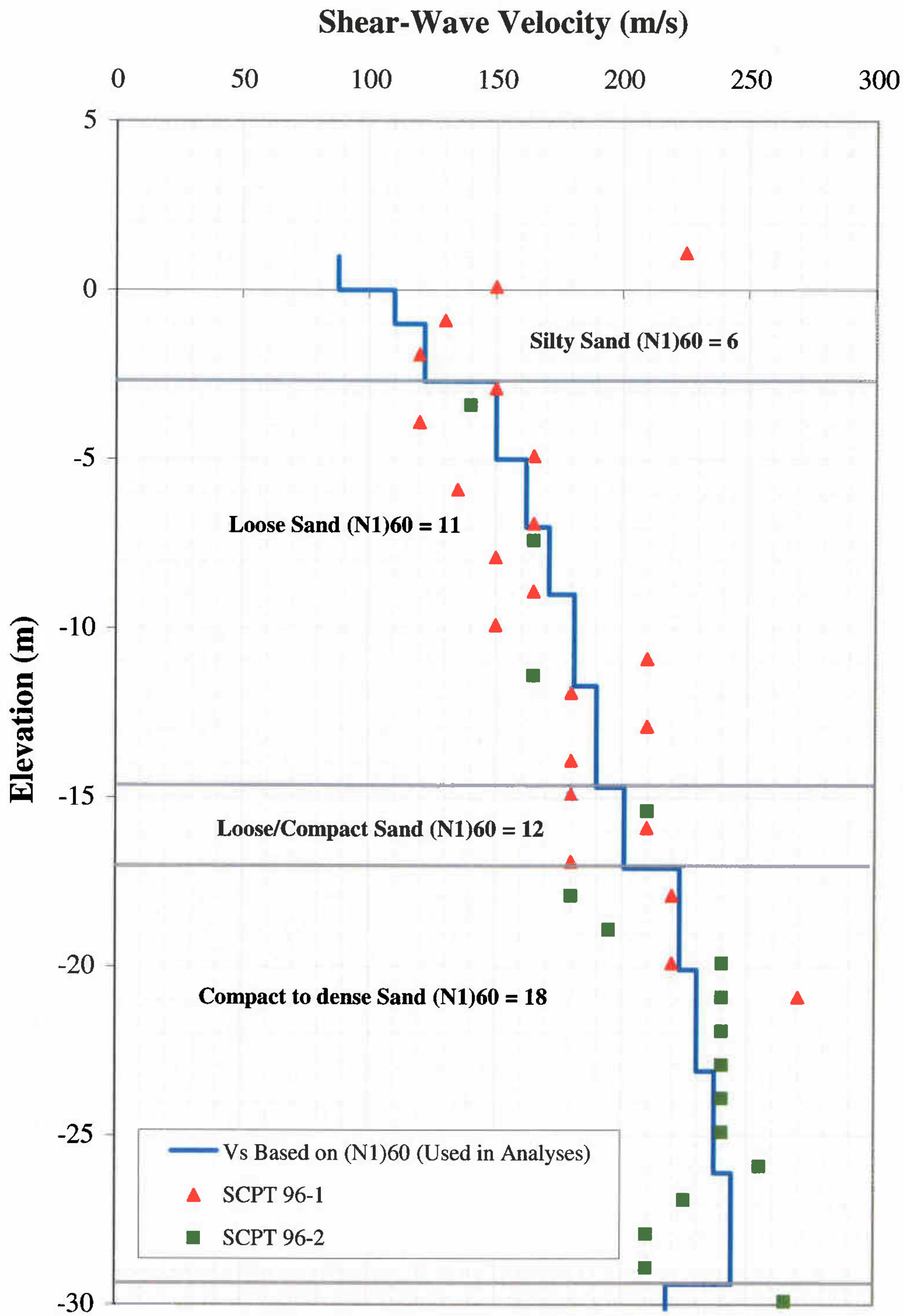
PROJECT
TERASEN GAS INC.
NPS 20 & 24 T.P. PIPELINE
SOUTH ARM-FRASER RIVER, DELTA/RICHMOND, B.C.

TITLE
SITE PLAN AND INTERPRETED STRATIGRAPHIC PROFILE

Golder Associates

PROJECT No.	03-1411-050		FILE No.	P1411-505-5
DESIGN	MK	15FEB06	SCALE AS SHOWN	REV. –
CADD	SRR	15FEB06		
CHECK	MK	15FEB06	**FIGURE 2-1**	
REVIEW	MTB	21FEB06		

REVISION DATE: 07/08/09 02:53PM By: [illegible] CADD FILE: G:\Active\2003-1\2003\1411\1301\03-1411-050 BC Gas South Bank-South Arm\August 2007 Summary for Terasen & BBC\Figure 2-1\P1411-050-5.dwg

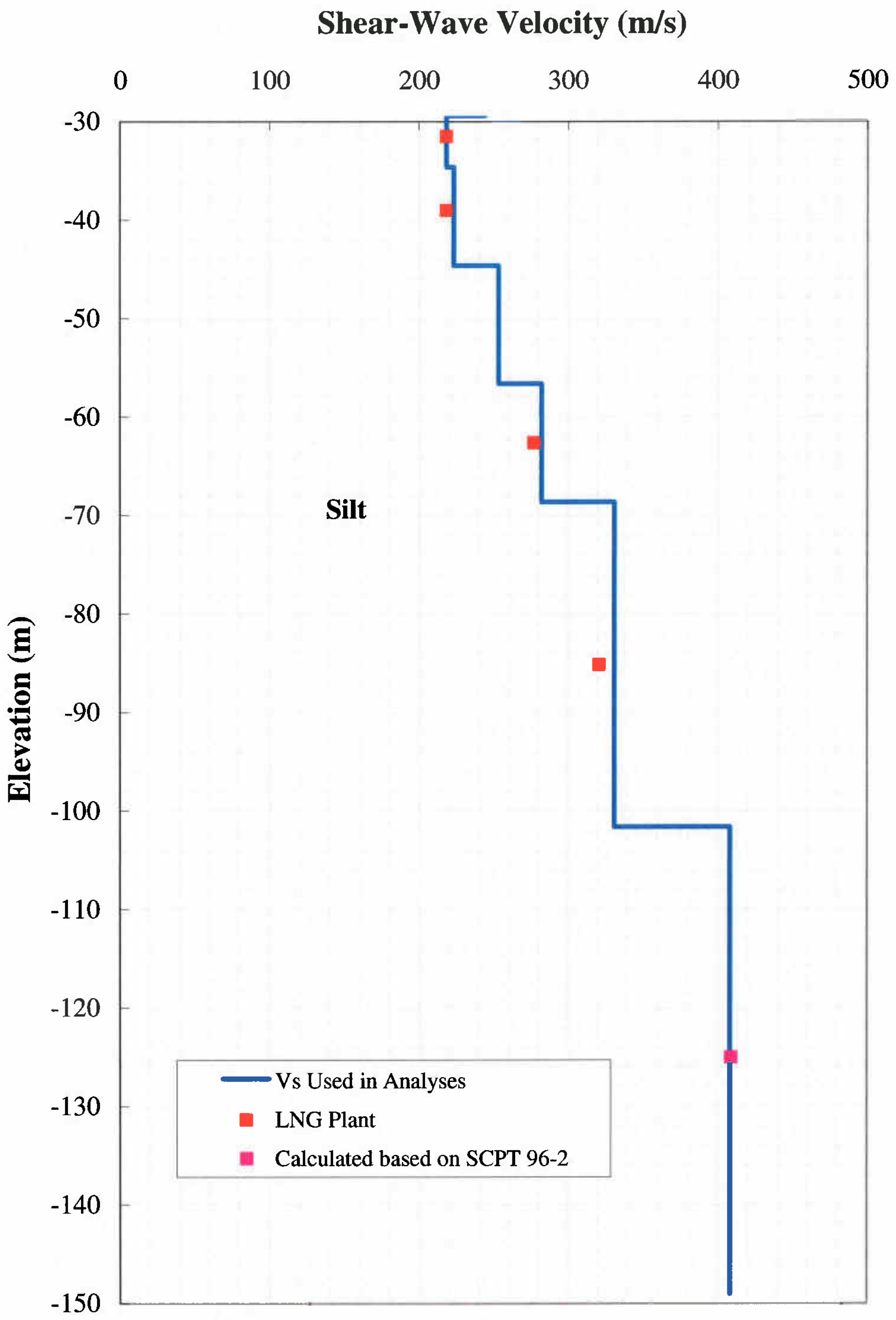


PROJECT
TERASEN GAS INC.
NPS 20 & 24 T.P. PIPELINE
SOUTH ARM FRASER RIVER, DELTA/RICHMOND, B.C

TITLE
MEASURED AND COMPUTED
SHEAR WAVE VELOCITY PROFILES AT SOUTH BANK

Golder Associates

PROJECT No.	03-1411-050		PHASE / TASK No.	
DESIGN	VF	29JUL07	SCALE NTS	REV.
CADD	--		FIG 2-2A	
CHECK	MB	29JUL07		
REVIEW				



PROJECT

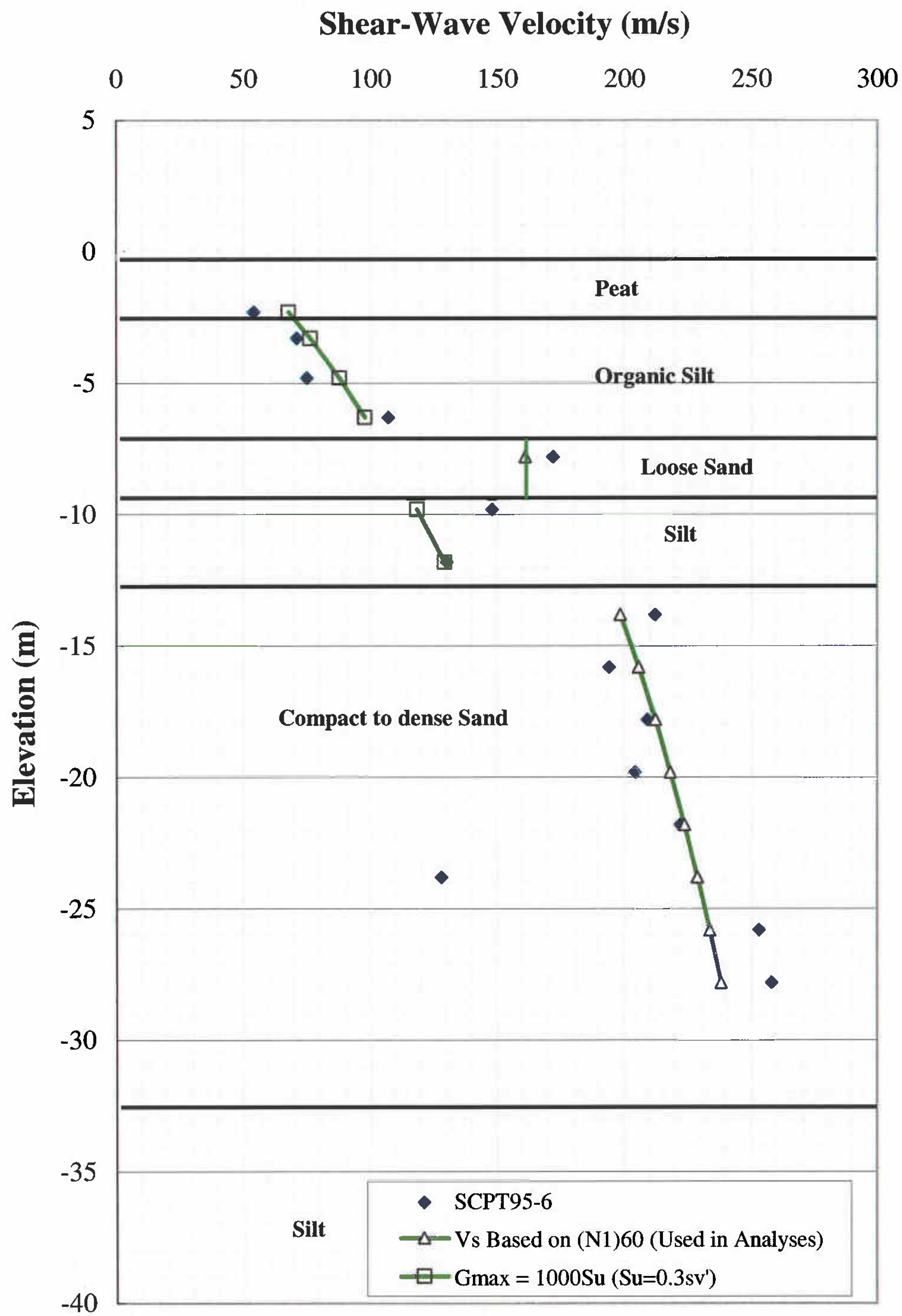
TERASEN GAS INC.
NPS 20 & 24 T.P. PIPELINE
SOUTH ARM FRASER RIVER, DELTA/RICHMOND, B.C

TITLE

MEASURED AND COMPUTED
SHEAR WAVE VELOCITY PROFILES AT SOUTH BANK

Golder Associates

PROJECT No.	03-1411-050		PHASE / TASK No.
DESIGN	VF	29JUL07	SCALE NTS REV.
CADD	--		
CHECK	MB	29JUL07	**FIG 2-2B**
REVIEW			



PROJECT

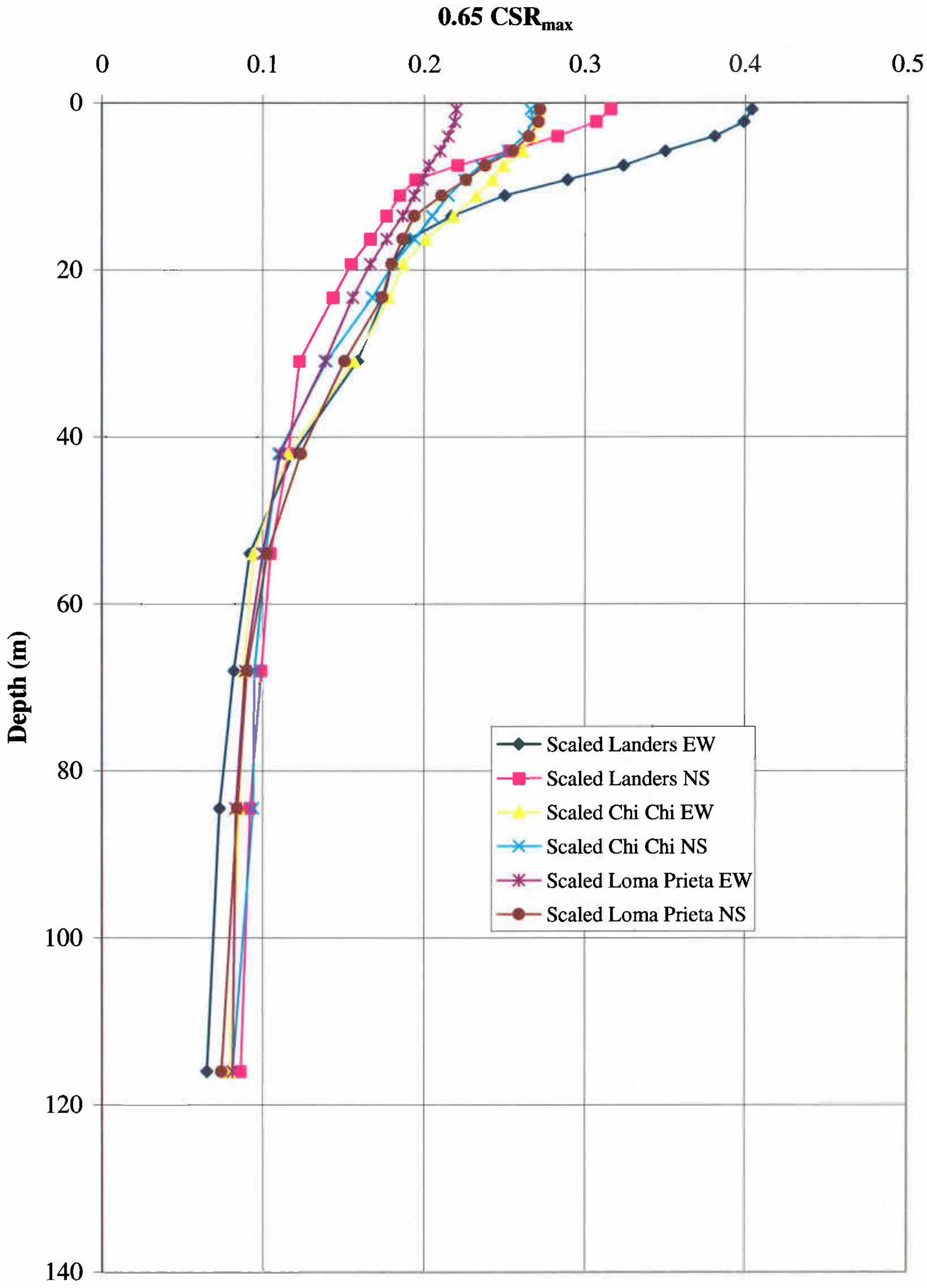
TERASEN GAS INC.
NPS 20 & 24 T.P. PIPELINE
SOUTH ARM FRASER RIVER, DELTA/RICHMOND, B.C

TITLE

MEASURED AND COMPUTED SHEAR WAVE VELOCITY PROFILES AT NORTH BANK

Golder Associates

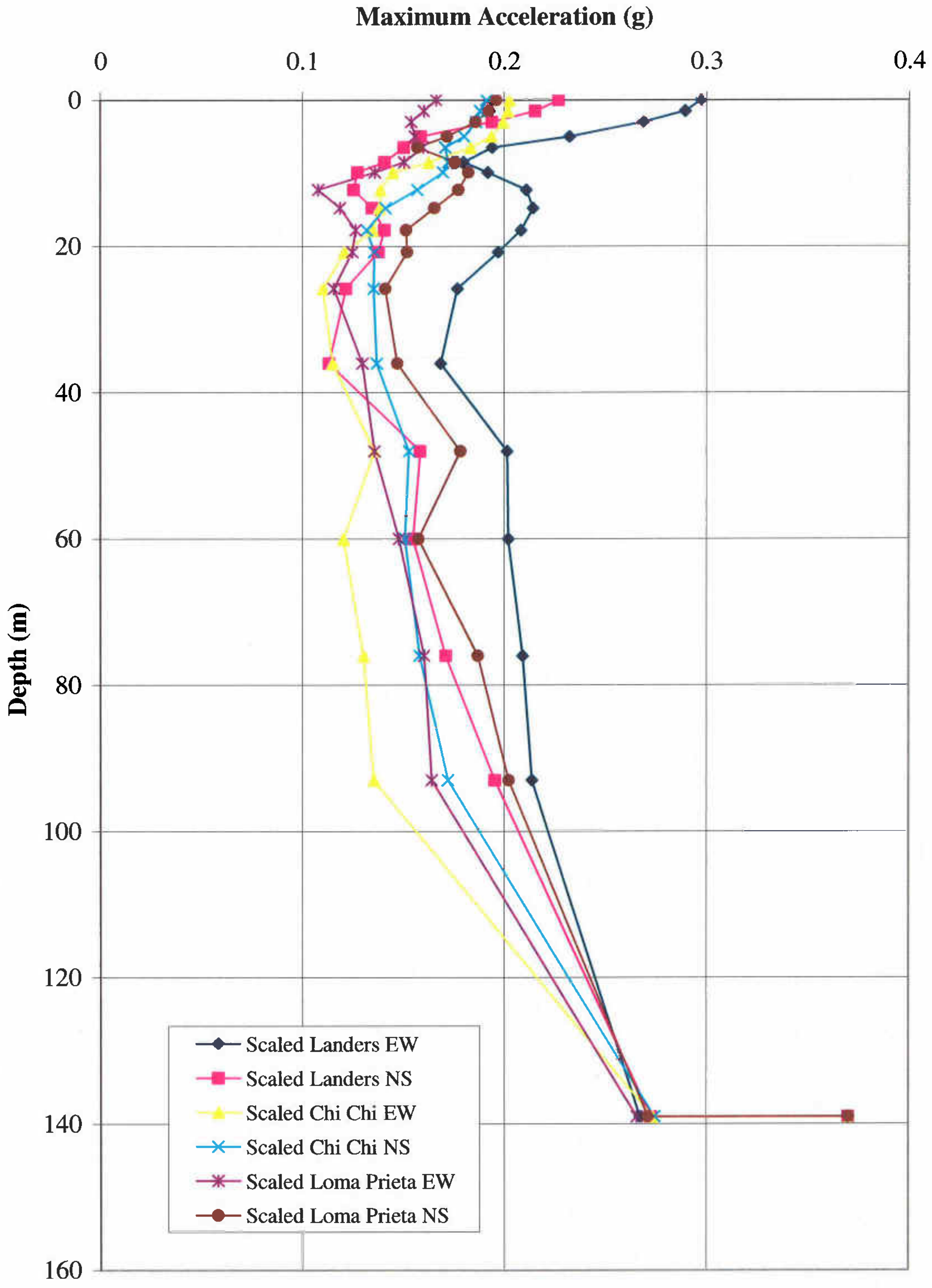
PROJECT No.	03-1411-050		PHASE / TASK No.
DESIGN	VF	29NOV05	SCALE NTS REV.
CADD	--		
CHECK	MB	29NOV05	FIG 2-3
REVIEW			



PROJECT	TERASEN GAS INC. NPS 20 & 24 T.P. PIPELINE SOUTH ARM FRASER RIVER, DELTA/RICHMOND, B.C
TITLE	TYPICAL CSR PROFILE AT SOUTH BANK

Golder Associates

PROJECT No.	03-1411-050		PHASE / TASK No.	
DESIGN	VF	29JUL07	SCALE NTS	REV.
CADD	--			
CHECK	MB	29JUL07	FIG 4-1	
REVIEW				



PROJECT

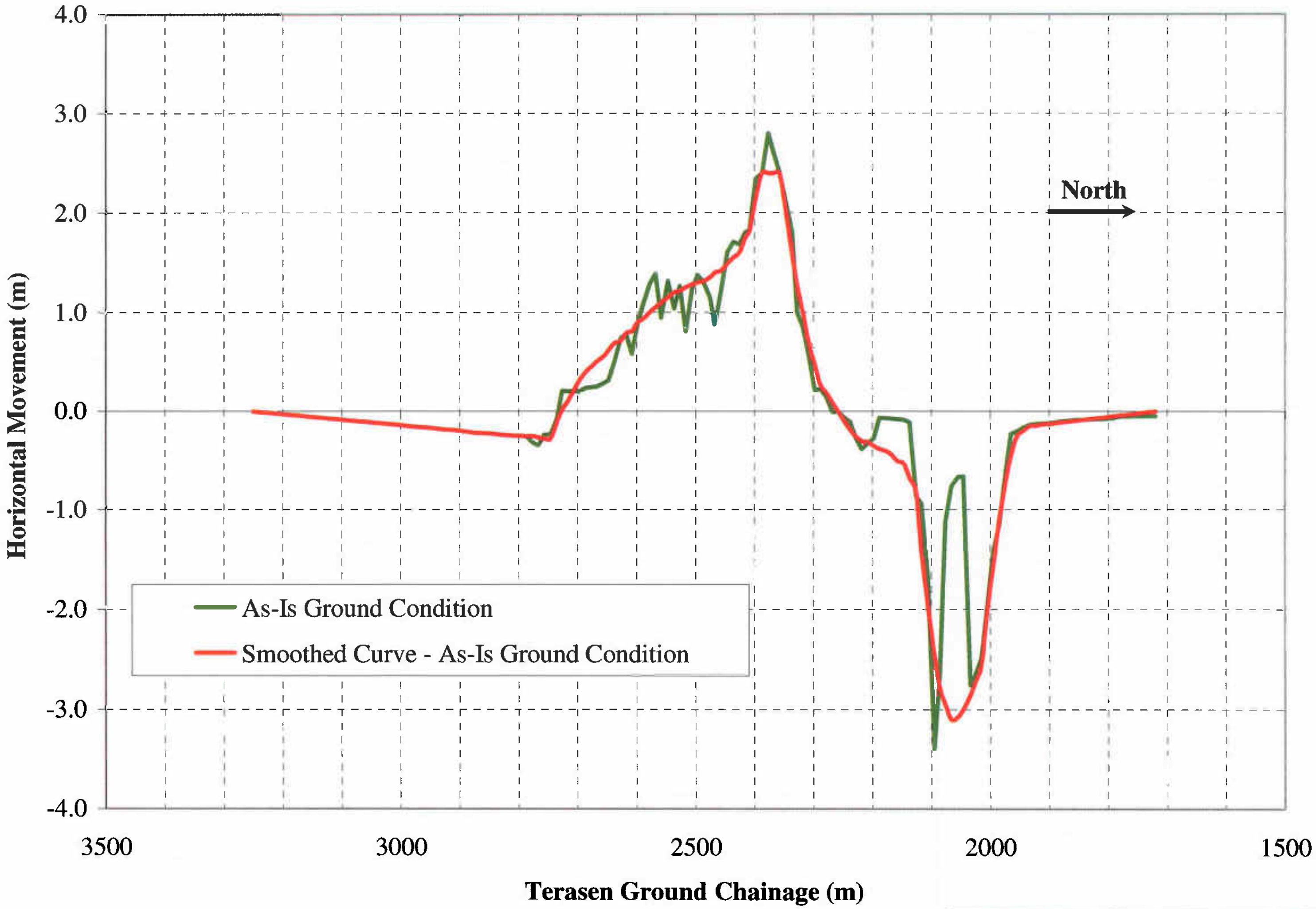
TERASEN GAS INC.
NPS 20 & 24 T.P. PIPELINE
SOUTH ARM FRASER RIVER, DELTA/RICHMOND, B.C

TITLE

TYPICAL ACCELERATION PROFILE AT SOUTH BANK

Golder Associates

PROJECT No.	03-1411-050		PHASE / TASK No.
DESIGN	VF	29JUL07	SCALE NTS REV.
CADD	--		
CHECK	MB	29JUL07	**FIG 4-2**
REVIEW			



PROJECT

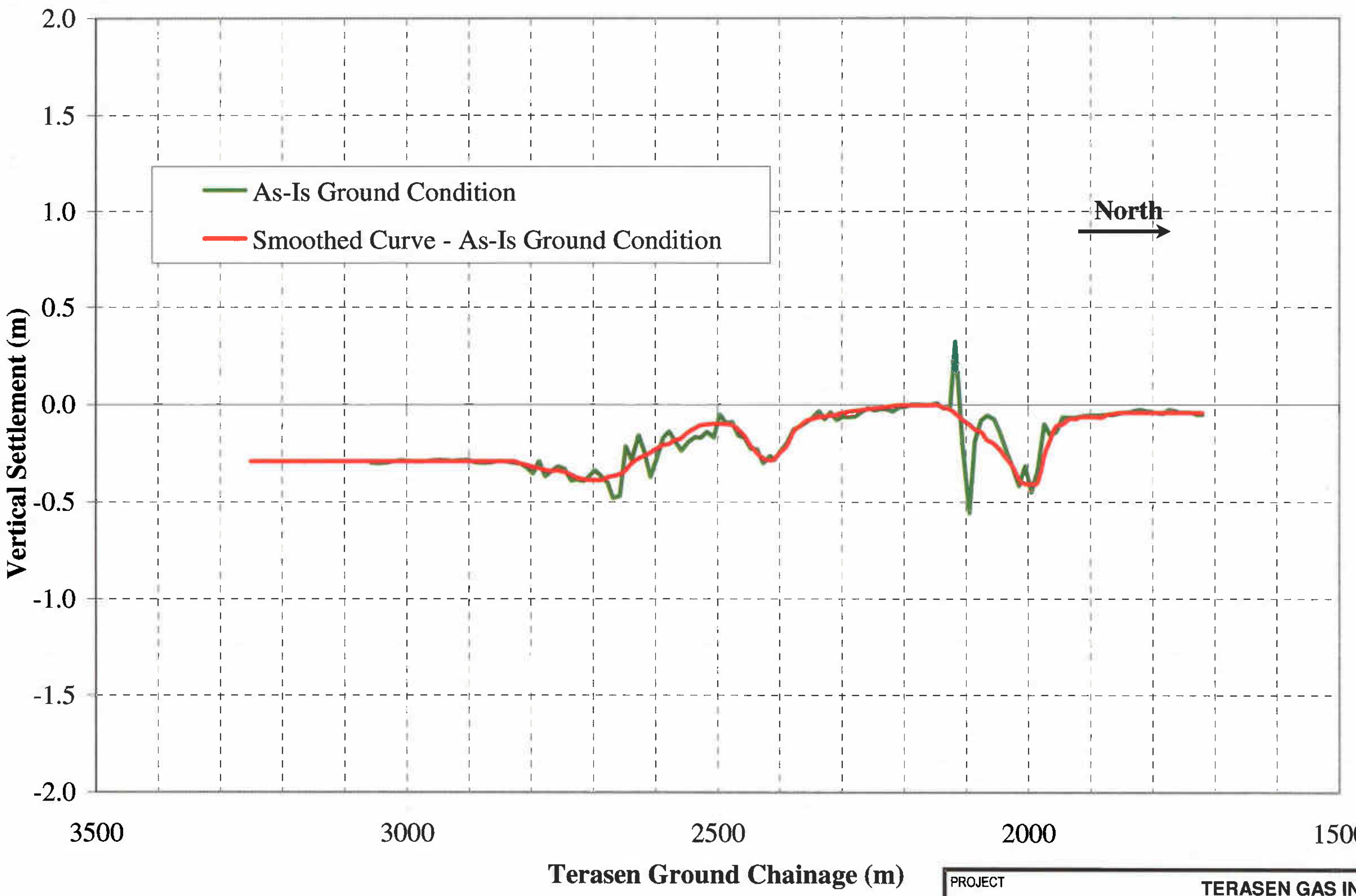
TERASEN GAS INC.
NPS 20 & 24 T.P. PIPELINE
SOUTH ARM FRASER RIVER, DELTA/RICHMOND, B.C

TITLE

HORIZONTAL DISPLACEMENT ALONG NPS 20 PIPELINE
AS-IS GROUND CONDITION

Golder Associates

PROJECT No.	03-1411-050		PHASE / TASK No.	
DESIGN	VF	07AUG07	SCALE NTS	REV.
CADD	--		**FIG 5-1**	
CHECK	MB	07AUG07		
REVIEW				



PROJECT

TERASEN GAS INC.
NPS 20 & 24 T.P. PIPELINE
SOUTH ARM FRASER RIVER, DELTA/RICHMOND, B.C

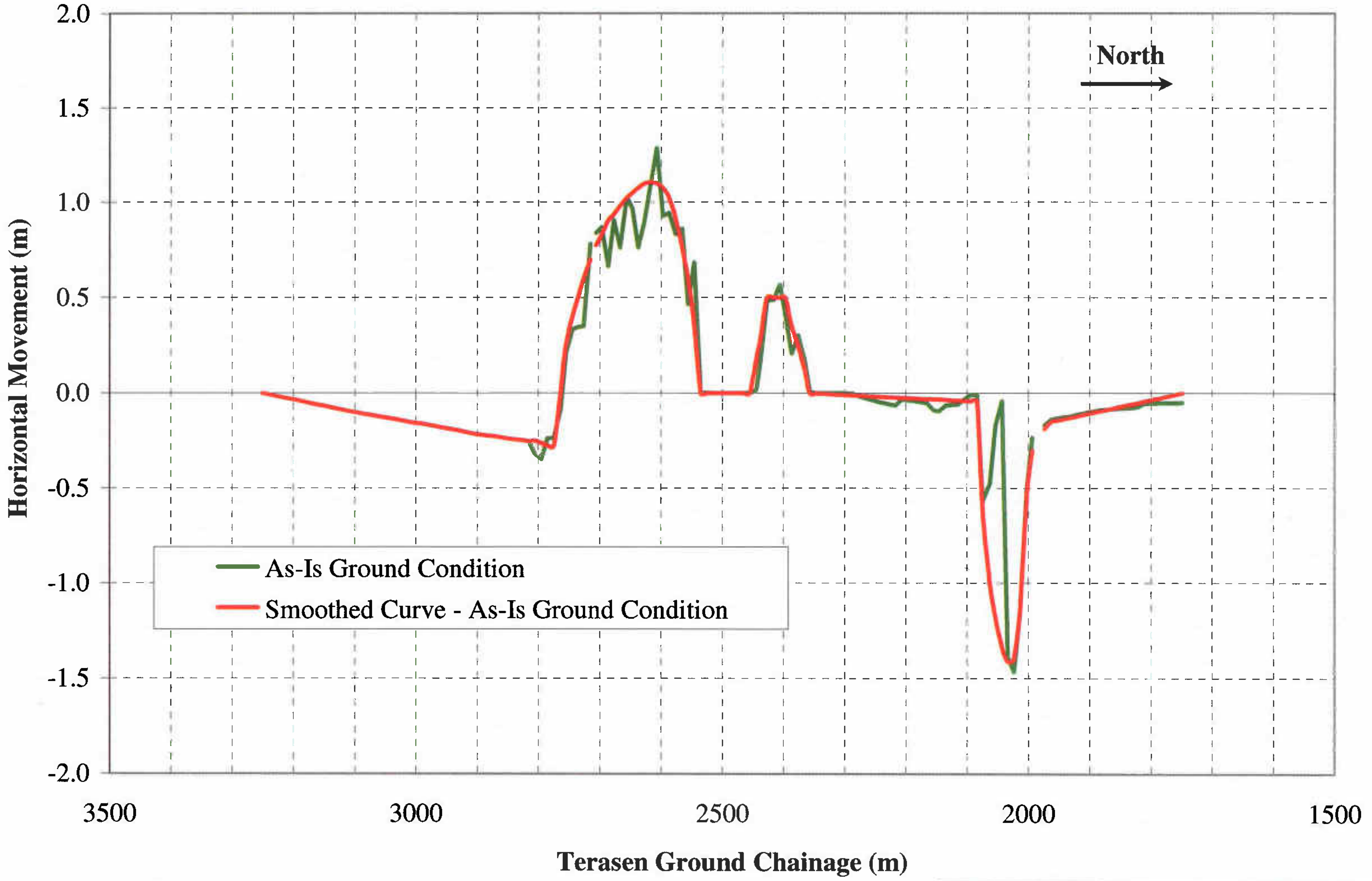
TITLE

VERTICAL SETTLEMENT ALONG NPS 20 PIPELINE AS-IS GROUND CONDITION

Golder Associates

PROJECT No.	03-1411-050		PHASE / TASK No.	
DESIGN	VF	07AUG07	SCALE NTS	REV.
CADD	--			
CHECK	MB	07AUG07		
REVIEW				

FIG 5-2



PROJECT

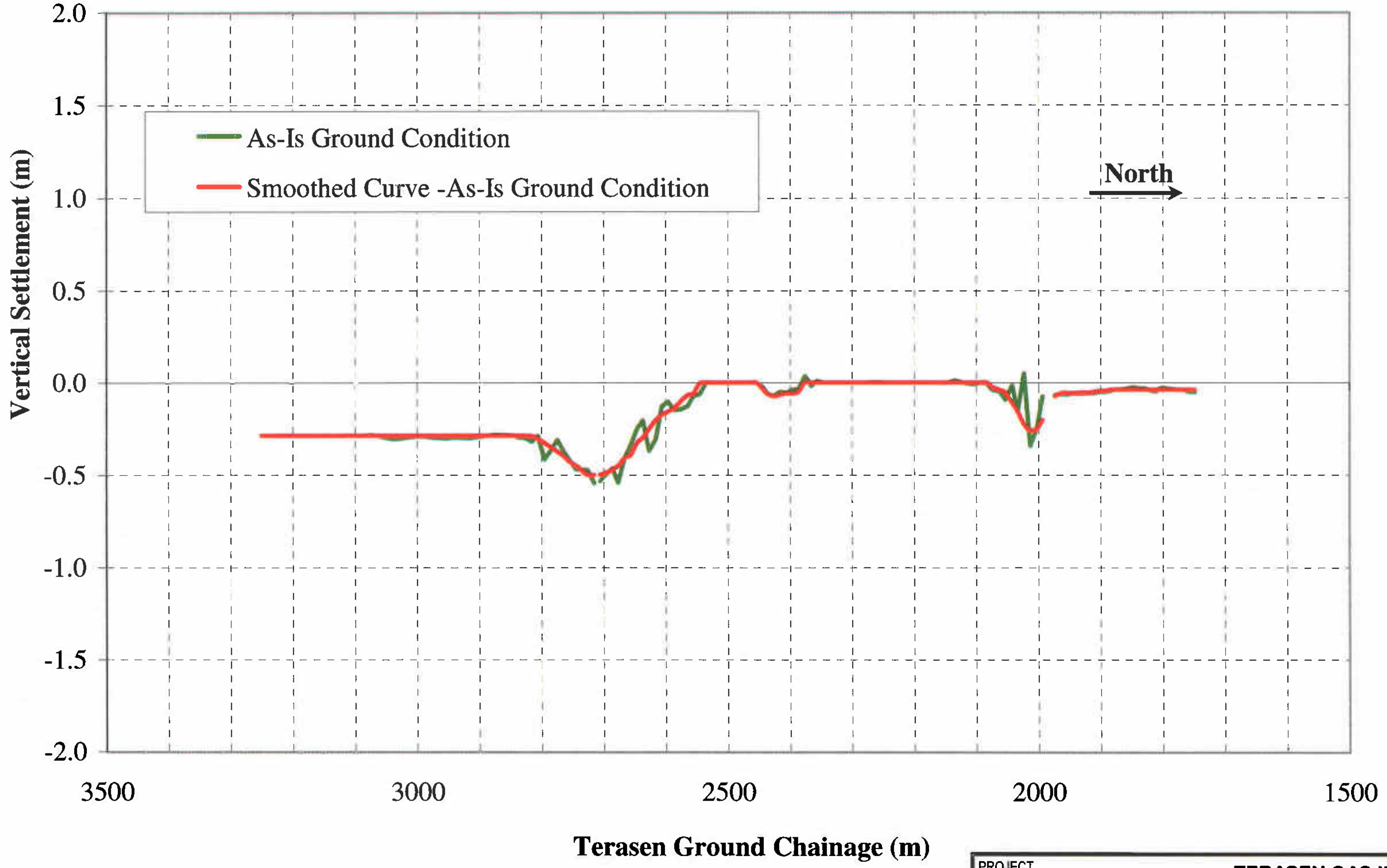
TERASEN GAS INC.
NPS 20 & 24 T.P. PIPELINE
SOUTH ARM FRASER RIVER, DELTA/RICHMOND, B.C

TITLE

HORIZONTAL DISPLACEMENT ALONG NPS 24 PIPELINE
AS-IS GROUND CONDITION

Golder Associates

PROJECT No.	03-1411-050		PHASE / TASK No.	
DESIGN	VF	07AUG07	SCALE NTS	REV.
CADD	--			
CHECK	MB	07AUG07	**FIG 5-3**	
REVIEW				



PROJECT

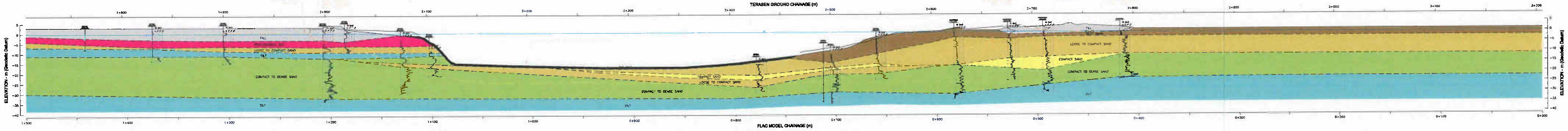
TERASEN GAS INC.
NPS 20 & 24 T.P. PIPELINE
SOUTH ARM FRASER RIVER, DELTA/RICHMOND, B.C

TITLE

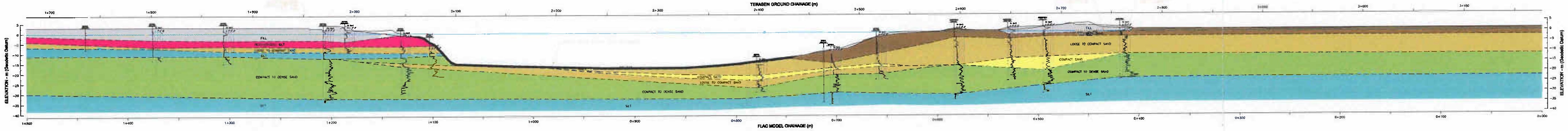
VERTICAL SETTLEMENT ALONG NPS 24 PIPELINE
AS-IS GROUND CONDITION

Golder Associates

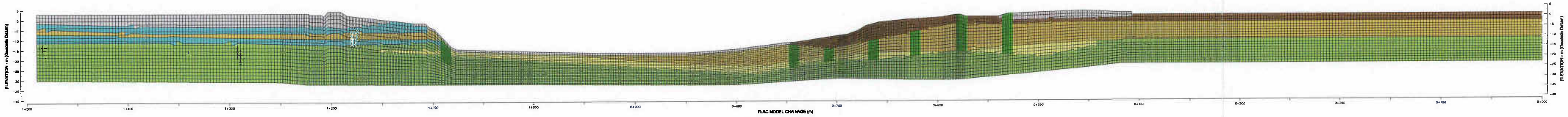
PROJECT No.	03-1411-050		PHASE / TASK No.	
DESIGN	VF	07AUG07	SCALE NTS	REV.
CADD	--		**FIG 5-4**	
CHECK	MB	07AUG07		
REVIEW				



PROFILE: NPS 24 (610mm) PIPE



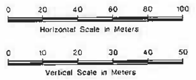
PROFILE: NPS 20 (508mm) PIPE



FINITE DIFFERENCE GRID

NOTE

THE CROSS-SECTION WITH THE INFERRED SOIL STRATIGRAPHY IS DEVELOPED AT A LOCATION MIDWAY OF TWO PIPELINES.



Terasen Gas

PROJECT

TERASEN GAS INC.
NPS 20 & 24 T.P. PIPELINE
SOUTH ARM-FRASER RIVER, DELTA/RICHMOND, B.C.

TITLE

STRATIGRAPHIC PROFILE AND FINITE DIFFERENCE GRIDS WITH LOCATION OF SEISMIC DYKES

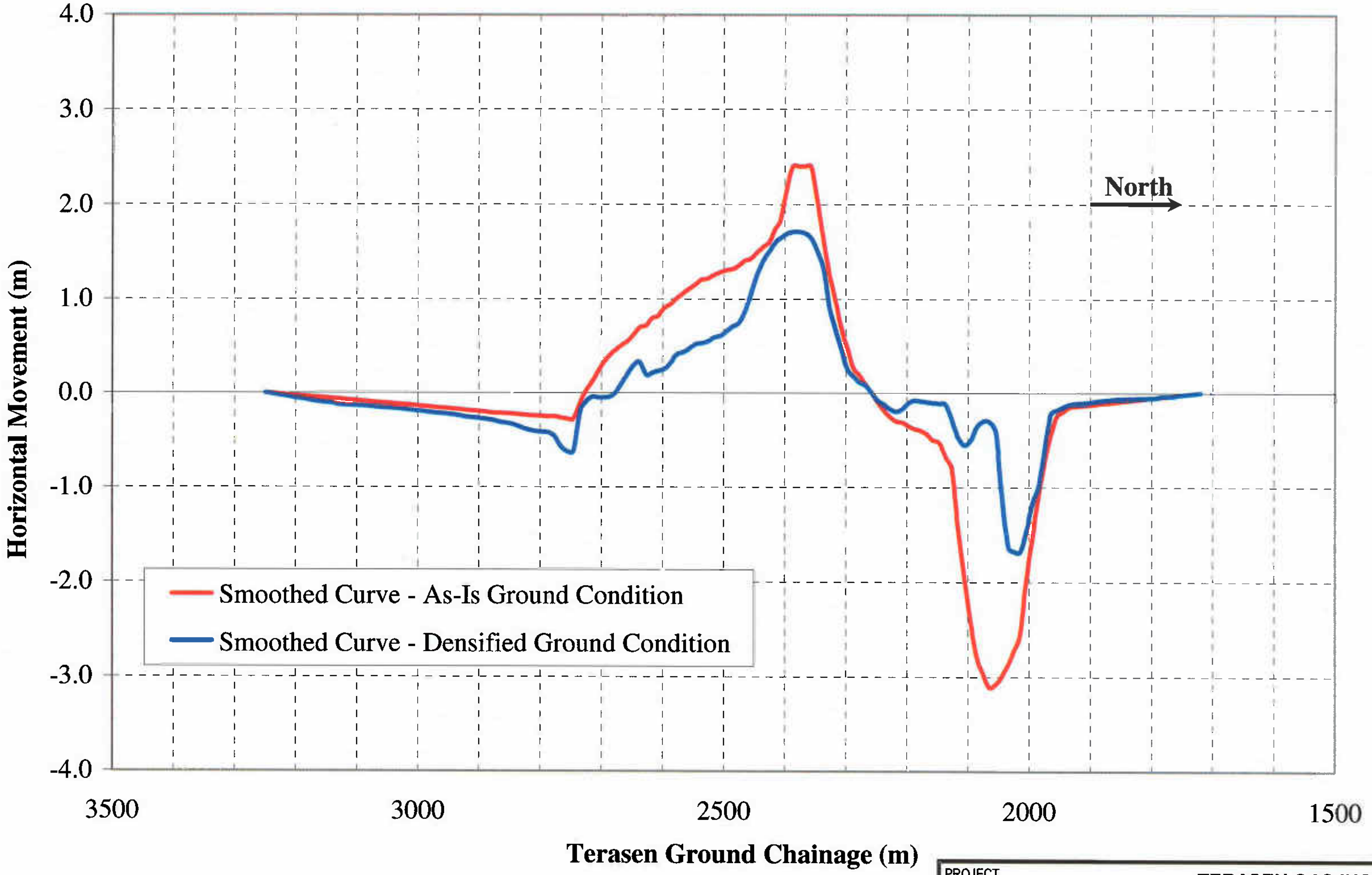
Golder Associates

PROJECT No.	03-1411-050	
DESIGN	VF	01JUN04
CADD	NV/GG/NT	19MAY05
CHECK	VF	11MAY05
REVIEW		

FILE No. 031411050-10
SCALE AS SHOWN REV. -

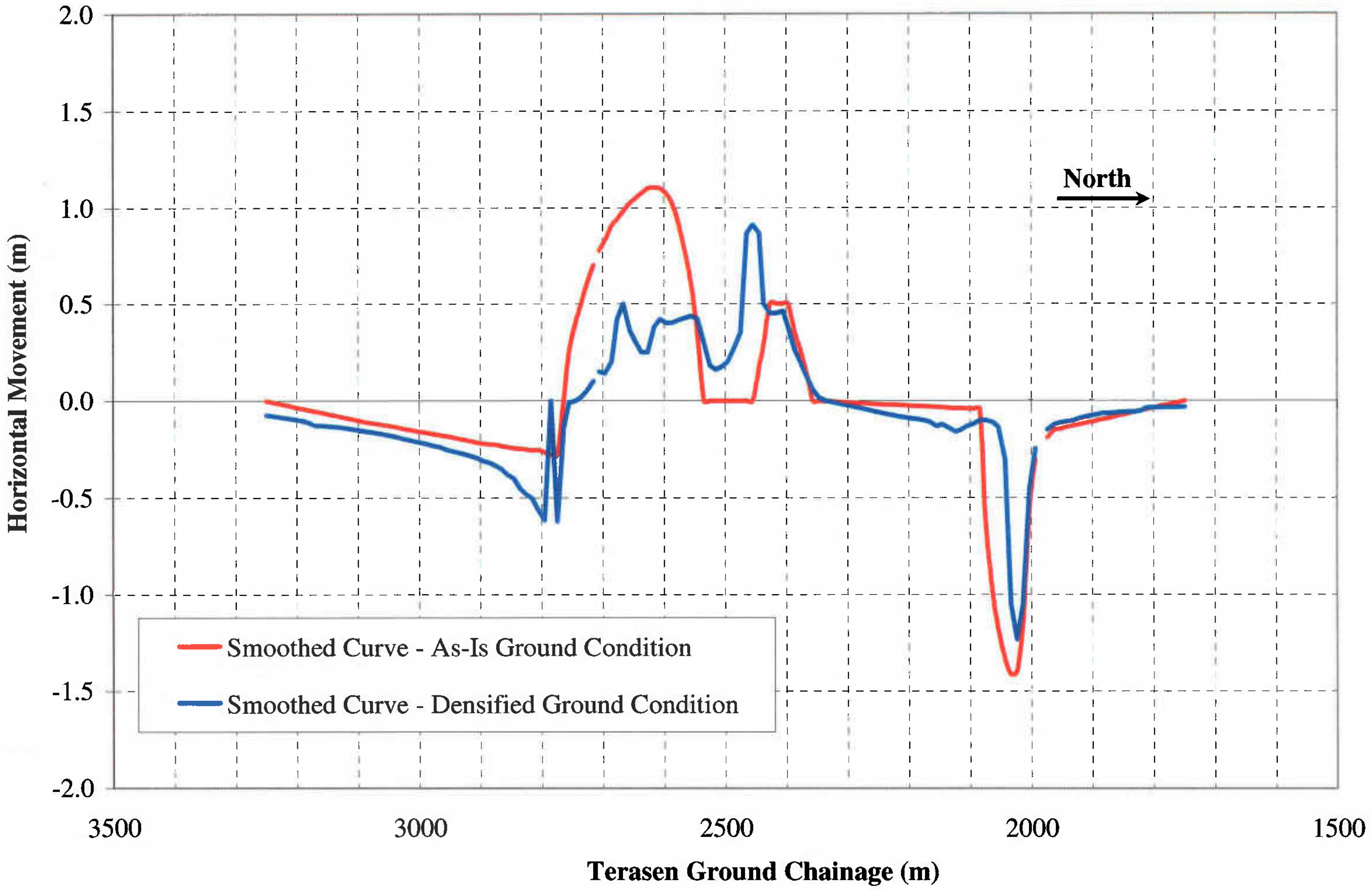
FIGURE 5-5

REVISION DATE. 07/08/09 02:06PM By. MKennedy CADD FILE: O:\Active\#2003-4\2003\1411\100\03-1411-050 BC Gas South Bank-South Arm\August 2007 Summary for Terasen & BGC\Figure 5-5\031411050-10_geo-model_flac-grid1.dwg



PROJECT	TERASEN GAS INC. NPS 20 & 24 T.P. PIPELINE SOUTH ARM FRASER RIVER, DELTA/RICHMOND, B.C		
TITLE	HORIZONTAL DISPLACEMENT ALONG NPS 20 PIPELINE AS-IS/DENSIFIED GROUND CONDITIONS		
PROJECT No.	03-1411-050	PHASE / TASK No.	
DESIGN	VF	07AUG07	SCALE NTS REV.
CADD	--		
CHECK	MB	07AUG07	FIG 5-6
REVIEW			

Golder Associates



PROJECT

TERASEN GAS INC.
NPS 20 & 24 T.P. PIPELINE
SOUTH ARM FRASER RIVER, DELTA/RICHMOND, B.C

TITLE

HORIZONTAL DISPLACEMENT ALONG NPS 24 PIPELINE
AS-IS/DENSIFIED GROUND CONDITIONS

Golder Associates

PROJECT No.	03-1411-050		PHASE / TASK No.	
DESIGN	VF	07AUG07	SCALE NTS	REV.
CADD	--			
CHECK	MB	07AUG07	**FIG 5-7**	
REVIEW				

APPENDIX I

RECORD OF BOREHOLE LOGS, CPT PLOTS AND SELECTED LABORATORY TEST RESULTS

PROJECT No.: 03-1411-050

RECORD OF BOREHOLE: BH03-2

SHEET 1 OF 2

LOCATION: South Bank, South Arm Fraser River
N: 5444053 E: 498737

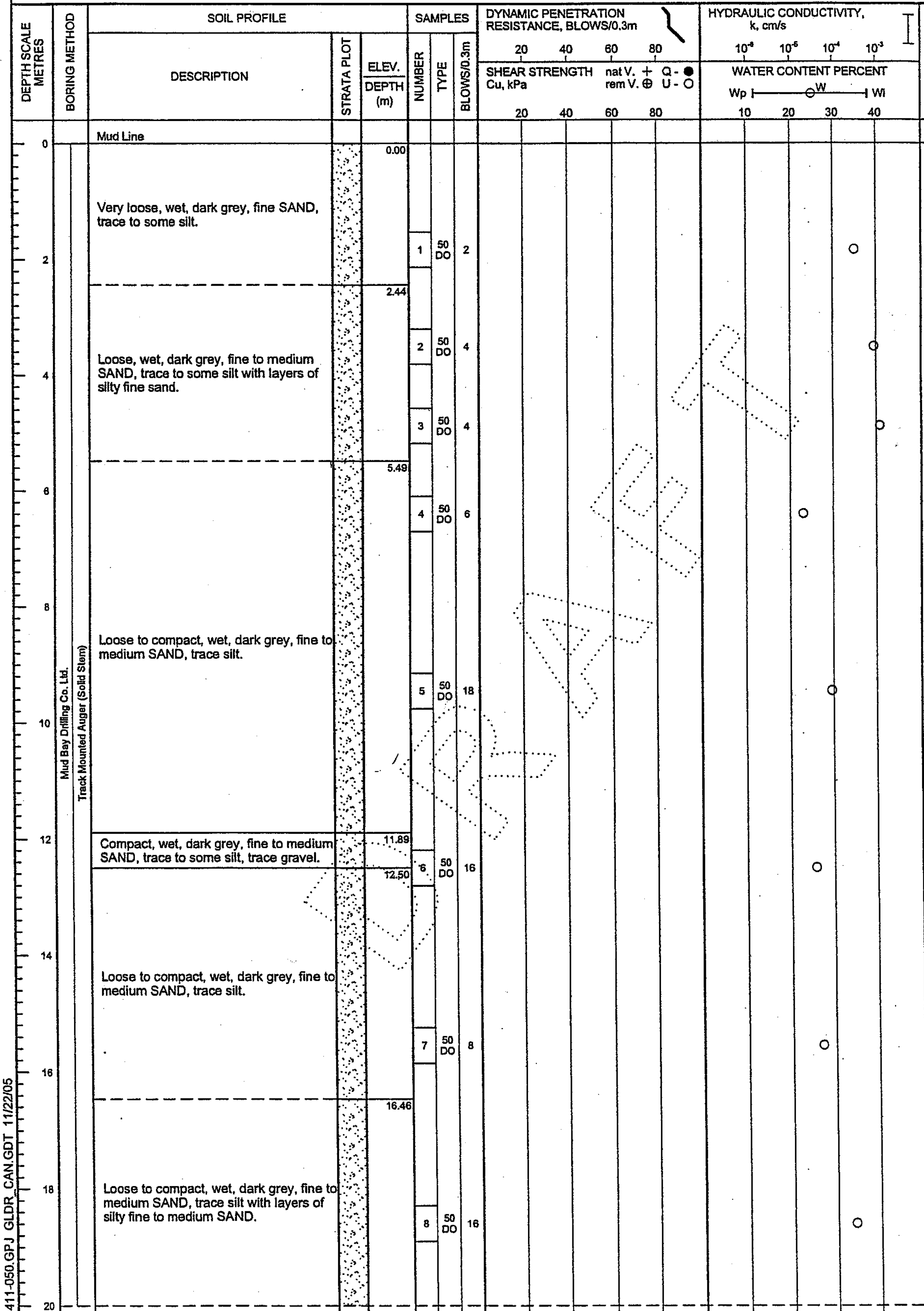
BORING DATE: December 3, 2003

DATUM:

BORING METHOD: Mud Bay Drilling Co. Ltd.
Track Mounted Auger (Solid Stem)

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
Mud Line	0.00
Very loose, wet, dark grey, fine SAND, trace to some silt.	0.00
Loose, wet, dark grey, fine to medium SAND, trace to some silt with layers of silty fine sand.	2.44
Loose to compact, wet, dark grey, fine to medium SAND, trace silt.	5.49
Compact, wet, dark grey, fine to medium SAND, trace to some silt, trace gravel.	11.89
Loose to compact, wet, dark grey, fine to medium SAND, trace silt.	12.50
Loose to compact, wet, dark grey, fine to medium SAND, trace silt with layers of silty fine to medium SAND.	16.46

SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
1	50 DO	2	M
2	50 DO	4	M
3	50 DO	4	M
4	50 DO	6	M
5	50 DO	18	M
6	50 DO	16	
7	50 DO	8	M
8	50 DO	16	



PIEZOMETER OR STANDPIPE INSTALLATION

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 100

Golder Associates

LOGGED: DEN
CHECKED: VF

PROJECT No.: 03-1411-050

RECORD OF BOREHOLE: BH03-2

SHEET 2 OF 2

LOCATION: South Bank, South Arm Fraser River
N: 5444053 E: 498737

BORING DATE: December 3, 2003

DATUM:

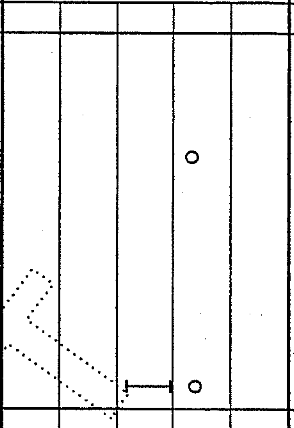
DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m
20	Mud Bay Drilling Co. Ltd. Track Mounted Auger (Solid Stem)	Loose to compact, wet, dark grey, fine to medium SAND, trace silt with layers of silty fine to medium SAND *(continued)*					
22		Firm to stiff, wet, dark grey, clayey SILT, trace shell fragments with thin layers of silty fine sand.		21.03	9	50 DO	10
24					10	50 DO	11
		End of BOREHOLE.		24.99			
26							
28							
30							
32							
34							
36							
38							
40							

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 10 20 30 40



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE
1 : 100

LOGGED: DEN
CHECKED: VF

PROJECT No.: 03-1411-050

RECORD OF BOREHOLE: BH03-3

SHEET 1 OF 2

LOCATION: South Bank, South Arm Fraser River
N: 5443928 E: 498761

BORING DATE: December 4, 2003

DATUM:

BORING METHOD: Mud Bay Drilling Co. Ltd. Track Mounted Auger (Solid Stem)

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
Mud Line	
Loose, moist, brown SAND, trace silt and organics.	0.15
Loose, moist, grey, fine to medium SAND, trace silt.	1.98
Firm, wet, grey SILT, trace sand and clay.	4.27
Loose to compact, wet, grey, fine to medium SAND, trace silt.	5.79
Loose, wet, grey SILT and SAND.	6.10
Loose to compact, wet, grey, well graded SAND, trace silt and gravel.	9.14
Loose to compact, wet, grey, fine to medium SAND, trace to some silt.	17.37
Compact, wet, grey, fine to medium SAND, trace silt with thin layers of silty sand and a 152mm layer of stiff clayey silt at 20.27m - 20.42m depth.	

SAMPLES NUMBER	TYPE	ADDITIONAL LAB. TESTING
1	AS	M
2	AS	
3	AS	
4	AS	
5	AS	
6	AS	M
7	AS	M
8	AS	
9	AS	
10	AS	
11	AS	M
12	AS	
13	AS	
14	AS	
15	AS	
16	AS	M
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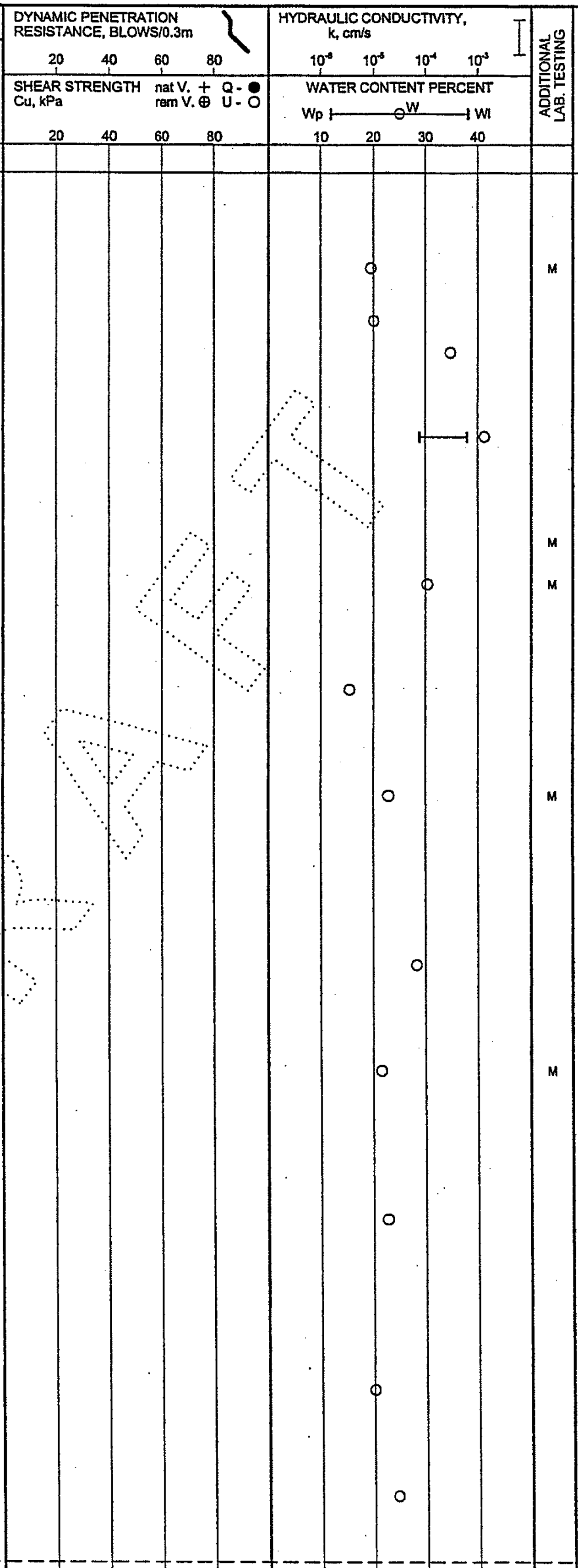
21	AS	
22	AS	
23	AS	
24	AS	
25	AS	



PIEZOMETER OR STANDPIPE INSTALLATION

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 100

Golder Associates

LOGGED: DEN
CHECKED: VF

PROJECT No.: 03-1411-050

RECORD OF BOREHOLE: BH03-3

SHEET 2 OF 2

LOCATION: South Bank, South Arm Fraser River
N: 5443928 E: 498761

BORING DATE: December 4, 2003

DATUM:

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. / DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (10 20 30 40)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
20		Compact, wet, grey, fine to medium SAND, trace silt with thin layers of silty sand and a 152mm layer of stiff clayey silt at 20.27m - 20.42m depth. *(continued)*	░		26	AS			○	M	
					27	AS					
		End of BOREHOLE.		21.34							
22											
24											
26											
28											
30											
32											
34											
36											
38											
40											

DEPTH SCALE
1 : 100

Golder Associates

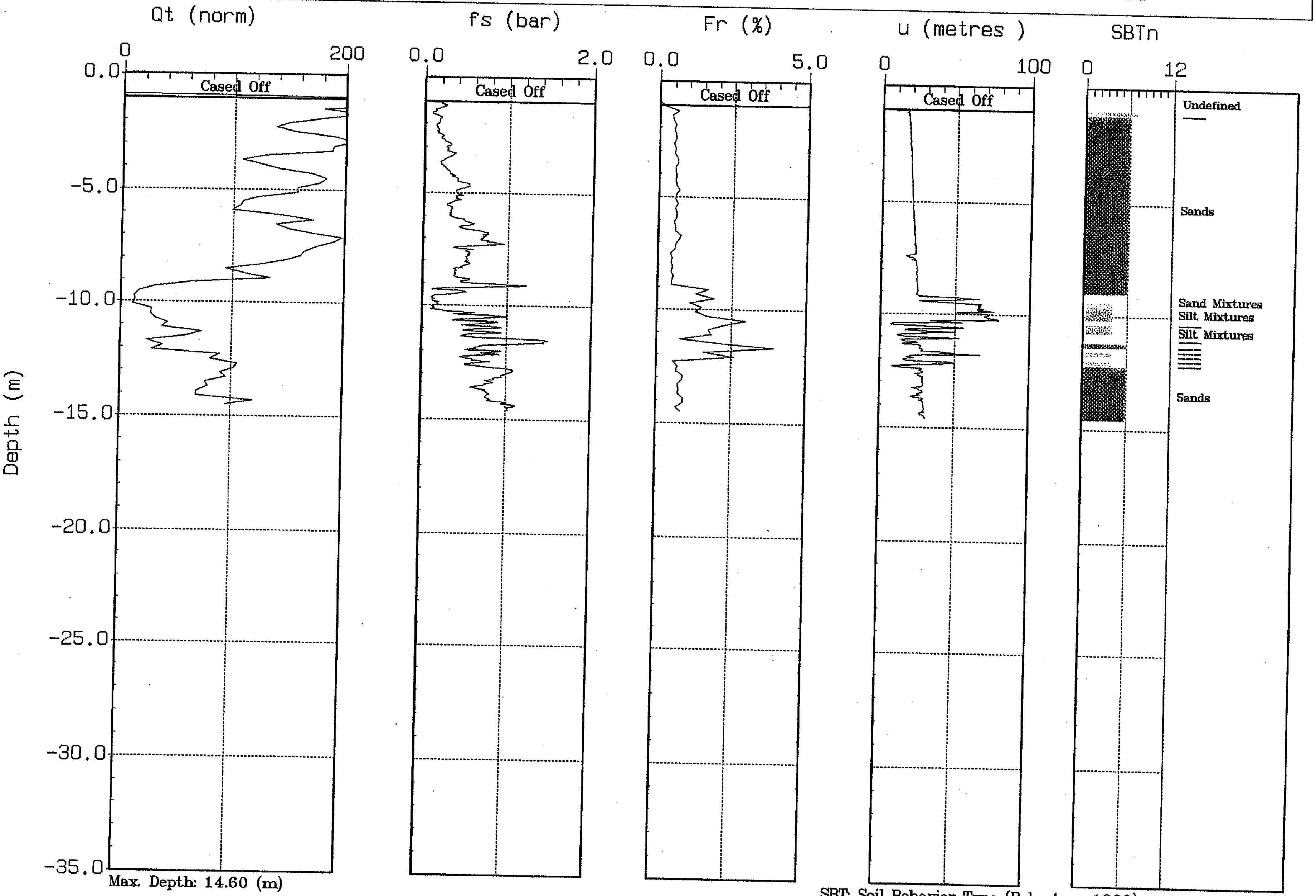
LOGGED: DEN
CHECKED: VF

CONETEC

GOLDER ASSOCIATES

Site: TILBURY ISLAND
Location: CPT03-1

Cone: 20 Ton St 113
Date: 12:02:03 11:01



Max. Depth: 14.60 (m)

Depth Inc.: 0.025 (m)

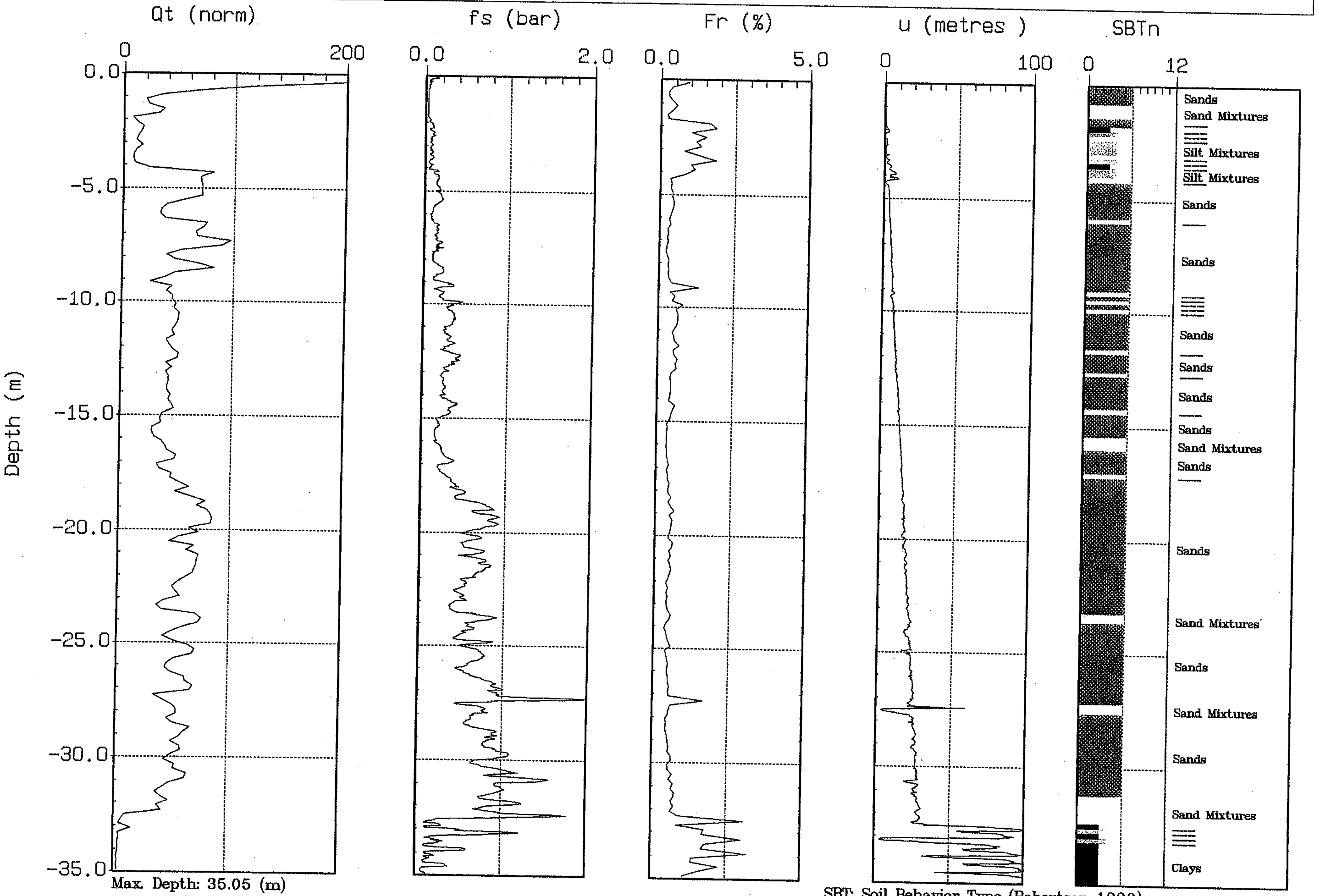
SBT: Soil Behavior Type (Robertson 1990)

Datum = Mudline, GPS N: 5 444 117 m E: 498 724 m

GOLDER ASSOCIATES

Site: TILBURY ISLAND
Location: CPT03-3

Cone: 20 Ton St 113
Date: 12:04:03 09:23



Max. Depth: 35.05 (m)

Depth Inc.: 0.025 (m)

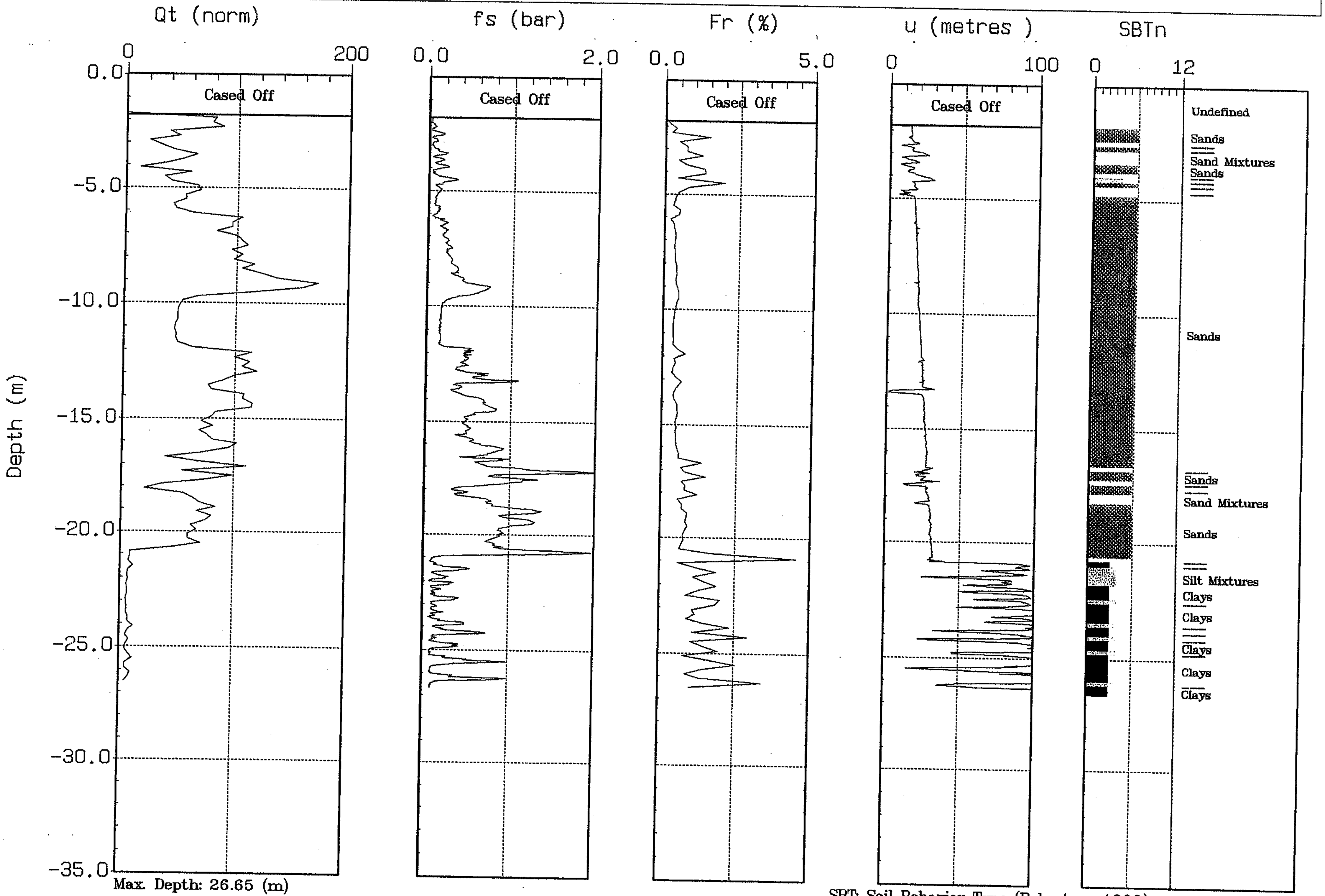
SBT: Soil Behavior Type (Robertson 1990)

CONETEC

GOLDER ASSOCIATES

Site: TILBURY ISLAND
Location: CPT03-2

Cone: 20 Ton St 113
Date: 12:02:03 16:03



Max. Depth: 26.65 (m)

Depth Inc.: 0.025 (m)

SBT: Soil Behavior Type (Robertson 1990)

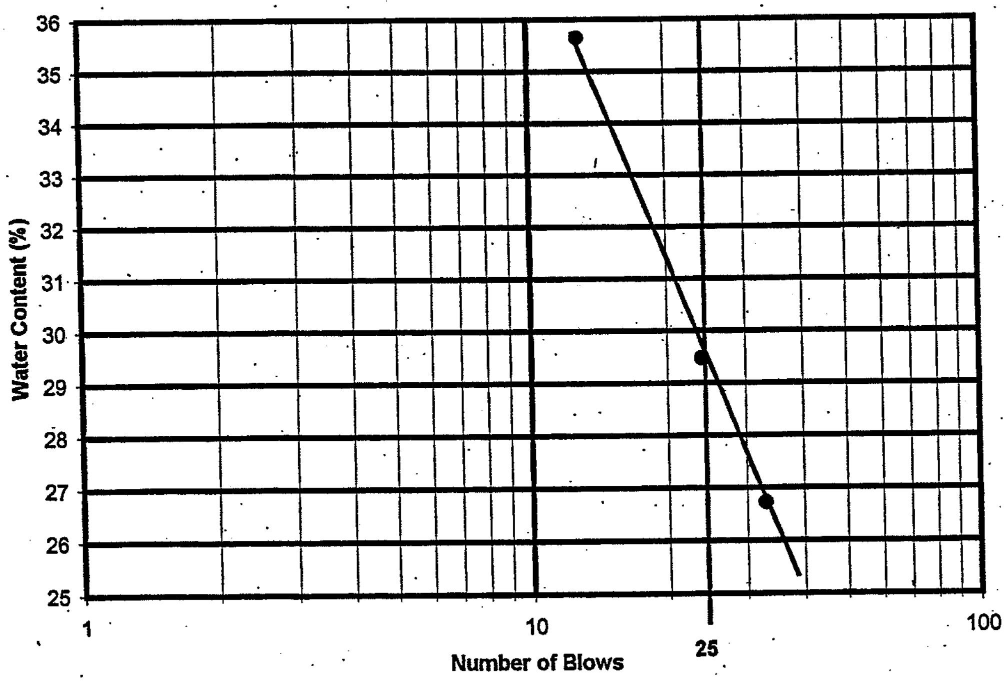
Datum = Mudline, GPS N: 5 444 048 m E: 498 735 m

Project # 031-411050 **Tech :** LL

Liquid Limit, Plastic Limit and Plasticity Index of Soils
ASTM D 4318-93

TYPE OF TEST	LL	LL	LL			W% Nat.
CONTAINER NUMBER	LL	K5	DA			
NUMBER OF BLOWS	13	24	33			
MASS WET SOIL + TARE	30.60	28.10	45.40			210.90
MASS DRY SOIL + TARE	22.90	22.00	36.10			159.70
MASS OF WATER	7.70	6.10	9.30			51.20
MASS OF CONTAINER	1.30	1.30	1.30			8.10
MASS OF DRY SOIL	21.60	20.70	34.80			151.6
WATER CONTENT W (%)	**35.6**	**29.5**	**26.7**			**33.8**

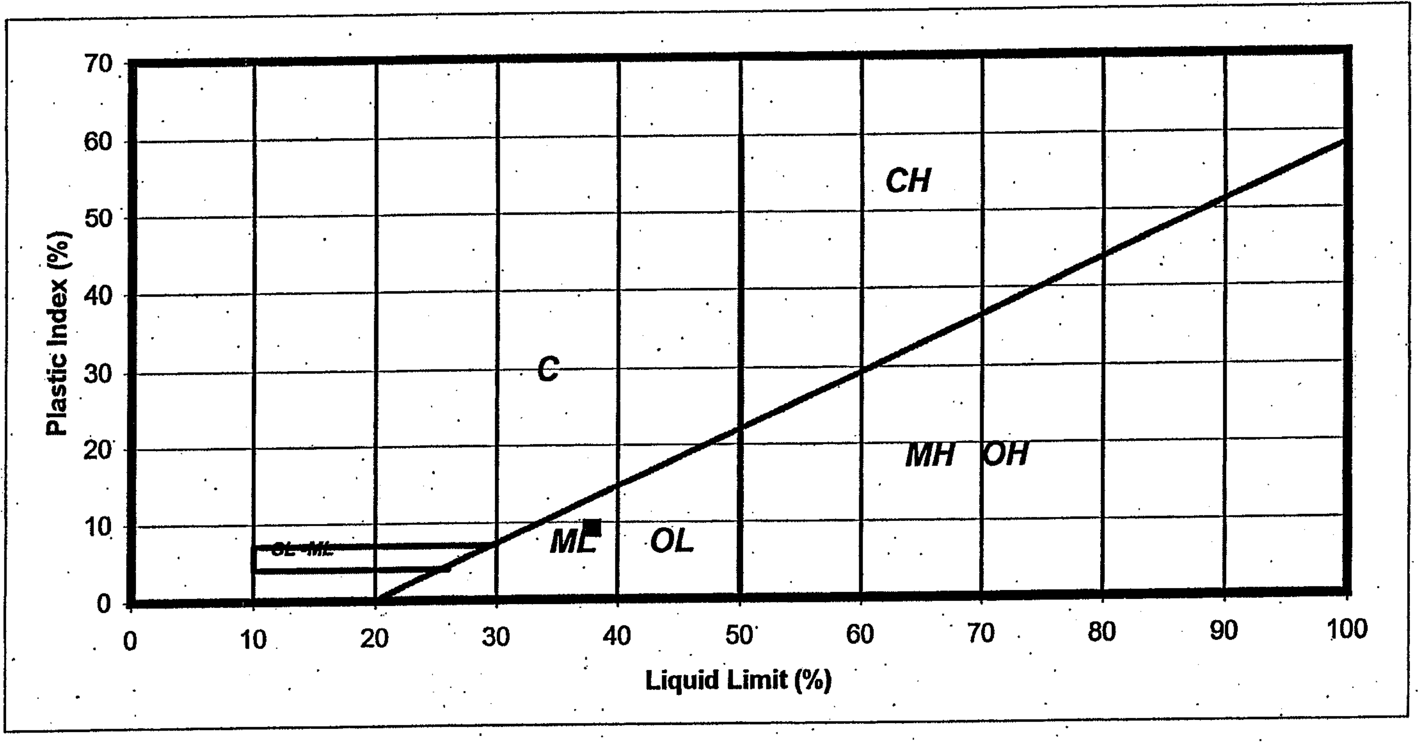
TYPE OF TEST	PL	PL	BOREHOLE NO.	BH 03-2
CONTAINER NUMBER	AT6	S	SAMPLE	SA 10
MASS WET SOIL + TARE	24.60	22.30	DEPTH (m)	24.4-25.0
MASS DRY SOIL + TARE	20.40	18.60	LIQUID LIMIT (%)	29.5
MASS OF WATER	4.20	3.70	PLASTIC LIMIT (%)	21.7
MASS OF CONTAINER	1.30	1.30	PLASTICITY INDEX (%)	7.8
MASS OF DRY SOIL	19.10	17.30	W% Natural (%)	33.8
WATER CONTENT W (%)	**22.0**	**21.4**	LIQUIDITY INDEX	1.55



SAMPLE DESCRIPTION : CL

SILT & CLAY, some fine sand

Casagrande Plasticity Chart



Classification of Fined Grained Soils

Silts and Clays L.L.<50

ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
OL	Organic silts and organic silt-clays of low plasticity

Silts and Clays L.L.>50

MH	Inorganic silts, micaeous or diatomaceous fine sandy or silty soils, elastic silts
CH	Inorganic clays of high plasticity, fat clays
OH	Organic clays of medium to high plasticity, organic silts

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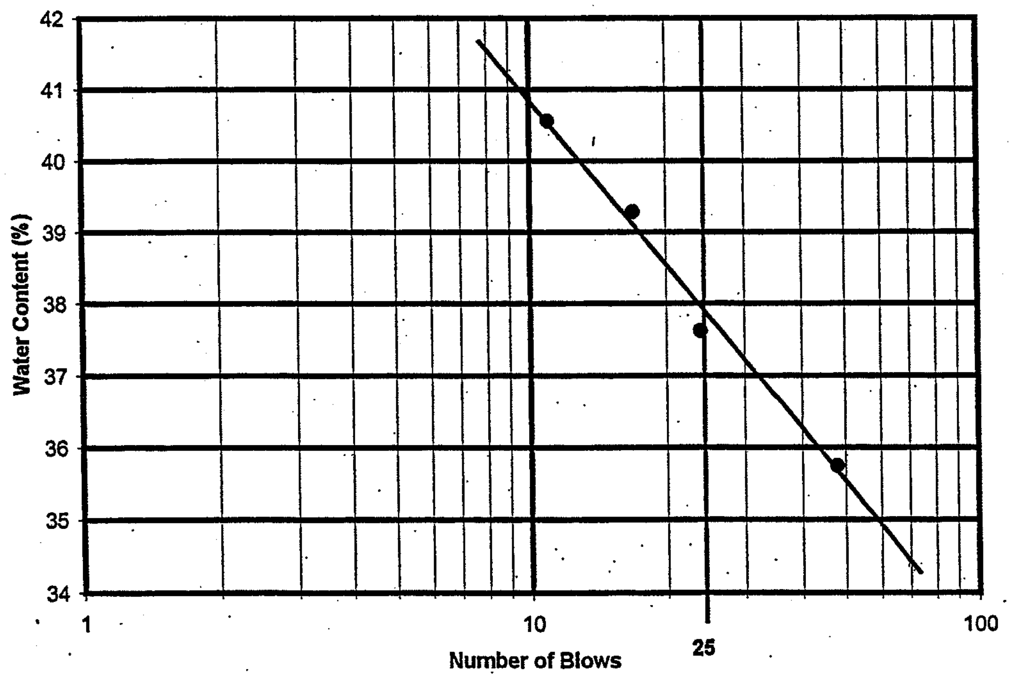
Project # 031-411050 **Tech :** LL

Liquid Limit, Plastic Limit and Plasticity Index of Soils
ASTM D 4318-93

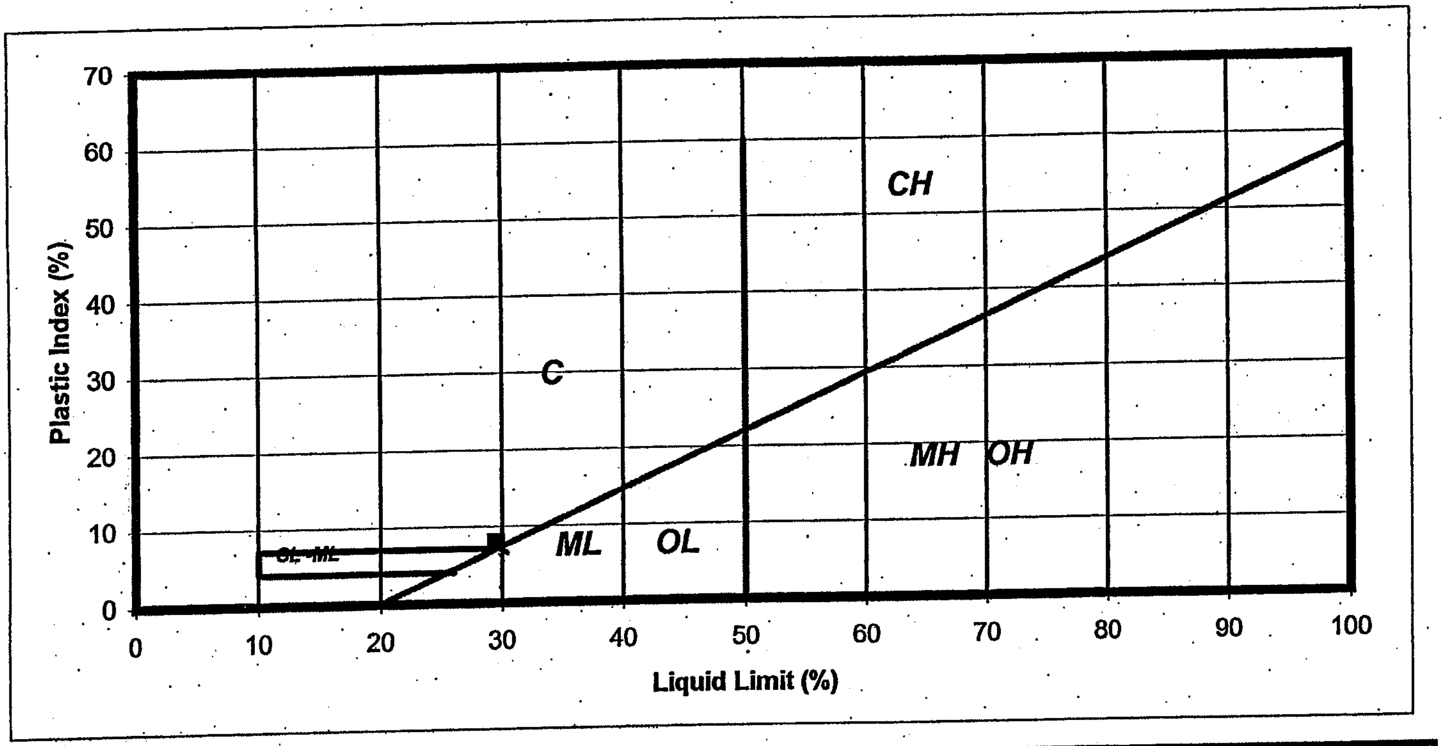
TYPE OF TEST	LL	LL	LL	LL		W% Nat.
CONTAINER NUMBER	T	M6	AT5	A2		
NUMBER OF BLOWS	11	24	48	17		
MASS WET SOIL + TARE	31.80	46.30	38.90	39.60		304.30
MASS DRY SOIL + TARE	23.00	34.00	29.00	28.80		217.90
MASS OF WATER	8.80	12.30	9.90	10.80		86.40
MASS OF CONTAINER	1.30	1.30	1.30	1.30		8.10
MASS OF DRY SOIL	21.70	32.70	27.70	27.50		209.8
WATER CONTENT W (%)	40.6	37.6	35.7	39.3		41.2

TYPE OF TEST	PL	PL	BOREHOLE NO.	BH 03-3
CONTAINER NUMBER	N 98	M7	SAMPLE	SA 4
MASS WET SOIL + TARE	16.80	17.10	DEPTH (m)	3.7-4.0
MASS DRY SOIL + TARE	13.30	13.60	LIQUID LIMIT (%)	37.9
MASS OF WATER	3.50	3.50	PLASTIC LIMIT (%)	28.8
MASS OF CONTAINER	1.30	1.30	PLASTICITY INDEX (%)	9.1
MASS OF DRY SOIL	12.00	12.30	W% Natural (%)	41.2
WATER CONTENT W (%)	29.2	28.5	LIQUIDITY INDEX	1.36



SAMPLE DESCRIPTION : ML - sandy SILT

Casagrande Plasticity Chart



Classification of Fined Grained Soils

Silts and Clays L.L.<50

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CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
OL	Organic silts and organic silt-clays of low plasticity

Silts and Clays L.L.>50

MH	Inorganic silts, micaeous or diatomaceous fine sandy or silty soils, elastic silts
CH	Inorganic clays of high plasticity, fat clays
OH	Organic clays of medium to high plasticity, organic silts

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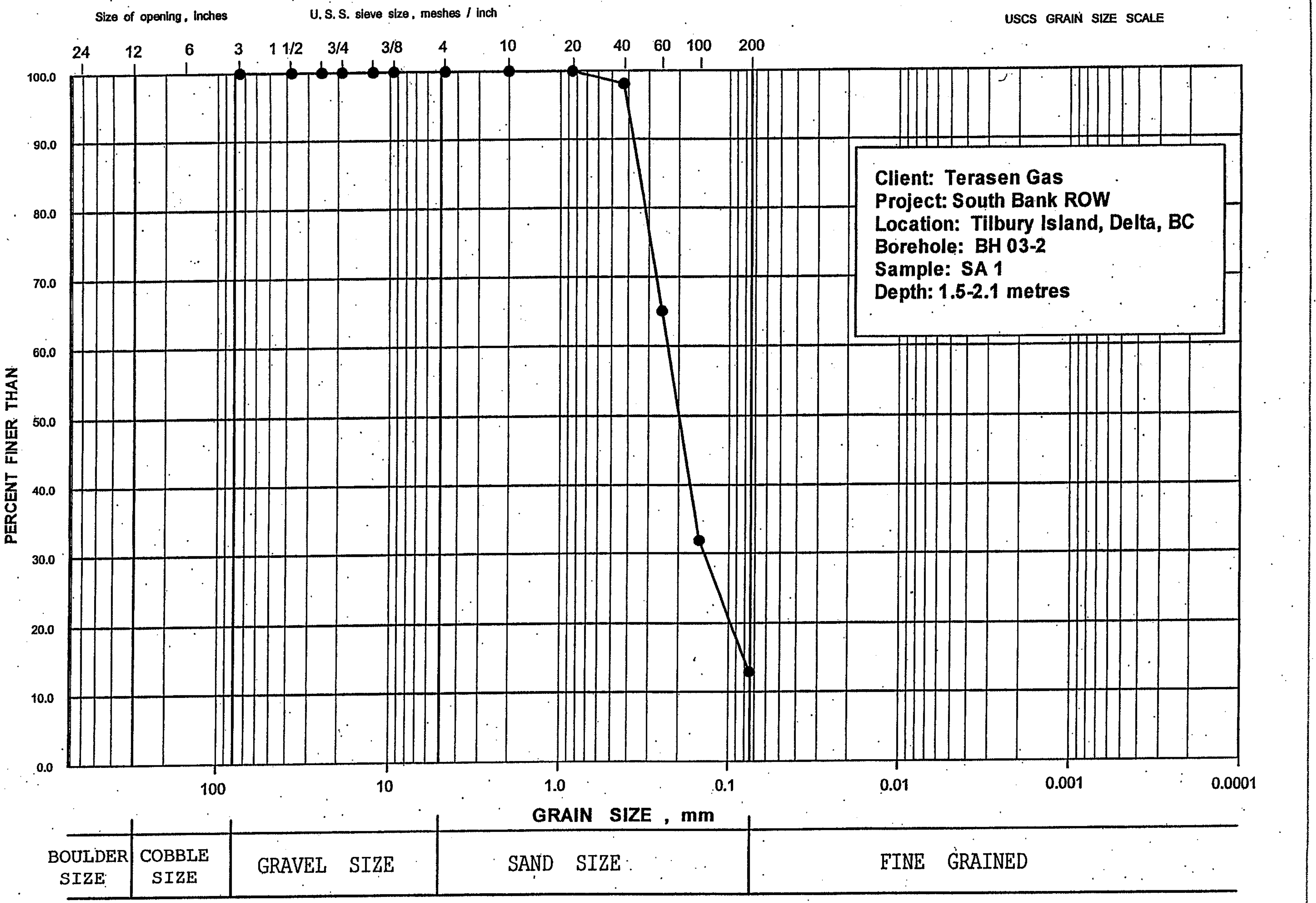
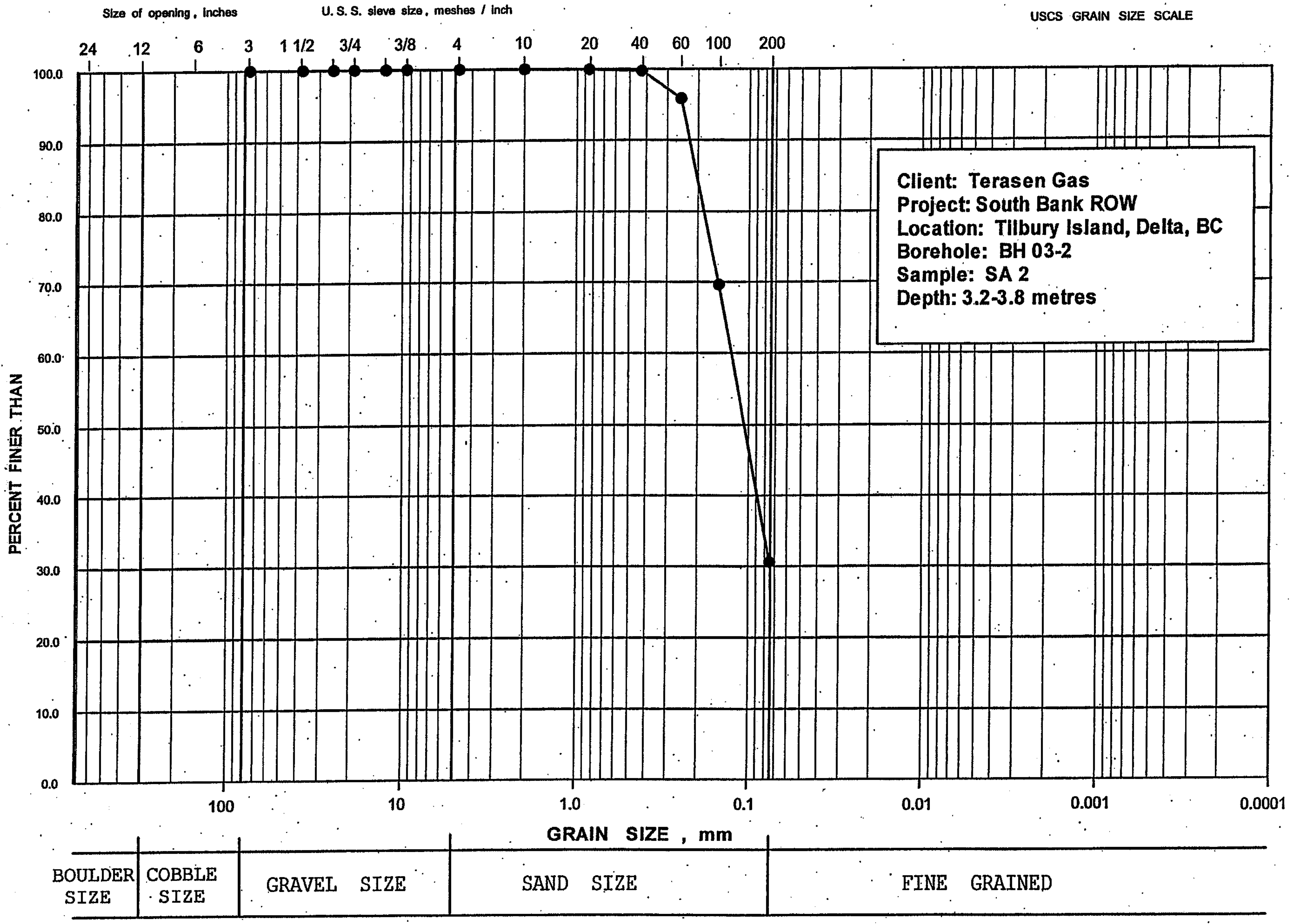


Client: Terasen Gas
Project: South Bank ROW
Location: Tilbury Island, Delta, BC
Borehole: BH 03-2
Sample: SA 1
Depth: 1.5-2.1 metres

Project No.: ..031-411050.. Drawn: ....LL.................. Reviewed: .... Date:....January 30/04.........	Golder Associates	GRAIN SIZE DISTRIBUTION	Figure



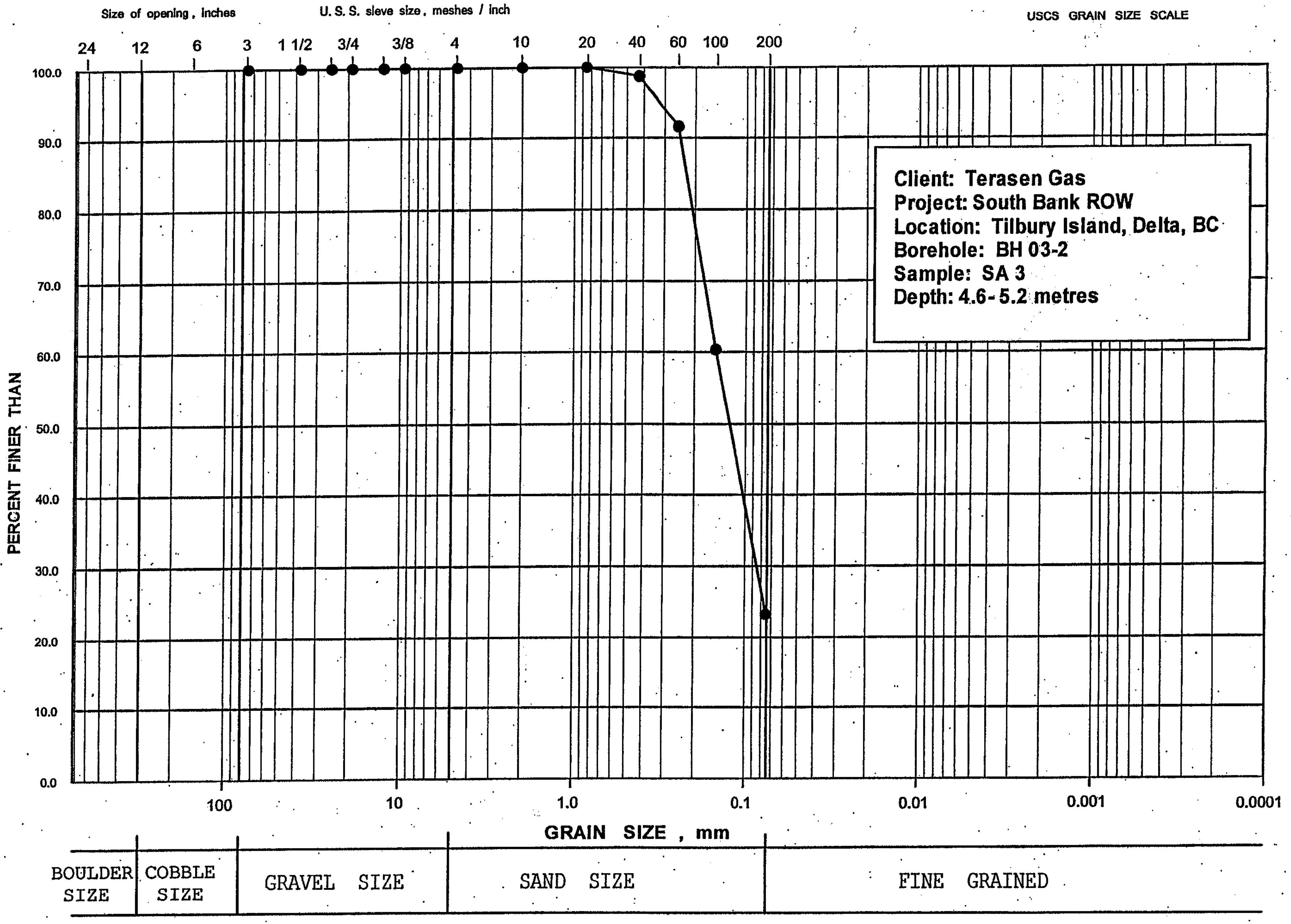
Client: Terasen Gas
Project: South Bank ROW
Location: Tilbury Island, Delta, BC
Borehole: BH 03-2
Sample: SA 2
Depth: 3.2-3.8 metres

Project No.: ..031-411050..
Drawn: ....LL..................
Reviewed: ....
Date:....January 30/04.........

Golder Associates

GRAIN SIZE DISTRIBUTION

Figure



Client: Terasen Gas
Project: South Bank ROW
Location: Tilbury Island, Delta, BC
Borehole: BH 03-2
Sample: SA 3
Depth: 4.6-5.2 metres

Project No.: ..031-411050..
Drawn: ....LL.................
Reviewed: ....
Date:....January 30/04.........

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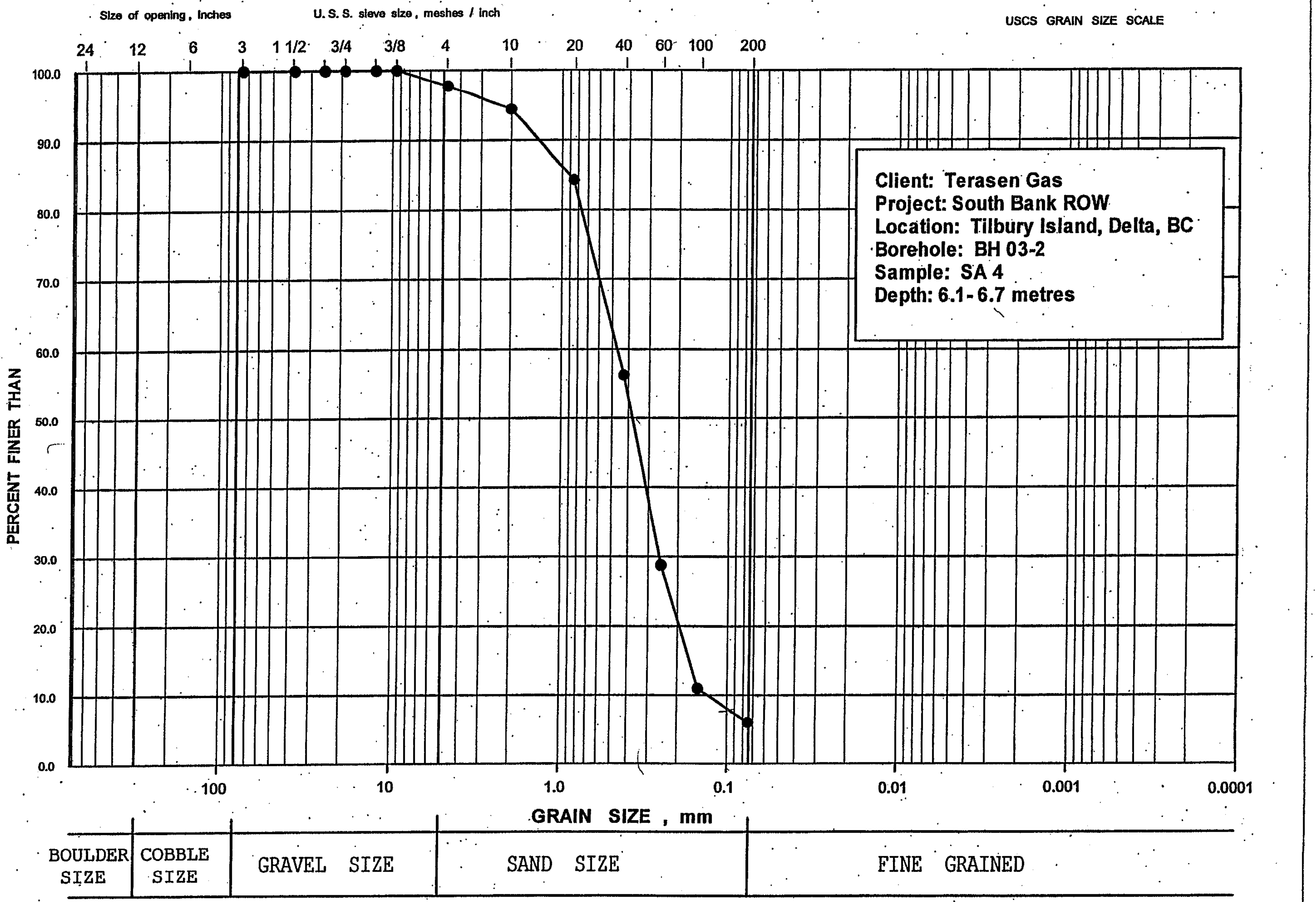
GRAIN SIZE DISTRIBUTION

Figure



Client: Terasen Gas
Project: South Bank ROW
Location: Tilbury Island, Delta, BC
Borehole: BH 03-2
Sample: SA 4
Depth: 6.1 - 6.7 metres

Project No.: ..031-411050..
Drawn: ....LL..................
Reviewed: ....
Date:....December 17/03..

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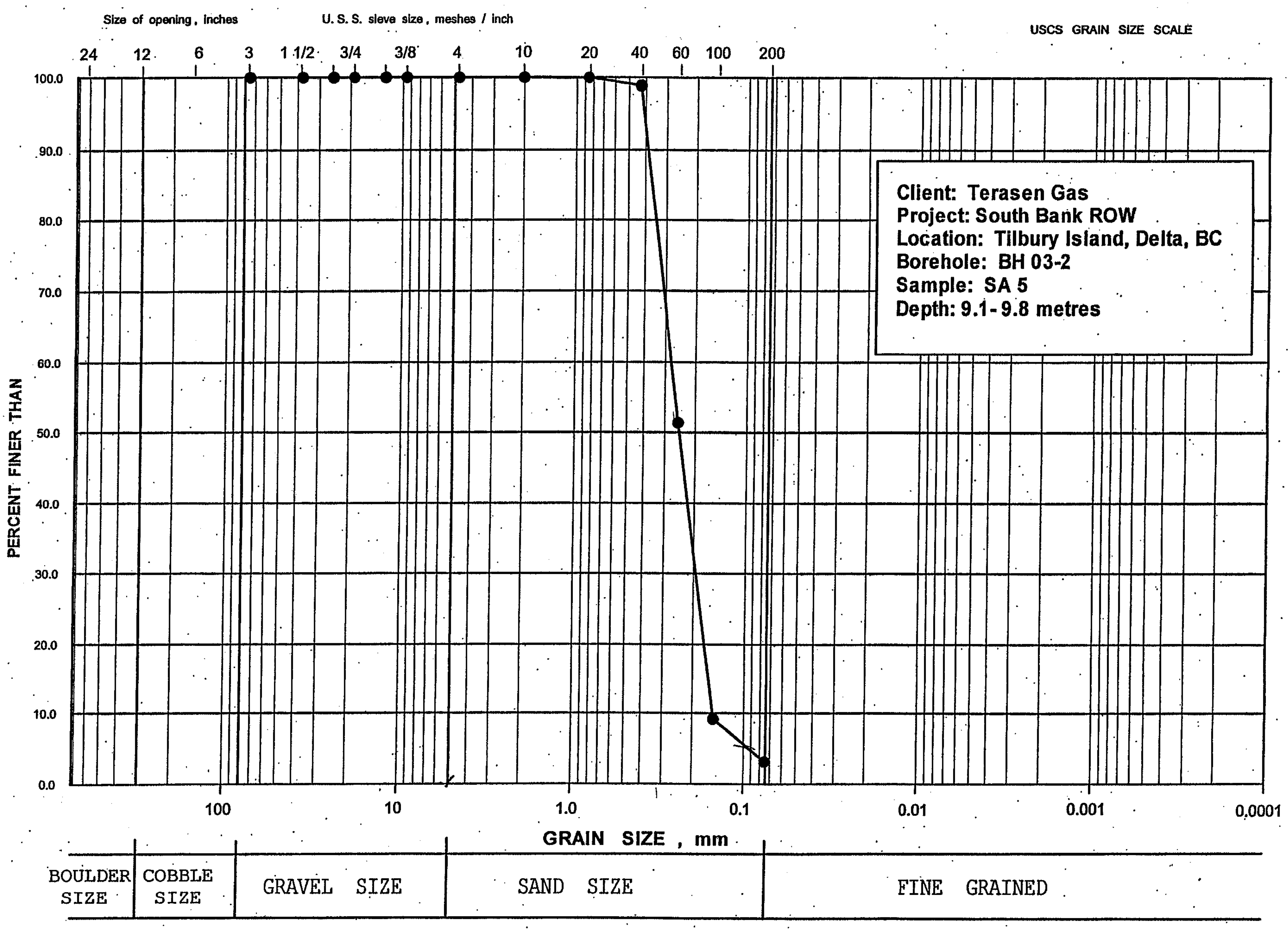
GRAIN SIZE DISTRIBUTION

Figure



Client: Terasen Gas
Project: South Bank ROW
Location: Tilbury Island, Delta, BC
Borehole: BH 03-2
Sample: SA 5
Depth: 9.1- 9.8 metres

Project No.: ..031-411050..
Drawn: ....LL.................
Reviewed: ....
Date:....December 17/03..

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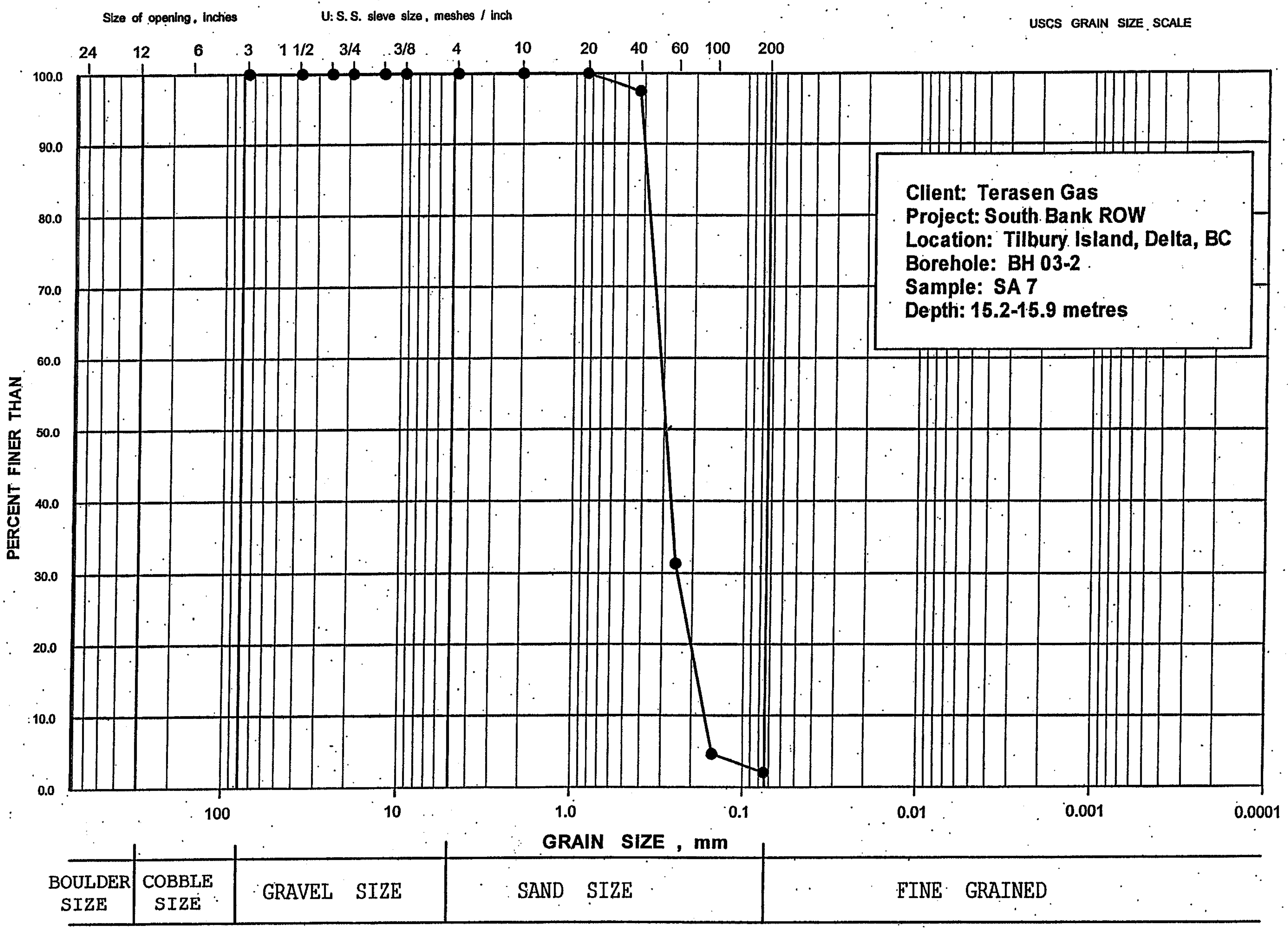
GRAIN SIZE DISTRIBUTION

Figure



Client: Terasen Gas
Project: South Bank ROW
Location: Tilbury Island, Delta, BC
Borehole: BH 03-2
Sample: SA 7
Depth: 15.2-15.9 metres

Project No.: ..031-411050..
Drawn: ....LL..................
Reviewed:.........................
Date:....December 17/03..

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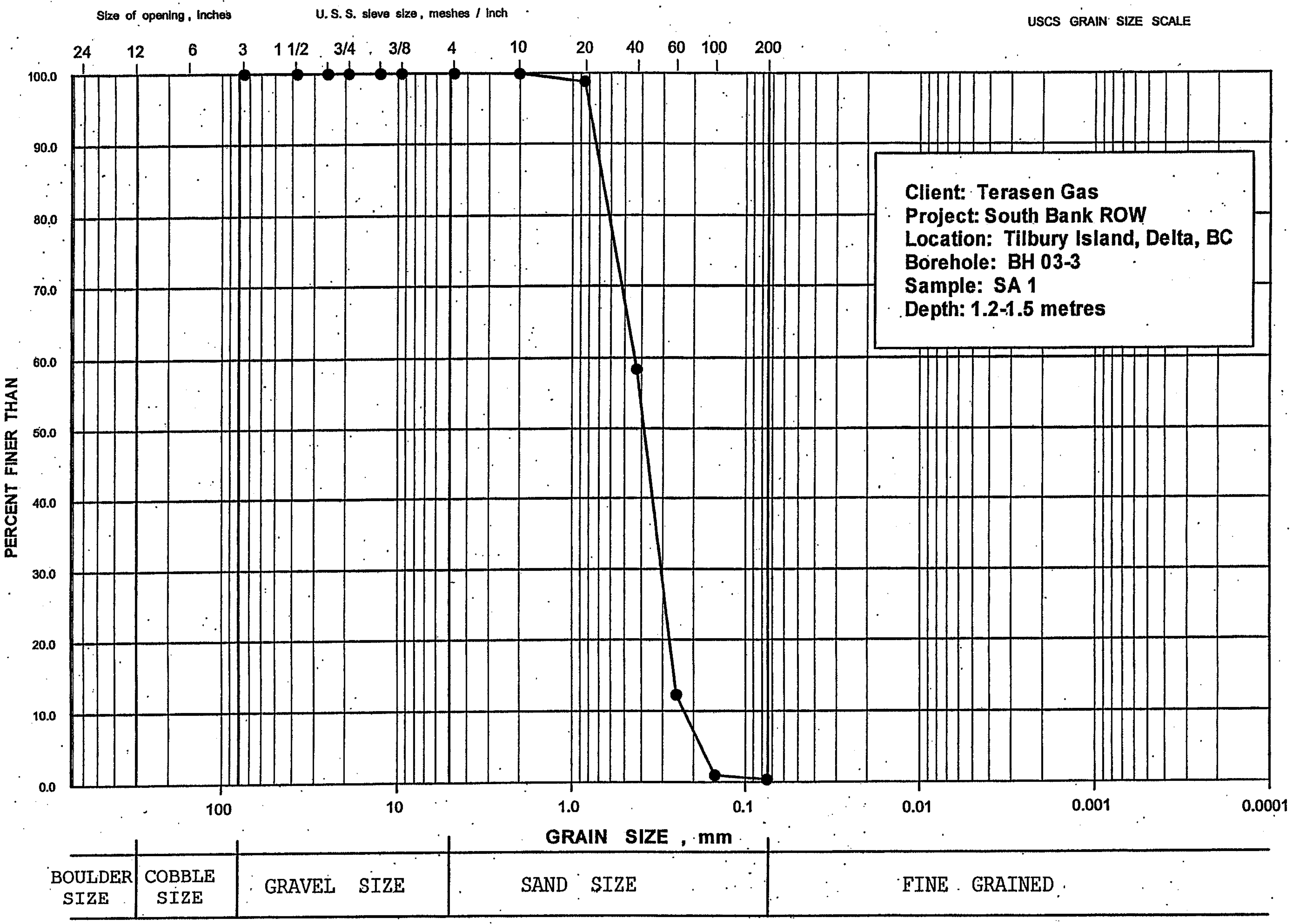
GRAIN SIZE DISTRIBUTION

Figure



Client: Terasen Gas
Project: South Bank ROW
Location: Tilbury Island, Delta, BC
Borehole: BH 03-3
Sample: SA 1
Depth: 1.2-1.5 metres

Project No.: ..031-411050..
Drawn: ....LL.................
Reviewed: ....
Date:....December 17/03..

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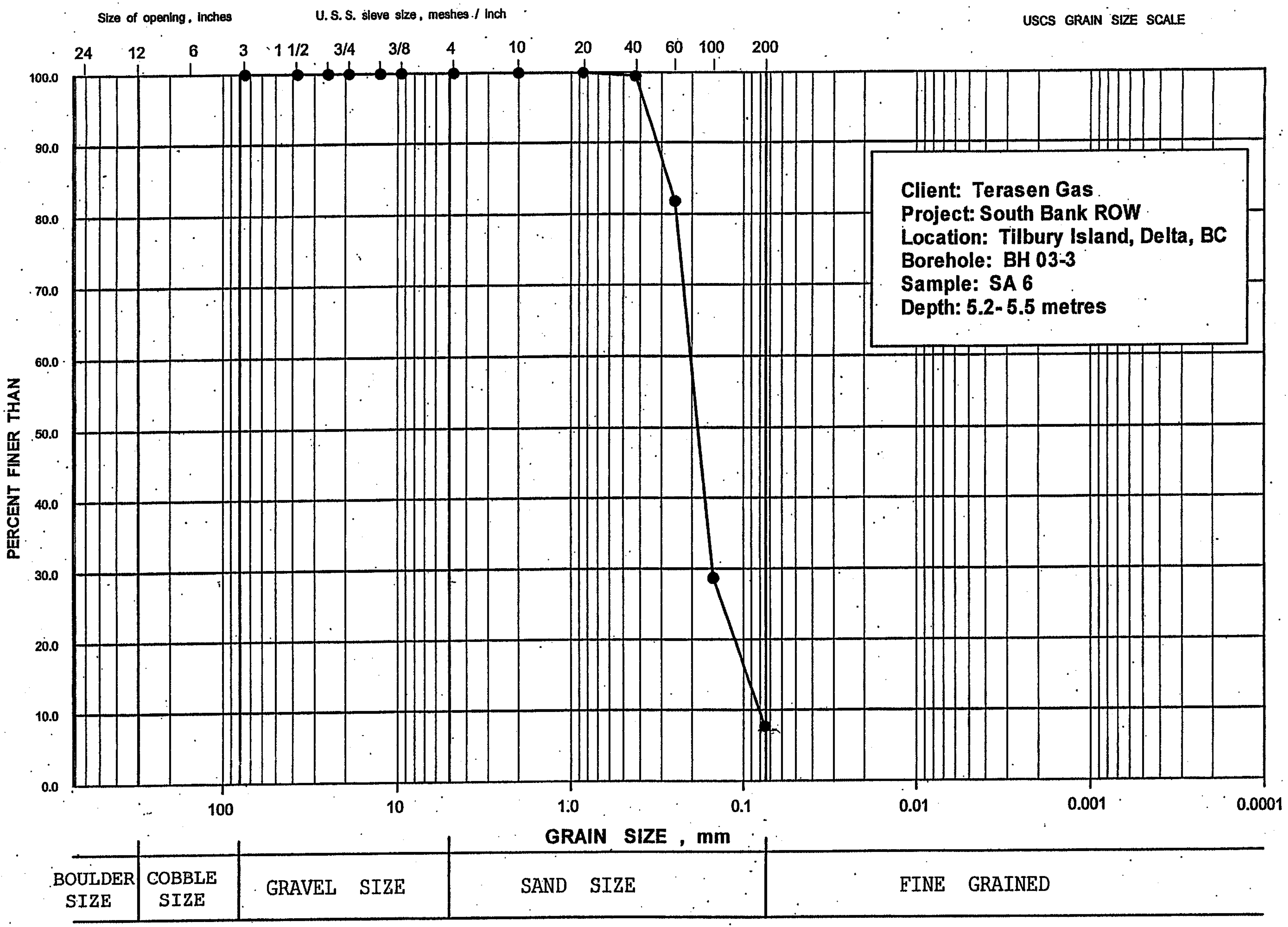
GRAIN SIZE DISTRIBUTION

Figure



Client: Terasen Gas
Project: South Bank ROW
Location: Tilbury Island, Delta, BC
Borehole: BH 03-3
Sample: SA 6
Depth: 5.2- 5.5 metres

Project No.: ..031-411050..
Drawn: ....LL..................
Reviewed: ....
Date:....December 17/03..

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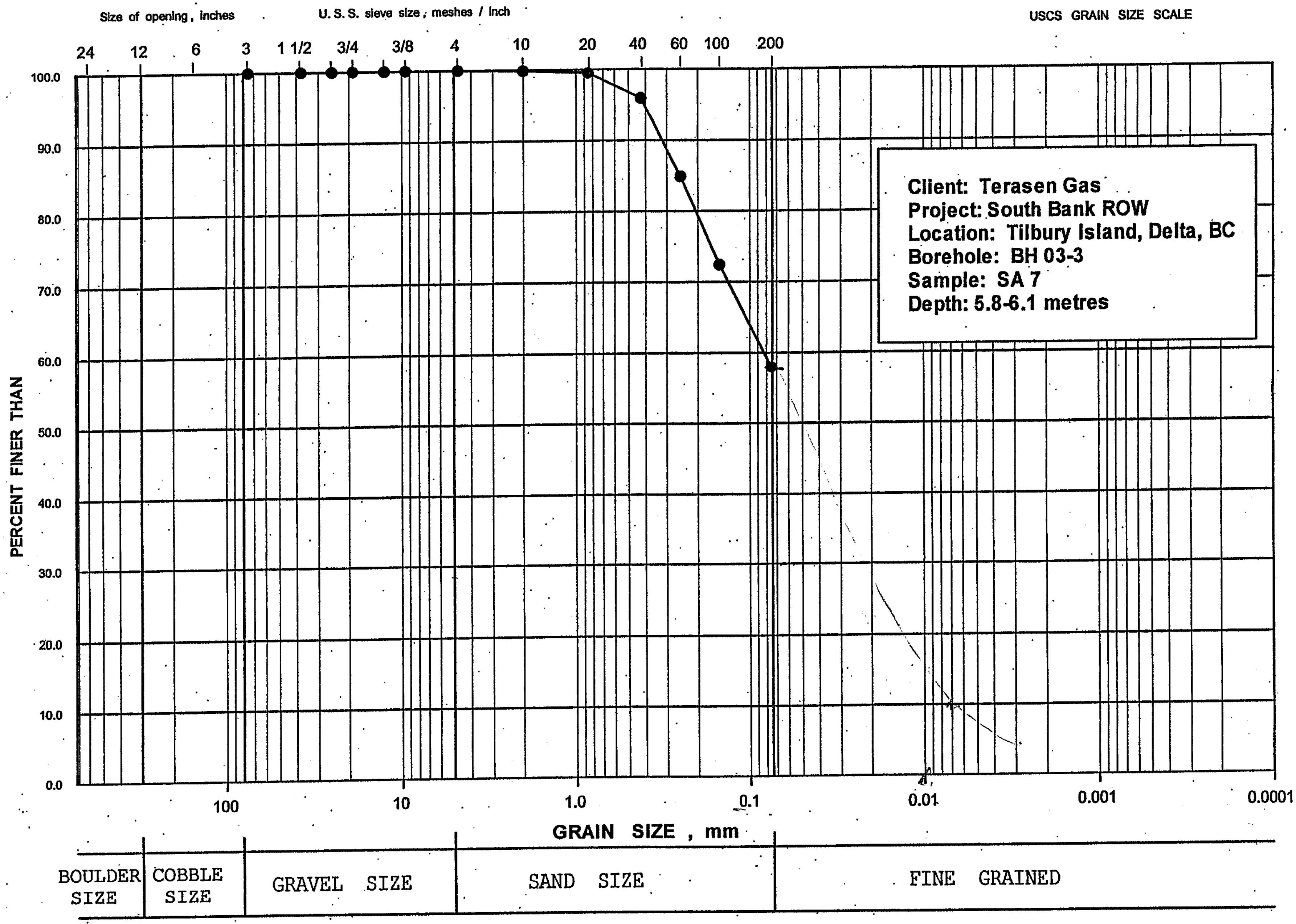
GRAIN SIZE DISTRIBUTION

Figure



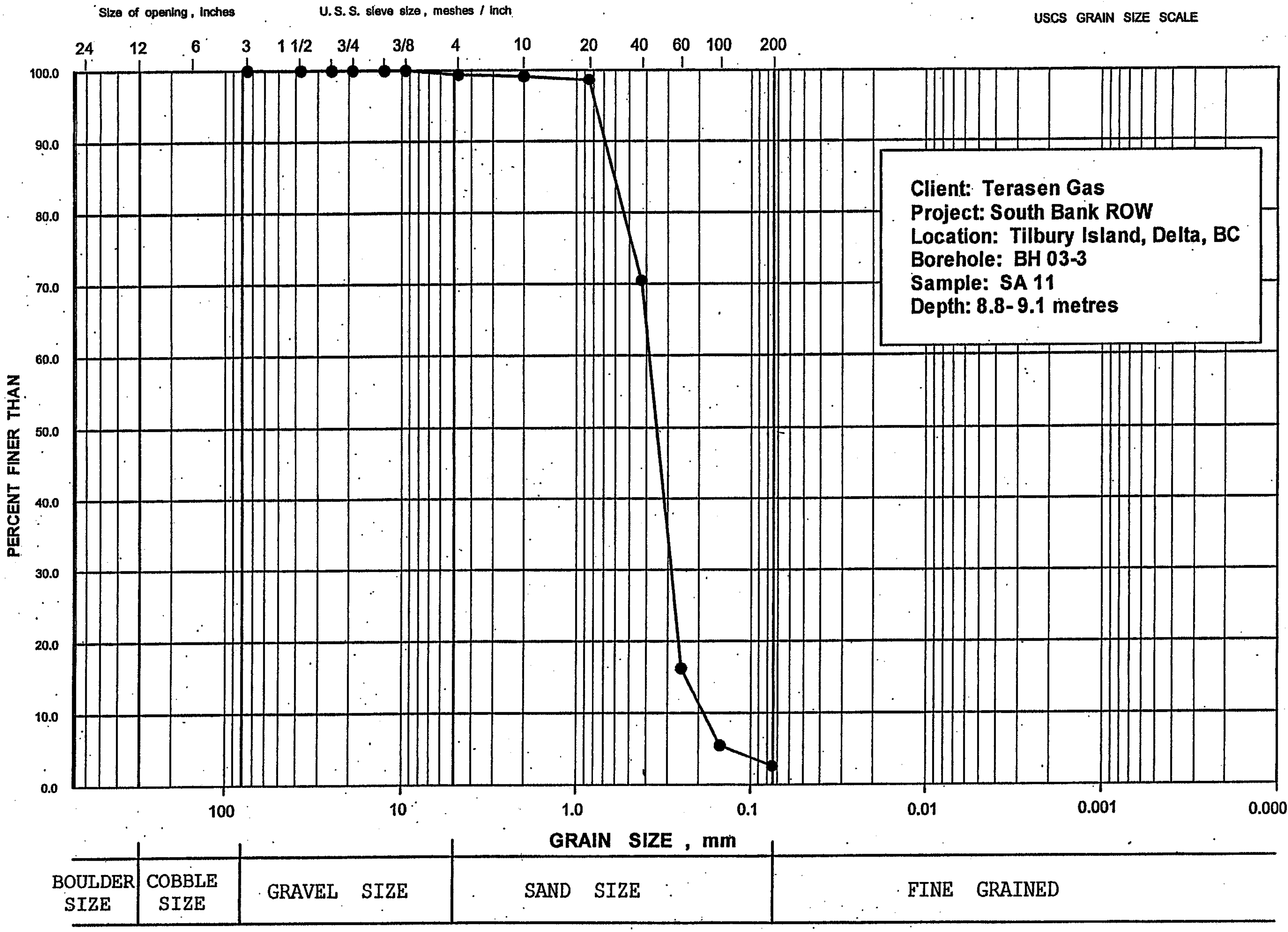
Client: Terasen Gas
Project: South Bank ROW
Location: Tilbury Island, Delta, BC
Borehole: BH 03-3
Sample: SA 7
Depth: 5.8-6.1 metres

Project No.: ..031-411050..
Drawn: ....LL..................
Reviewed: ....
Date:....December 17/03..

Golder Associates

GRAIN SIZE DISTRIBUTION

Figure



Client: Terasen Gas
Project: South Bank ROW
Location: Tilbury Island, Delta, BC
Borehole: BH 03-3
Sample: SA 11
Depth: 8.8- 9.1 metres

Project No.: ..031-411050..
Drawn: ....LL..................
Reviewed: ....
Date:....December 17/03..

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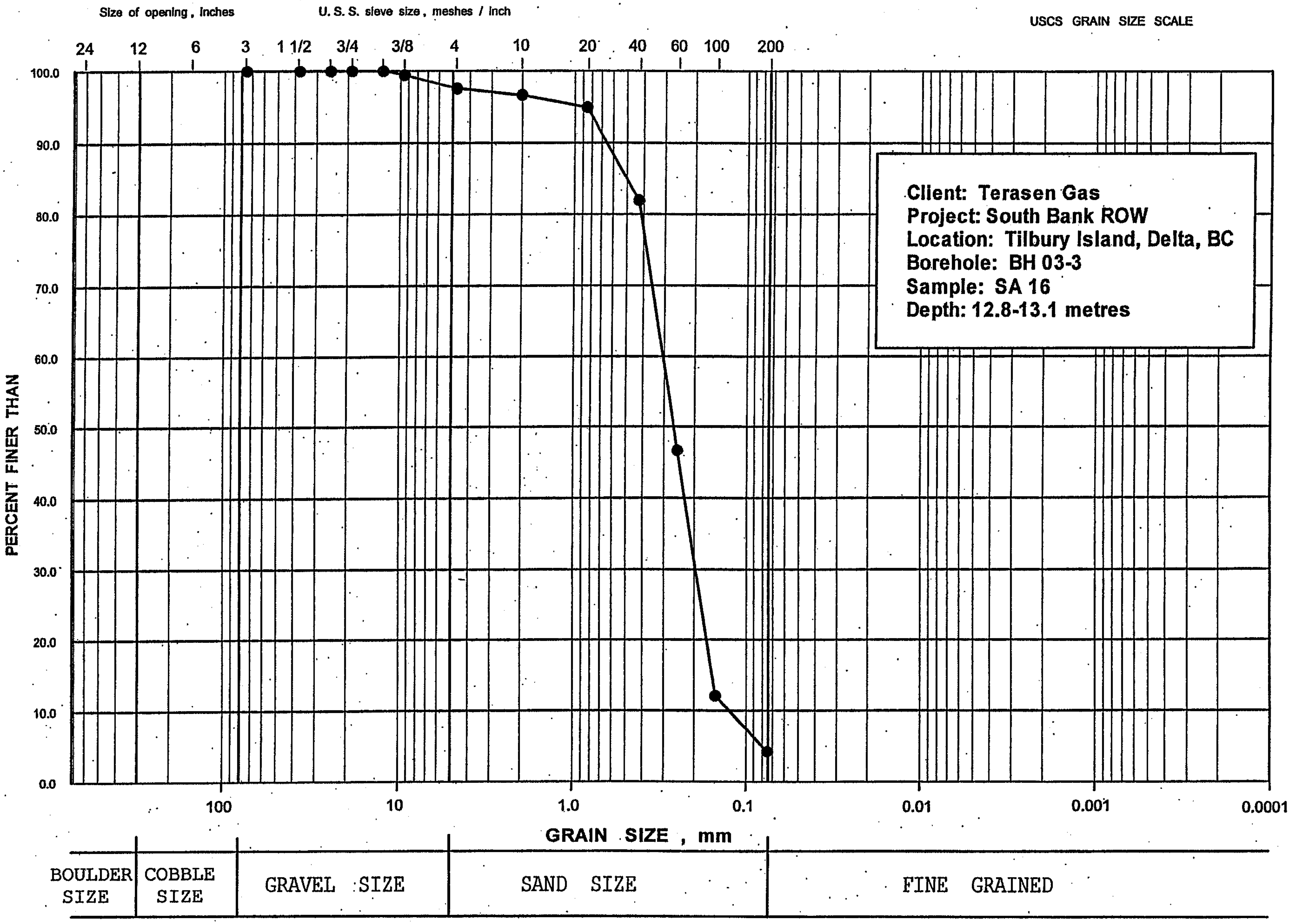
GRAIN SIZE DISTRIBUTION

Figure



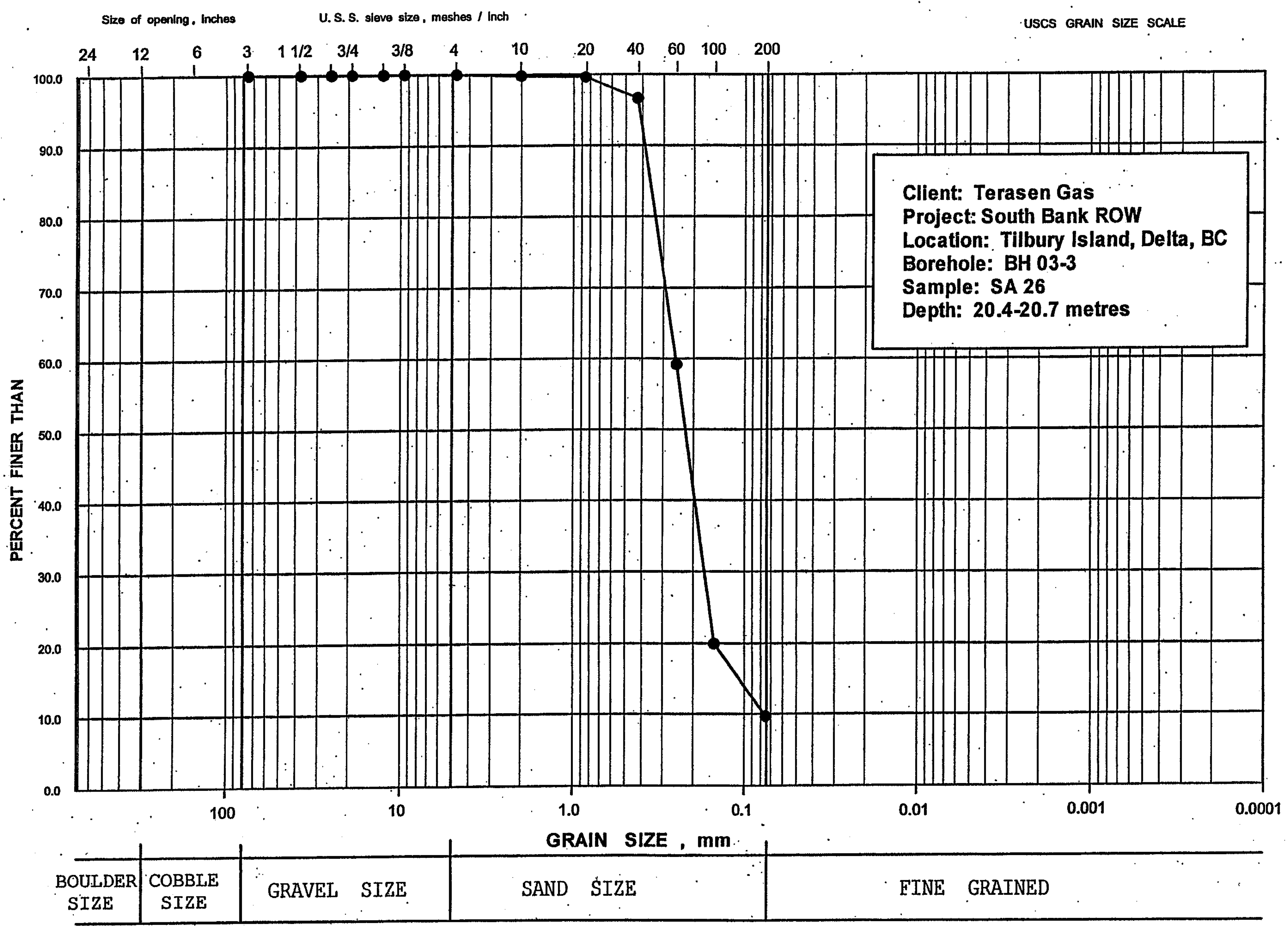
Client: Terasen Gas
Project: South Bank ROW
Location: Tilbury Island, Delta, BC
Borehole: BH 03-3
Sample: SA 16
Depth: 12.8-13.1 metres

Project No.: ..031-411050..
Drawn: ....LL.................
Reviewed: ....
Date:....December 17/03..

Golder Associates

GRAIN SIZE DISTRIBUTION

Figure



Client: Terasen Gas
Project: South Bank ROW
Location: Tilbury Island, Delta, BC
Borehole: BH 03-3
Sample: SA 26
Depth: 20.4-20.7 metres

Project No.: ..031-411050..
Drawn: ....LL.................
Reviewed: ....
Date:....December 17/03..

Golder Associates

GRAIN SIZE DISTRIBUTION

Figure

APPENDIX II

LETTER FROM DGHC DATED SEPTEMBER 29, 2005

D.G. Honegger
Consulting

September 29, 2005

Mr. Allen Mitchell, P.Eng.
Project Manager
Terasen Gas Inc.
1975 Springfield Road
Kelowna, British Columbia
CANADA V1Y 7V7

Subject: Reanalysis of Terasen Gas NPS 20 and NPS 24 Pipelines at the South Arm of the Fraser River for Modified Estimates of Seismically-Induced Lateral Spread Displacements

Mr. Mitchell:

This letter summarizes the most recent assessments of the NPS 20 and NPS 24 transmission pressure Terasen Gas Inc. (Terasen) pipelines that cross the south arm of the Fraser River. This assessment has identified potential vulnerabilities to both pipelines as currently configured and provides recommendations for improving pipeline performance to provide reasonable confidence that the pipelines will maintain pressure integrity for earthquake ground motions with an annual probability of exceedance less than 0.05% (1/2,000). This performance requirement accepts a risk that local damage may occur (e.g., pipe wall wrinkling) and some pipeline repair or replacement may be required following the earthquake.

This letter is intended to provide Terasen with the basis for formulating decisions on what mitigation actions are warranted to meet the above performance objectives. To this end, three general options are provided for consideration. Each of these options has several benefits and drawbacks and differs considerably with respect to initial implementation costs and potential post-earthquake repair costs.

Summary of Past Efforts

The south arm crossing has been evaluated several times D.G. Honegger Consulting (DGHC) and Golder Associates Ltd. (Golder) since the potential vulnerability of the crossing was identified in a 1994 regional seismic hazard risk assessment.

Golder has provided input to these analyses by:

- carrying out subsurface investigations to define the soil stratigraphy;
- identifying zones of potential earthquake-induced soil liquefaction;
- overlaying pipeline geometry data (derived initially by geophysical exploration, then by applying fitted geopig data);
- carrying out ground response analyses to provide estimates of soil displacements at the pipeline locations, with and without possible ground improvement measures; and

- providing input on the feasibility and order-of-magnitude costs of possible ground improvement and horizontal directionally drilled (HDD) pipeline replacement options.

DGHC has performed finite element analyses to compute the response of the pipelines from the soil displacements estimated by Golder with the following goals:

- compute the deformations induced in the pipelines produced by the estimated soil displacements in their current configuration and the impact of the pipeline deformations on the ability of the pipeline to retain pressure integrity or long-term safe operation;
- assess and make recommendations for improvements in pipeline response that might result from physical modifications to the pipelines (e.g.,. replacement pipe with increased wall thickness, induction bends, or alternate on-shore alignment).
- assess the improvements in pipeline response from implementing ground improvement measures to reduce the amount of soil displacement;

A summary of the key findings with respect to expected pipeline performance for ground displacements with an annual probability of exceedance less than 0.05% is provided in Table 1. Some key characteristics of the analyses that have been performed since 1997 are provided in Table 2 and are summarized below.

1997 Assessment: The initial pipeline assessments were performed in 1997 based upon ground deformations estimated at the north and south banks using the finite element computer program SOILSTRESS. This assessment concluded that at the north bank the NPS 20 pipeline performance was acceptable, and that acceptable performance could be achieved by modifying the onshore portion of the NPS 24 pipeline on the north bank in conjunction with planned pipeline modifications to accommodate soil loading on the north bank (part of Terasen's Fraser River to Nelson Gate Pipeline Right-of-Way Improvement Project, now completed). At the south bank, the displacement capacity for the NPS 20 pipeline was determined to be much greater than the estimated bank displacements while the NPS 24 pipeline was considered to be marginally acceptable with a displacement capacity nearly equal to the estimated ground displacement. Critical locations in terms of pipeline strains were noted as being beneath the river for both the NPS 20 and NPS 24 pipelines.

2003 Assessment: A reassessment of the pipelines at the south bank in 2003 examined the impact of new information on the pipeline profiles and soil cover over the pipelines derived from plotting of pipeline geometry "geopigging" data and using ground displacement estimates similar to those used in the 1997 analyses. The 2003 assessment utilized more refined analysis methods and identified a potential for pipeline buckling beneath the river for both the NPS 20 and NPS 24 pipelines. This buckling response was not captured in the 1997 analyses because of computer storage limitations that restricted the number of applied displacement increments that could be applied in the pipeline analysis. Analyses of the response of the NPS 20 and NPS 24 pipelines at the north bank were repeated using the refined methodology and confirmed that the conclusions from the 1997 analyses remained valid.

Spring 2004 Assessment: New analyses were performed in 2004 to provide an improved estimate of the likely ground deformations on the south bank using the finite difference computer program FLAC (Fast Langrangian Analysis of Continua). The primary reason for the revised ground displacement analyses was to confirm the prior results obtained using SOILSTRESS since the FLAC program incorporates a much more robust and rigorous method for estimating liquefaction-induced ground displacements. In addition, supplementary geotechnical investigations were undertaken to better define the variations in subsurface conditions at the site and additional geometry pig data was incorporated to provide more accurate pipeline profiles at the crossing. Completely new analytical models for the pipelines were also developed using the same stationing information incorporated into the FLAC analyses. The maximum ground displacement computed using FLAC was comparable to prior estimates using SOILSTRESS but the variation of ground displacement was significantly different. However, the conclusions were essentially the same with respect to finding both pipelines to have inadequate displacement capacity resulting from buckling beneath the river. Additional pipeline analyses performed in 2004 indicated that improved pipeline performance might be achieved if ground improvement measures could be implemented to reduce the amount of liquefaction-induced ground displacement.

2004 to 2005 Assessment: Efforts between April 2004 and January 2005 focused on defining possible ground improvement options to reduce the estimated lateral spread displacements at the south bank to a level that could be tolerated by the pipelines. At the same time, Terasen began to assess the potential for developing a new replacement crossing, installed using horizontally directional drilling (HDD) methods to improve seismic performance. Slightly revised ground deformations patterns were recommended for the analyses that incorporated some smoothing of the discontinuous ground displacements computed with FLAC and the decay of ground displacements outside of the region modeled with FLAC. With these modified displacement patterns, the NPS 20 pipeline performance was found to be marginally acceptable without ground improvement, and both the NPS 20 and NPS 24 pipelines were found to acceptable with the construction of five densified soil barriers (seismic dykes) on the south bank. Analyses were also performed for an alternate alignment of the NPS 24 pipeline in which the pipeline offset at the southern river bank, used to provide separation between the NPS 20 and NPS 24 pipelines through the river crossing, was relocated several hundred meters to the south to be outside of the zone of ground deformation. With this alternate alignment, which would require new right-of-way acquisition, the NPS 24 pipeline was found to be acceptable without ground improvement. Based upon these findings, it was concluded that a new HDD pipeline crossing was not required to meet Terasen's current seismic performance objectives (no loss of pressure integrity).

Spring-Summer 2005 Assessment: Considering that the conclusions from the efforts through January 2005 were dependent upon assumptions regarding ground displacements outside of the region modeled in the FLAC analyses and the importance of having high confidence in the selected mitigation strategy, it was decided to extend the FLAC model to encompass both banks as well as a region well beyond the river banks. For similar reasons the pipelines were exposed and surveyed at several locations in order to reconcile anomalies in the geometry pig data. The pipeline model geometry was also completely revised to reflect the changed pipeline geometry and changes to the configuration of the NPS 20 and NPS 24 pipelines on the north bank that were implemented in 1998.

The revised pipeline geometry resulted in a shift of the pipeline depths within the layers of soil deposits susceptible to liquefaction and experiencing lateral spread displacement. Since the ground displacements along the pipeline are directly related to the position of the pipeline within the liquefiable soil layers, the amount and distribution of ground displacements along the pipeline changed, with the maximum displacement increasing for the NPS 20 pipeline and decreasing for the NPS 24 pipeline.

The extended FLAC model computes simultaneous ground displacements for both river banks with some ground displacement along the pipeline occurring throughout the crossing. Based upon anecdotal observations in past earthquakes and studies to develop probabilistic estimates of liquefaction, the likelihood of experiencing the computed lateral spread displacements at either the north bank or south banks is judged to be in the range of 30% to 70%. Consequently, the likelihood that both banks will simultaneously experience the computed lateral spread displacements is judged to be in the range of 10% to 50%. On this basis, it is considered too conservative to assume simultaneous bank displacements in combination with ground motions that have a very low likelihood of occurrence. Conversely, it is considered unconservative to only assume movement at one bank when, as is the case for the south arm analyses, the ground displacements are not limited to the regions near the river banks. There are no generally accepted methods for resolving this issue. The approach adopted for the south arm assessments was to consider only 50% of the opposite bank displacement as occurring simultaneously.

Note that several analyses were performed with simultaneous bank displacements on the basis that demonstrating adequate performance for a ground displacement scenario that is more severe than what is considered likely minimizes the importance of assumptions regarding the apportionment of displacements between opposite river banks.

The pipeline analyses based upon the extended FLAC model indicated that the NPS 24 pipeline is marginally acceptable with piping modifications on the south bank that include replacing the 7.1 mm X52 pipe with 13.7 mm X60 pipe north of the dyke and replacing the 3D elbows with 12D induction bends. The NPS 20 pipeline was found to be susceptible to damage at 60% of the predicted ground displacement. Additional FLAC analyses were performed to determine the effectiveness of constructing ground densification barriers across both pipeline alignments at the north and south banks. With the ground improvement barriers, the NPS 20 pipeline was found to be acceptable from the standpoint of maintaining pressure integrity, and may remain operational following the earthquake. With the placement of ground improvement barriers in combination with modifying the onshore portion of the NPS 24 pipeline at the south bank, the NPS 24 pipeline was also found to be acceptable from the standpoint of maintaining pressure integrity. For both the NPS 20 and modified NPS 24 pipeline, the most highly strained portions of the pipelines are located beneath the river.

Summary of Options to Improve Pipeline Seismic Performance

The analyses performed since 2003 indicate that the NPS 20 and NPS 24 pipelines are vulnerable to marginally acceptable if exposed to ground displacements that can potentially occur as the result of a severe earthquake. The number of analyses that have been considered since 2003 have highlighted the sensitivity in computed ground displacement patterns along the pipelines with the elevation of the pipelines within soil layers undergoing liquefaction. This sensitivity is a key factor in the changes in the reported level of vulnerability assigned to the NPS 20 and NPS 24 pipelines in past evaluation efforts.

Given that the predicted performance of both the NPS 20 and NPS 24 pipelines is either marginal or unacceptable (in that they fail to meet Terasen's seismic performance objectives), our recent assessment has confirmed that the "do nothing option" is not a viable alternative at this site and is thus excluded from further consideration herein.

If significant ground improvement measures are implemented on the south bank (comprising the construction of six densification barriers and limited onshore piping improvements at the NPS 24 pipeline) and a single densification barrier is constructed on the north bank, the performance of the pipelines can be improved to the point that pressure integrity can be considered likely for both pipelines. The most critical location in terms of pipeline strains for both pipelines is likely to be beneath the river. Considering that the computed pipeline strains are sufficient to cause local distortion of the pipe wall, it is possible that repair or limited replacement of one or more pipelines will be necessary, even with ground improvements measures, following a severe earthquake. With these considerations in mind, three options are presented in Table 3 for consideration by Terasen.

The option that carries the lowest initial cost involves only limited modification to the onshore portion of the NPS 24 pipeline at the south bank. This option accepts the likely loss of pressure integrity for the NPS 20 pipeline in a severe earthquake, making post-earthquake replacement of the NPS 20 pipeline by a new HDD crossing very likely. There is also a likelihood of damage to the NPS 24 pipeline that will require repair to restore the pipeline to the pre-earthquake conditions or possible replacement with a new HDD crossing. It should be noted that this option does not meet the performance requirements that have been used in past pipeline seismic assessments for Terasen.

Modifying the onshore portion of the NPS 24 pipeline at the south bank, combined with installation of ground densification barriers across both pipelines at both the north and south banks of the river to reduce the amount of ground displacement, is also an option. This option provides reasonable assurance that both pipelines will retain pressure integrity following a severe earthquake and achieves a level of pipeline performance that has been considered acceptable in past pipeline evaluations performed for Terasen. While there is a possibility that both pipelines will remain operational following the earthquake, it is equally possible that local pipe wall distortion could result in the need to repair or replace one or both pipelines.

A third option is to replace one of the pipelines with a new HDD crossing. The NPS 20 pipeline is considered to be the best candidate for replacement because of its greater seismic vulnerability and the potential interference issues that may exist with attempting to replace the NPS 24 pipeline, which is located between the NPS 20 pipeline and a NPS 42 GVRD water pipeline on the south bank (Note: the GVRD watermain is also considered to be potentially vulnerable to rupture during strong seismic shaking and is currently the subject of a separate review). This option also includes the same modifications to the onshore portion of the NPS 24 pipeline considered in the other two options in order to provide a reasonable level of assurance that the NPS 24 pipeline will retain pressure integrity following a severe earthquake. The HDD replacement option provides a much more robust mitigation measure as the HDD crossing can be designed to provide a relatively high level of confidence of continued operation of the NPS 20 pipeline following a severe earthquake, which could be a significant added advantage. While this option achieves a higher level of performance than has been established in past evaluations for Terasen, this improved performance may be warranted because of post-earthquake operational considerations.

The order-of-magnitude costs associated with the three proposed options identified above and summarized in Table 3 are very approximate and identify both initial costs and costs that may be incurred following the occurrence of a severe earthquake to return the pipelines to their pre-earthquake conditions. The potential post-earthquake costs in Table 3 are substantial, with the upper range of cost estimates associated with the assumption that it will not be possible to implement repairs beneath the river, thus necessitating the replacement of one or two pipeline crossings using HDD. The potential post-earthquake repair costs could be substantially less if it is possible to implement repair of local pipe damage or replacement of a limited length of pipeline located beneath the river.

I hope the information in this letter report meets your needs. Please let me know if you have any questions.

Best regards,

Doug Honegger

Douglas G. Honegger

cc: Golder Associates Ltd.

Table 1: Summary of Findings from Analyses at South Arm Crossings

Date	Reason for Assessment	Key Findings
February 1997	Detailed evaluation of vulnerability identified in the 1994 regional seismic risk assessment	• NPS 24 vulnerable on north bank and marginally acceptable on south bank • NPS 20 pipeline acceptable • Modifications made to NPS 24 on north bank to increase displacement capacity
July 2003	Assess impact of additional soil cover and geometry pig information	• NPS 20 and NPS 24 pipelines vulnerable to buckling failure beneath river at 40% to 60% of the 1/2,000 ground displacement[1]
April 2004	Assess for new ground displacement estimates for south bank using detailed FLAC analysis model and supplementary borehole data	• NPS 20 and NPS 24 pipelines vulnerable to buckling failure beneath river at 50% to 75% of the 1/2,000 ground displacement • To be effective, ground improvement measures would be needed to reduce offshore ground displacements
January 2005	Assess benefits of various ground improvement strategies on south bank	• NPS 20 marginally acceptable • NPS 24 acceptable for case with 5 ground improvement barriers on south bank • NPS 24 acceptable if portion of pipeline parallel to river bank moved south of extent of ground deformation (requiring new right-of-way acquisition) • Questions raised regarding validity of assumed ground displacements outside of region represented in the FLAC model
July 2005	Assess pipeline response for extended FLAC analyses encompassing both the north and south banks with modified pipeline geometry (geopig) data	• NPS 20 vulnerable to loss of pressure integrity at approximately 60% of estimated displacement • Existing NPS 24 pipeline configuration vulnerable to loss of pressure integrity at 50% to 90% of the estimated 1/2,000 displacement • NPS 24 marginally acceptable with modification of pipeline on south bank
September 2005	Assess pipeline response for extended FLAC analyses with ground improvement measures on both north and south banks	• NPS 20 acceptable for pressure integrity and may remain operational following the earthquake • NPS 24 acceptable for pressure integrity with modification of pipeline on south bank; may remain operational following the earthquake

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[1] The vulnerability to buckling was largely the result of a more refined analysis performed in 2003 that incorporated smaller applied displacement intervals. These refinements were not possible given computational capabilities in 1997 and as a result, the 1997 analyses did not capture the buckling response of the pipelines.

Table 2: Summary of Results for Analyses Performed at South Arm Crossings

Description		Zone of Ground Displ. (m)	Maximum Ground Displ. (m)	Pipeline Displ. Capacity[2] (m)	Critical Strain Location
1997[1]	NPS 20 North Bank	200	1.1	1.1+	Beneath River
	NPS 24 North Bank	225	1.1	1.8	On-Shore Bend
	NPS 20 South Bank	430	2.8	2.8+	Beneath River
	NPS 24 South Bank	430	2.8	2.8	Beneath River
2003	NPS 20 South Bank	430	2.8	1.4	Beneath River
	NPS 24 South Bank	430	2.9	1.7	Beneath River
	NPS 24 South Bank with Straight Pipeline Alignment through Ground Displacement Zone	430	2.9	1.9	Beneath River
	NPS 24 South Bank with No Ground Displacement South of Nearshore Bend	320	2.9	2.0	Beneath River
Spring 2004	NPS 20 South Bank	489	2.2	1.4	On-Shore
	NPS 24 South Bank (No Firm Ground Zone)	489	2.2	1.7	Beneath River
	NPS 24 South Bank (Firm Ground Zone)	418	2.2	2.2	Beneath River
	NPS 20 South Bank with No Ground Displacement South of Nearshore Bend on NPS 24 Pipeline (No Firm Ground Zone)	306	2.2	1.4	Beneath River
	NPS 24 South Bank with No Ground Displacement South of Nearshore Bend (No Firm Ground Zone)	306	2.2	1.7	Beneath River
	NPS 24 South Bank with No Ground Displacement South of Nearshore Bend (Firm Ground Zone)	235	2.2	2.9+	Beneath River
Fall 2004- Spring 2005	NPS 20 South Bank	510	1.4	1.5	Beneath River
	NPS 24 South Bank	544	1.6	1.1	Beneath River
	NPS 20 South Bank with Six Ground Densification Barriers (Liquefaction within Barriers)	510	1.0	1.9+	Beneath River
	NPS 20 South Bank with Six Ground Densification Barriers (No Liquefaction within Barriers)	510	1.0	1.3	Beneath River
	NPS 24 South Bank with Six Ground Densification Barriers (Liquefaction within Barriers)	544	0.7	1.2	Beneath River
	NPS 24 South Bank with Six Ground Densification Barriers (No Liquefaction within Barriers)	544	0.7	1.0	Beneath River
	NPS 24 South Bank with Straight Pipeline Alignment through Ground Displacement Zone	544	1.6	2.9+	Beneath River
	NPS 24 South Bank with Straight Pipeline Alignment through Ground Displacement Zone and Extended Displacement Zone	644	1.6	1.9	Beneath River
Summer 2005[3]	NPS 20 (100% SB, 50% NB)	468 NB 529 SB	1.6 NB 2.4 SB	1.1 NB 1.6 SB	Beneath River
	NPS 24 (Firm Ground Zone, 100% NB, 100% SB)	337 NB 335 SB	1.4 NB 1.1 SB	0.8 NB 0.6 SB	On-Shore Elbow
	NPS 24 (No Firm Ground Zone, 100% NB, 100% SB)	557 NB 356 SB	1.4 NB 1.1 SB	1.3 NB 1.0 SB	Beneath River
	NPS 24 with Modified South Bank Piping (Firm Ground Zone, 100% NB, 100% SB)	337 NB 335 SB	1.4 NB 1.1 SB	1.4 NB 1.1 SB	Beneath River
	NPS 20 with Ground Densification Barriers (100% SB, 100% NB)	538 NB 468 SB	1.7 NB 1.7 SB	2.3 NB 2.3 SB	Beneath River
	NPS 24 with Modified South Bank Piping and Ground Densification Barrier (100% NB, 100% SB)	588 NB 408 SB	1.2 NB 0.9 SB	1.4 NB 1.1 SB	Beneath River

1. Displacement capacities reflect current allowable compression strain limits instead of those used in 1997
2. A + after the number indicates that the displacement capacity exceeds the displacement applied in the analyses
3. 2005 analyses compute displacements on both banks. Values of the length of pipeline exposed to ground displacement provided for the north bank (NB) and south bank (SB) for comparison with other table entries.

Table 3: Options to Improve Pipeline Performance at South Arm Crossings

Option	Features	Approx. Cost Factors
Modify NPS 24 onshore pipeline	👍 Increases pressure integrity displacement capacity of NPS 24 pipeline to equal the computed lateral spread ground displacement 👍 Can be implemented within existing pipeline right-of-way 👎 Accepts potential for loss of pressure integrity to NPS 20 pipeline from damage beneath river 👎 Accepts likelihood for repair of pipeline damage beneath the river or replacement of one or both pipeline crossings to restore to normal operating condition.	Current Likely less than $300,000 for pipeline modifications Post-Earthquake Likely $8M to $12M if HDD replacement crossing is needed Possibly $16M to $24M if two HDD replacement crossings are needed
Modify NPS 24 onshore pipeline and install ground densification barriers at onshore and offshore locations across both pipelines	👍 Reduces computed ground displacement to a level that can be accommodated by the NPS 20 and NPS 24 pipelines for pressure integrity and may allow continued operation 👎 Accepts likelihood for repair of pipeline damage beneath the river or replacement of one or both pipeline crossings to restore to normal operating condition (much more likely for the NPS 20 pipeline). 👎 Construction of ground densification barriers may require significant steps to limit or mitigate environmental disturbance on the river banks and within the river channel and carries some risk associated with unexpected soil conditions. 👎 There is some level of risk for pipeline damage during construction of densification barriers that must be constructed near the pipelines.	Current $4M to $6M for ground densification Post-Earthquake Possibly $16 to $24M if HDD replacement of both crossings is needed
Modify NPS 24 onshore pipeline and install new HDD crossing for the NPS 20 pipeline	👍 Increases pressure integrity displacement capacity of NPS 24 pipeline to equal the computed 1/2,000 lateral spread ground displacement 👍 Can provide high confidence that NPS 20 pipeline crossing will remain fully operational for the computed 1/2,000 lateral spread ground displacement. 👍 Pipeline replacement and improvements can be constructed with relatively low risk to existing pipelines and limited environmental disturbance. 👎 Accepts possibility for repair of pipeline damage beneath the river or replacement of NPS 24 pipeline crossing to restore to normal operating condition.	Current $8M to $12M for new NPS 20 HDD crossing and limited NPS 24 onshore piping improvements Post-Earthquake Possibly $8M to $12M if HDD replacement crossing is needed for NPS 24 pipeline

Appendix 4

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

#500-1045 Howe Street
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Canada V6Z 2A9
Tel: 604.684.5900
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September 28, 2007

Mr. Dan Ellis, P.Eng.
Manager, System Integrity Programs
Terasen Gas Inc.
16705 Fraser Highway
Surrey, BC
V3S 2X7

Dear Mr. Ellis,

<u>Re: Tilbury Crossing Seismic Review</u>

1.0 INTRODUCTION

Further to your request, BGC Engineering Inc. (BGC) has reviewed Golder Associates' (Golder's) assessment of the seismic performance of the Tilbury pipeline crossing of the south arm of the Fraser River between the Cities of Delta and Richmond. The intent of the review undertaken by BGC on behalf of Terasen Gas Inc. (Terasen) was to confirm the suitability of the approach adopted by Golder as measured against the current standard of practice for similar seismic assessments. As discussed with Terasen, BGC's scope of work was limited to reviewing the documents and figures provided along with responses to any posed questions. Due to time limitations and proprietary concerns raised by Golder, a detailed review of the input parameters, constitutive model and output from the numerical models created as part of the assessment was not possible. This review focussed principally on the following documents submitted to BGC in early August 2007:

- <u>Assessment of Seismic Performance - Terasen Gas Inc. NPS 20 and NPS 24 T.P Pipelines South Arm of Fraser River Tilbury Island (Delta) to Richmond BC</u>, dated August 9, 2007
- <u>Site-Specific Seismic Vulnerability Assessment of BC Gas Transmission Pipelines at the South Bank of the North Arm of the Fraser River Richmond BC</u>, dated March 5, 1997.
- <u>Site-Specific Seismic Vulnerability Assessment of BC Gas Transmission Pipelines at the South Bank of the South Arm of the Fraser River Delta BC</u>, dated March 5, 1997.

2.0 REVIEW OF GENERAL METHODOLOGY

Golder's initial assessment of the Tilbury crossing was in their 1997 report. Subsequent revisions to the analysis occurred in 2003, 2004 and again in 2005. The reasons behind these revisions can generally be split into two groups, as follows:

1. Advancement of analytical techniques (including changing standards of practice, improved analytical software and increased computer power)
2. Refinements to knowledge of the site (including improved definition of the pipeline location and the inclusion of additional boreholes)

The results from BGC's review of the 2007 Golder report indicate that while much of the September 2005 assessment relies upon previous assumptions and data, through each iteration, attempts have been made to consistently adopt the standard of practice at that time while incorporating either new knowledge of the site or improved analytical techniques.

Reviewing the results from the development of the seismic record to be used as an input for the ground deformation assessment, no major issues or inconsistencies are evident with the implementation of these records. Some points of discussion, however, were raised regarding the decision to select only one seismic record for implementation into the deformation model, and in the decision to not analyse for the subduction earthquake event. For the first point, Golder selected six earthquake records from 3 different historical earthquakes, scaled the records to match the target spectrum for the Lower Mainland, and through the use of the computer program SHAKE, estimated the site response and the cyclic stress ratio (CSR) with depth. As described in the Task Force Report on Geotechnical Design Guidelines for Buildings on Liquefiable Sites in Accordance with NBC 2005 for Greater Vancouver Region (Anderson, Byrne et al. 2007), the Task Force has recommended that a minimum of 3 records should be used. Due to time and budget constraints, Golder elected to use only the record producing the highest CSR. Whilst the CSR is an important factor in determining the triggering of liquefaction, other features from the earthquake records including the number of cycles and duration of the earthquake will also influence the deformation results. By not analyzing for the longer duration subduction earthquake event, an unconservative estimate on the total ground displacement may occur. These two points will not have a significant effect on the outcome of the overall assessment as the current assessment already indicates the need for mitigation of the crossing.

The methodology and procedure to calculate the ground deformations are in accord with the current standard of practice. The analysis was conducted using the finite difference based software, FLAC-2D Version 4.0. Liquefiable soil layers within the analysis were modelled with the UBCTOT soil model (Byrne et al. 2003), a synthesized approach for modelling both liquefaction triggering and liquefaction induced displacements within a single analytical model. As with the development of the seismic record, the review by BGC was limited to the methodology and no independent data analysis or numerical modelling was conducted.

It should be noted that a significant input to the numerical analysis is the interpreted stratigraphic profile of the subsurface, which itself is based on the results of the site investigation. Within the profile, the actual thickness and properties of the soil layers at positions along the pipeline crossing may be thicker or thinner than identified at the specific locations in the site investigation, and similarly, material properties, such as grain size or density which may affect the behaviour of identified soil types may vary away from the specific test locations. Due to the large number of parameters that are utilized in these forms of analyses, full parametric studies beyond the variation of only one or two parameters are not typically practical, and hence representative values based either on the results from samples obtained during the site investigation or approximated values are typically adopted. The interpreted stratigraphic profile produced by Golder and soil parameters appear reasonably consistent with the original site investigation data. Points of discussion were raised with Golder regarding the lateral extent of some layers and the change in ground conditions over time including filling, pre-loading and construction since the earliest boreholes were drilled, but overall these issues will not result in a significant change to the assessment.

The results from the most recent soil deformation assessment conducted by Golder are illustrated in Figure 1. These results indicate that liquefaction will extend over the full length of the crossing, and with ground displacements of up to almost 6 metres occurring. These results appear reasonable and within the range of displacements predicted for other crossings within the Lower Mainland. Points of discussion were raised over the potential for liquefaction of the silt, and it was determined that current methods for liquefaction assessment of the silts were implemented in this study.

The pipeline deformation assessment was conducted by Mr. Douglas Honegger of D.G. Honegger Consulting (DGHC) in California, USA. Discussion on the methodology and results used for this assessment was included as an appendix in the 2007 Golder report. To assess the pipeline deformation, DGHC conducted numerical modelling by finite element analysis techniques to compute the response of the pipelines from the soil displacements estimated by Golder. BGC has not reviewed the detailed methodology used for this study. However, BGC has performed an independent analysis of the soil-pipeline interaction using a simplified method recommended by O’Rourke et al. (1995). Using O’Rourke’s simple inelastic model, wrinkling is predicted for the approximately 700 metres of pipeline exposed to large soil displacements during or immediately following the design earthquake. This result is in agreement with those presented by DGHC.

3.0 REVIEW OF ASSESSMENT CONCLUSIONS AND RECOMMENDATIONS

From the perspective of design solutions, Golder has provided a number of mitigative alternatives including:

1. Replacement of the vulnerable on-shore segments using conventional trenching and pipeline replacement techniques to both straighten the alignment and strengthen the pipe;
2. Implementation of a ground improvement program to reduce the extent and consequences of seismically-induced soil liquefaction near the river banks;
3. Replacement of the vulnerable pipeline crossings with horizontal directional drilling (HDD) techniques; and
4. Combinations of the above alternatives.

Each of these alternatives provides a method for reducing the seismic vulnerability of the pipelines, ranging from altering the structural performance of the pipeline, to changing the ground conditions, to avoiding the vulnerability problem altogether by replacing the pipeline crossing by HDD. While each of these alternatives provided by Golder has the potential to be successful in reducing the seismic vulnerability to acceptable levels, both the costs associated with implementing these solutions and the level of assurance that the seismic vulnerability will be adequately lowered, need to be assessed. As mentioned previously, the ground displacement analysis is highly sensitive to variations in the input parameters. Consequently, those mitigation alternatives which rely most on the results of the ground displacement analysis will also be highly sensitive to such variations, and thus the hardest to assure that an adequate lowering of the seismic vulnerability has been achieved without an overly conservative approach being adopted. This sensitivity and its impact on the assurance of achieving a suitable level of seismic vulnerability are most apparent for the ground improvement mitigation alternative. The results from the Golder assessment have indicated that by undertaking a ground improvement program involving the creation of a series of seismic “dykes”, the extent of liquefaction and degree of lateral spreading or flow failure can be controlled. The risk associated with implementing this mitigation strategy is that the number, size, and spacing of these dykes are dependent upon the extent of liquefaction predicted by the ground deformation assessment. Since the extent of liquefaction is highly sensitive to the soil profile, input motion, and selected soil parameters, discrepancies between the model and ‘real world’ will lead to uncertainty in the ability of the ground improvement program to prevent excessive ground displacement.

In the 2007 Golder report, the recommended mitigation options have been limited to replacing the vulnerable onshore pipeline segments and replacing the entire crossing with the HDD technique, dropping the option of ground improvement. Given the magnitude of the predicted liquefaction zone spanning the entire crossing, as illustrated in Figure 1, consideration should be given to ground improvement at the entry and exit point locations of the HDD, where load from displacing soils could excessively strain the HDD pipeline.

4.0 CONCLUSIONS

Based on the review of the provided documents, Golder has conducted a seismic assessment of the Tilbury crossing that generally follows the current standard of practice. The overall conclusion that both the NPS 20 and NPS 24 pipelines are vulnerable to deformations exceeding Terasen's performance criteria is in agreement with BGC's opinion.

BGC fully supports Golder's recommendation that the crossing be replaced by HDD. However, should Terasen wish to adopt the seismic dyke mitigation strategy, a sensitivity analysis of the capability of this mitigation method to successfully reduce the seismic vulnerability to acceptable levels given varying soil parameters should be conducted. The option of re-aligning and strengthening the vulnerable onshore sections of the NPS 24 pipeline will improve those areas, but will still leave the offshore components at some level of risk. Should an HDD be undertaken to replace the NPS 20 pipeline, it is recommended that the NPS 24 pipeline be likewise replaced by HDD to ensure that risks to the survivability of this pipeline are minimised. Should the HDD option be approved, as part of detailed design, further site investigation will likely be necessary within the centre of the Fraser River channel to characterise the subsoils where no information currently exists. At that time, both the necessity for a ground improvement zone around the entry and exit points and the effect of the subduction event could be incorporated into a refined analysis as part of the detailed design phase with a minimal cost implication to the project.

5.0 CLOSURE

BGC Engineering Inc. (BGC) prepared this report for the account of Terasen Gas Inc. The material in it reflects the judgment of BGC staff in light of the information available to BGC at the time of report preparation. Any use which a third party makes of this report, or any reliance on decisions to be based on it, are the responsibility of such third parties. BGC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

As a mutual protection to our client, the public, and ourselves, all reports and drawings are submitted for the confidential information of our client for a specific project. Authorization for any use and/or publication of this report or any data, statements, conclusions or abstracts from or regarding our reports and drawings, through any form of print or electronic media, including without limitation, posting or reproduction of same on any website, is reserved pending BGC's written approval. If this report is issued in an electronic format, an original paper copy is on file at BGC Engineering Inc. and that copy is the primary reference with precedence over any electronic copy of the document, or any extracts from our documents published by others.

We trust this report meets your requirements at this time. A signed and stamped hardcopy of this letter report will be mailed to you for Terasen's files. Please feel free to contact the undersigned should you have any questions regarding this report's content or on any other related issues.

BGC ENGINEERING INC.
per:

[Signed Originals to Follow]

Dr. Hamid Karimian	Dr. Alex Baumgard, P.Eng.
Geotechnical Engineer	Senior Geotechnical Engineer

Reviewed by

Adrian Wightman, P.Eng.
Principal Consultant

REVISION DATE:07/09/10 03:05PM By: MKennedy CADD FILE: O:\Active\#2003-4\2003\1411\100\03-1411-050 BC Gas South Bank-South Arm\August 2007 Summary for Terasen & BGC\FIGURE - Zone of Liquefaction\Fig1 - Zone of Liq.dwg

Exaggerated Grid Distortion
Magnification = 1.000E+00
Max Disp = 5.922E+00

LEGEND

- 🟦 NO LIQUEFACTION
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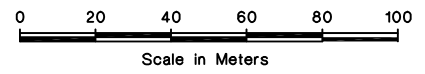


Terasen Gas

PROJECT
TERASEN GAS INC.
NPS 20 & 24 T.P. PIPELINE
SOUTH ARM-FRASER RIVER, DELTA/RICHMOND, B.C.

TITLE

ZONE OF LIQUEFACTION

Golder Associates

PROJECT No. 07-1411-0127			FILE No.	–
DESIGN	VF	07SEP07	SCALE AS SHOWN	REV. –
CADD	MJK	09SEP07		
CHECK	VF	10SEP07		
REVIEW				

FIGURE 1

Appendix 5

(Report security settings prevent insertion into the main PDF document. To view the attached file, click on the Attachment Tab to access the file, or the Bookmark for Appendix 5)

Appendix 6

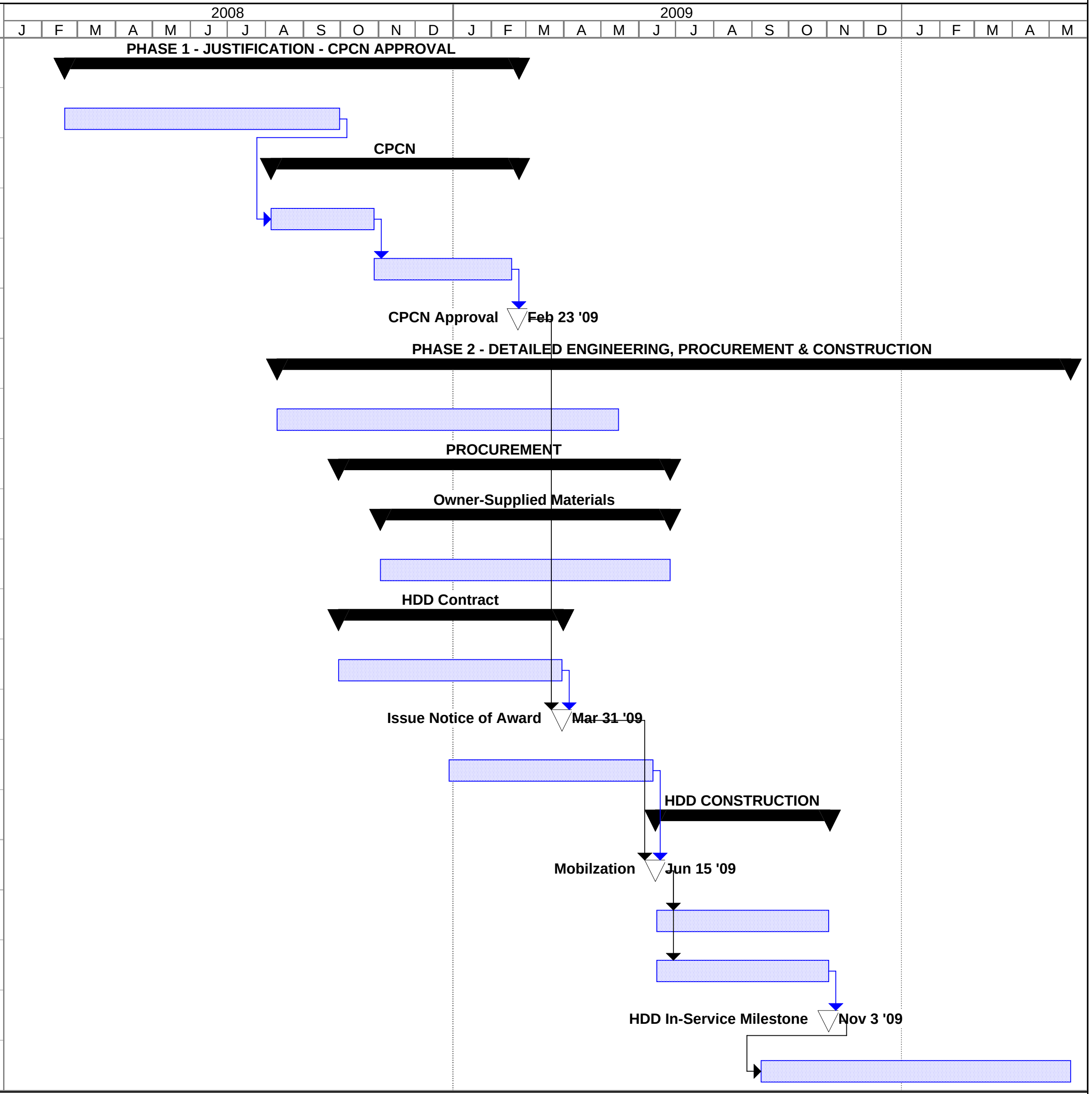
South Arm Fraser River With Transmission Pipelines
Scale: 1:5000 10cm Pixel – 2008 Orthophoto

MUJIB RAHMAN	Page:	2008/05/14

Appendix 7

FRASER RIVER SOUTH ARM CROSSING UPGRADE PROJECT : Fall 2009 In-Service Target

ID	ℹ	Task Name	Duration
1		**PHASE 1 - JUSTIFICATION - CPCN APPROVAL**	**264 days?**
2	▦	Preliminary Engineering - Environmental - Public Consultation	8 mons
3		**CPCN**	**144 days?**
4	▦	Prepare CPCN	3 mons
5		Application Review	4 mons
6	▦	CPCN Approval	1 day?
7		**PHASE 2 - DETAILED ENGINEERING, PROCUREMENT & CONSTRUCTION**	**462 days?**
8	▦	ENGINEERING	10 mons
9		**PROCUREMENT**	**194 days?**
10		**Owner-Supplied Materials**	**170 days**
11	▦	Linepipe Procurement & Other Materials	8.5 mons
12		**HDD Contract**	**131 days?**
13		Contract Preparation - Tender Process	6.5 mons
14	▦	Issue Notice of Award	1 day?
15		PERMITS	6 mons
16		**HDD CONSTRUCTION**	**102 days?**
17	▦	Mobilzation	1 day?
18		HDD Drilling	5 mons
19		Pipeline Construction	5 mons
20		HDD In-Service Milestone	1 day?
21		RESTORATION	9 mons



Project: FRSAUP Concept Schedule -
Date: Wed 10/22/08

Task	▨	Target Milestone	▼	Project Summary	▬	Deadline	▽
Split	┈	Milestone	▽	External Tasks	▬	Windows	▥
Progress	■	Summary	▬	External Milestone	◆		

Appendix 8

September 16, 2008

Terasen Gas Inc.
16705 Fraser River Highway
Surrey, BC
V4N 0E8

Attention: Mr. Art Kanzaki, P.Eng.
Project Director

Dear Mr. Kanzaki:

Re: Environmental Screening – Terasen Gas Fraser River South Arm Seismic Upgrade

Introduction

Dillon Consulting Limited (Dillon) has been retained by Terasen Gas to provide environmental consulting services in support of the proposed seismic upgrade of the existing Transmission Pressure (TP) pipeline crossing between Delta (Tilbury Island) and Richmond. This letter provides Terasen Gas with an overview of key environmental features and a screening-level assessment of predicted impacts to the environment based on the conceptual design dated May 26, 2008.

Specifically, the intent of this screening report is to identify the following:

- Existing key environmental and archaeological features within the project area;
- Potential impacts associated with the proposed project; and
- Agency consultation and timing windows.

Project Overview

It is expected that either the existing 20” or 24” NPS gas pipelines will be replaced under the South Arm of the Fraser River using trenchless technology (Horizontal Directional Drill (HDD)). In the event that the 24” pipeline is replaced, Terasen Gas may also complete in-water scour protection activities adjacent to the south bank to ensure long-term protection of the 20” pipeline.

The proposed project is located within the Fraser River Estuary Management Program (FREMP) area and the operational jurisdiction of the Fraser River Port Authority (FRPA).

Preliminary Environmental Overview of the Project Area

Dillon completed a limited walk-through assessment of accessible areas (*i.e.,* that did not require trespassing on private property) on both the north and south sides of the Project Area in support of this screening. The site visit was intended to provide supplemental/confirmatory information related to existing conditions and environmental attributes, such as the aquatic and terrestrial habitat characteristics and fish and wildlife use of the local ditches, sloughs, riparian areas and upland habitat. Fish community composition was examined to obtain information on the present condition of the aquatic habitats and to identify potentially sensitive elements within the project area. Fish community composition information is also important for the future evaluation of overall sensitivities of fish species and communities to potential changes in channel characteristics that might result from the project design. Terrestrial habitat composition was coarsely examined to determine the potential for the right-of-way to provide habitat suitable for utilization of rare element species and bird nesting. This information is deemed important to avoid conflicts with provincial and federal legislation.

This screening also includes the review of available literature and electronic databases (*e.g.,* Freshwater Fisheries Society of BC. 2008 “Fish Wizard” website). Mapping and fish inventory data contained within the Fish Wizard website were reviewed to determine which fish species may be present. The provincial Conservation Data Centre (CDC), managed under the BC Ministry of Environment (MoE), and Environment Canada’s *Species at Risk Act* (SARA) websites, were also reviewed to determine if there was any potential for rare element species to occur at the crossing or in the surrounding area.

Tilbury Island (South Side)

Tilbury Slough

Tilbury Slough is a large, cattail-dominated wetland surrounded by industrial development, fallow fields and native vegetation in retained woodlots and is considered an important habitat feature within the Project Area. This wetland extends east/west parallel to River Road and joins the Fraser River at the east side of Tilbury Island. The riparian area consists of mostly cattails, reed canary grass (*Phalaris arundinacea*), willow (*Salix spp.*) and tree stands.

Tilbury Slough has not been identified under the Corporation of Delta’s (the Corporation) Watercourse Classification System; however, the FREMP Habitat Atlas identifies the slough as a red-coded habitat. Red coded habitats include productive and diverse habitat features that support critical fish and wildlife functions on-site or as part of a more regional context. Project construction in this red coded area is restrictive, but may occur, provided that mitigation is applied through site re-location and/or re-design to avoid impacts on habitat features and functions of the area. “Fish Wizard” indicates that the slough is utilized by a large number of fish species, but this is likely reflective of its proximity to the Fraser River and ease of fish access.

Preliminary minnow trapping sessions confirmed the presence of threespine stickleback and minnows (brassy and northern pike), pumpkinseed, and bullfrog tadpoles. Salmonid access/presence in the slough requires further confirmation. Based on the condition of the habitat observed at the time of the site assessment, the aquatic and riparian habitat values for the slough are considered to be “moderate”.

Wildlife utilization is expected to include any number of species that are adapted to urban areas. This may include passerines (perching birds), woodpeckers, rodents, raccoons or coyotes. In addition, raptor species such as Bald Eagles and Red-tailed Hawks can be expected to utilize the foreshore areas of the Fraser River, which include part of Tilbury Slough, for nesting and foraging.

A review of the CDC’s online database indicated that there are known occurrences of four (4) provincially listed species on Tilbury Island: flowering quillwort, streambank lupine, small spike-rush and three-flowered waterwort. A fifth species has also been identified, the white sturgeon, which would most likely not occur within Tilbury Slough, but be restricted to the mainstem of the Fraser River. Other potential rare element species that may occur within the slough, include the Pacific water shrew, which is listed as endangered under Schedule 1 of the federal *Species at Risk Act*. Various amphibians such as the Red-legged frog, a provincially blue listed species and the Western toad, which is a species of special concern under SARA, may also occur (Government of Canada 2008).

A review of the provincial BC Species and Ecosystem Explorer generated a list of 88 rare element species within the Coastal Douglas Fir biogeoclimatic zone found at the south side of the Project Area. A review of the online Committee on the Status of Endangered Wildlife in Canada (COSEWIC) online database generated a list in excess of 150 species. There is potential for some of these species to occur in the Tilbury Slough area. In this regard, further investigation of rare element species would be warranted during future phases of the project.

Berg Road Ditch (Tilbury Island)

The Berg Road ditch has a trapezoidal cross section, with a very low channel gradient. From observation of air photo images, it is assumed that this ditch runs north/west parallel to Berg Road, through an agricultural field and connects further downstream to the Fraser River. It is also assumed that the ditch continues north east of Berg Road around the perimeter of the agricultural field, and continues south towards Tilbury Slough, where it connects to the slough via a culvert leading under the CN tracks. The extent of the unnamed ditch will be confirmed further in the ECA phase.

The Berg Road ditch is presently not considered a significant habitat for aquatic life, since preliminary water quality sampling indicated values outside of the acceptable Canadian Water Quality Guidelines (CCME)). As a result, it is unlikely there are any salmonids present, and in addition, very few non-salmonid species would be able to survive in such poor water quality conditions.

Riparian vegetation around the Berg Road ditch consists of approximately a 2 m strip on either side of the ditch, composed of mostly reed canary grass, willow and alder trees (*Alnus rubra*), which are intermittently spaced along the edge of the watercourse. Wildlife usage of the habitat adjacent to the ditch is limited by the nearby road and agricultural field, and would most likely include small rodents and perching birds.

Since the online database review for rare element species indicated a general list for the whole Tilbury Island area, it can be assumed at this time that the species-at-risk mentioned in the Tilbury Slough section above, also have the potential to exist within the Berg Road ditch and riparian corridor.

Lulu Island, Richmond (North Side)

Dyke Road Swale

This dry swale is located along the north side of Dyke Road, and bordered by agricultural fields to the east and woodlots on west side. During dry weather conditions this swale is assumed to be mostly dry; however, during rainfall events, water flows through the surface grass which assists in promoting settlement of suspended sediments. The riparian area surrounding this swale, consists of mostly reed canary grass, willow and some alder trees.

This channel has low value as fish habitat and is best described as Type I habitat under the City of Richmond's Watercourse Classification System (*i.e.*, "insignificant habitat value" and does not support salmonids).

Wildlife habitat is severely impacted in this area by past and current industrial activities; however, wildlife utilization is expected to include any number of species that are adapted to such urban environments, which would include small mammals, raccoons or coyotes along with a selection of passerine bird species.

No rare elemental occurrences have been recorded by the City of Richmond for this area.

Unnamed Agricultural Ditch #1

The ditch is located parallel to the Terasen Right of way within an agricultural field between 6220-No. 8 Road (Sec: 7-4-4; Pl: 53425) and 6211-Nelson Road (Sec: 7-4-4; Pl: Sec7) properties.

This ditch is not indicated on the "Fish Wizard" database or the City of Richmond's Watercourse Classification System; however, it is assumed that this channel provides Type II habitat (potential salmonid presence). This classification requires confirmation given that the ditch could not be accessed at the time of the field walk-through.

Since this ditch was inaccessible during the field investigation, riparian vegetation species composition has not been determined.

Wildlife habitat for this area has been severely impacted by agricultural activity. Wildlife utilization within this area is therefore most likely restricted to species that are adapted to urban environments, such as coyotes, passerines, rodents and raccoons. In addition, hawks and eagles are expected to use these areas as foraging habitats.

No rare element occurrences have been recorded for the City of Richmond side of the river.

Unnamed Agricultural Ditch #2

This unnamed ditch branches off northeast of the Unnamed Agricultural Ditch #1, within the agricultural field belonging to 6220-No.8 Road. Based on the fact that this ditch is within the same agricultural field as the Unnamed Agricultural Ditch #1, it is assumed that this ditch has comparable vegetation, wildlife and fisheries characteristics as the Unnamed Agricultural Ditch #1.

Preliminary Agricultural Overview of the Project Area

Madrone Environmental Consulting (Madrone) completed a preliminary agricultural assessment of the potentially affected ALR regulated property (*i.e.*, the Gilmour Farm property) in Richmond. Madrone expects that any temporal impacts associated with construction can be mitigated through standard BMP's (*e.g.*, topsoil stripping, ground pressure reduction measures, etc.). Compensation for any required temporary work space and access will need to be negotiated with the land owners and applications will be submitted for all required permits.

Archaeological Overview Assessment of the Project Area

Altamira Consulting Ltd. (Altamira) conducted an Archaeological Overview Assessment (AOA) to identify any areas within or adjacent to the Project Area that have the potential to contain archaeological resources and to identify any potential interactions with known archaeological resource locations.

Based on a database review and evaluation of the existing level of disturbance within the Project Area, it is Altamira's professional opinion that there is no potential for archaeological resources to exist within the Project Area due to the substantial disturbance from previous industrial and agricultural activities both on the Richmond and Tilbury Island sides. Therefore, there is limited potential for the project to adversely affect any known or unknown archaeological sites. This is.

Altamira has confirmed the existence of two previously recorded archaeological resource sites in relatively close proximity to the Project Area (*e.g.,* in Richmond); however, the locations are well outside the predicted area of disturbance and further concern for is not warranted.

Potential Impacts to Environmental, Agricultural, and Archaeological Sensitive Areas

It is expected that the entry point and drill rig staging will be positioned on Tilbury Island (*i.e.,* the south side) and the drill head exit point and drill string laydown area will be located south of Blundell Road in Richmond. A north side drill string layout option was also reviewed and concluded to be a reasonable alternative to the south side laydown area. All HDD-related work is expected to occur behind the existing Fraser River dykes and therefore no disturbance to the Fraser River foreshore is anticipated.

A number of residual effects are anticipated to result from the proposed activities. These include disturbances to potential species-at-risk habitat, fish habitat, vegetation and wildlife habitat on Tilbury Island. These impacts are considered temporal in nature and it is expected that mitigation and restoration measures implemented during construction and post-construction periods will be effective in minimizing impacts to both fish and wildlife habitat.

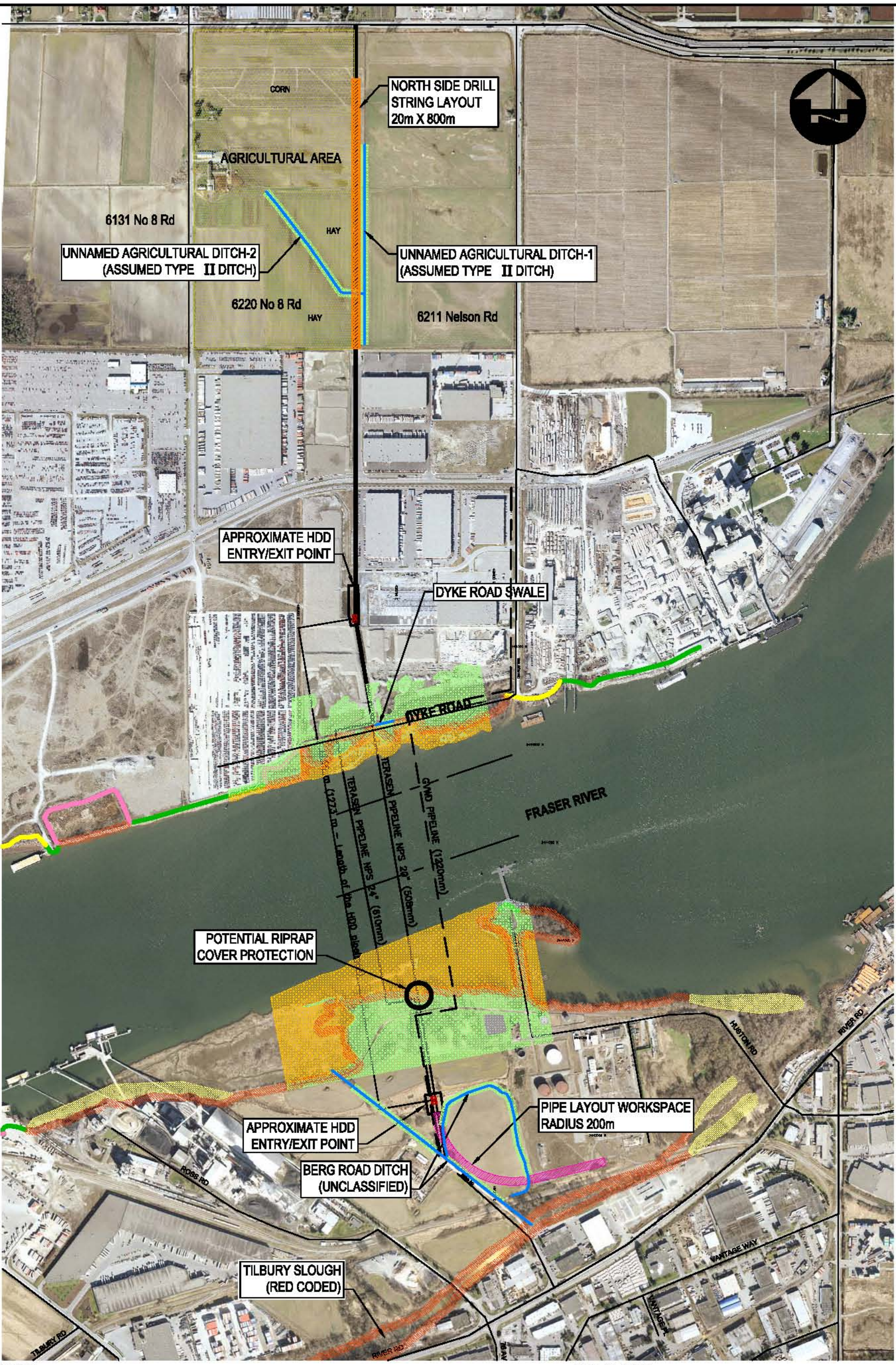
The workspace required to support the entry and exits pads is expected to be 2000 m^2 and 1200 m^2, respectively. The conceptual drill string layout alignment prepared by Entec Engineering (dated May 15, 2008) will require a 200 m radius layout and is expected to be aligned parallel to Berg Road and arc to the east and parallel the CN Railway right-of-way. At a minimum, the drill string layout has the potential to interact with known environmentally sensitive areas (*i.e.*, the Berg Road ditch and the Tilbury Slough) (**Figure 1**). Further assessment of predicted impacts will be necessary following completion of pre-design work.

A north side drill string layout would result in disturbance of agricultural lands on the Gilmour property adjacent to No. 8 Rd. The disturbance will consist of a narrow strip about 20 m wide, extending south to north for a total length of approximately 800 m and a total disturbance area of roughly 1.6 ha. Soil compaction and alteration to the agricultural productivity of the site should be carefully mitigated for to ensure the productivity of the property can be regained after works are completed. Any agricultural impacts associated with construction may be mitigated by means of standard topsoil stripping and ground pressure reduction measures (see Madrone report). Compensation for any required temporary work space and access will be negotiated with the land owners and applications will be submitted for all required permits post CPCN approval. There are no anticipated interactions with known environmentally-sensitive areas on the North side based on Entec's drawings.

A notification of proposed works should be submitted to DFO in the event that the proposed works interact with any fish habitat. All instream activities should occur during the reduced risk timing windows. Instream works timing windows for the Tilbury Slough is between August 1 and September 15 of any given year for most salmonid species, and from August 16 to February 28 for amphibian species. In Richmond, both of the unnamed Type II ditches have windows extending from June 15 to February 28.

The timing widow for clearing riparian vegetation which may have the potential to hold bird nests is before April 1 and after July 31. If works are to occur outside of this window, a technical rational completed by an appropriately qualified professional should be provided, and should demonstrate that there will be no increased risk to breeding birds as a result of the proposed works.

Based on the Archaeological Assessment Overview completed by Altamira Consulting, there is no potential for archaeological resources to exist within the Project Area; therefore, there exists little to no possibility that the proposed project could adversely affect archaeological sites.



LEGEND

🟦	WATERCOURSE
🟩	LOW HABITAT PRODUCTIVITY
🟨	MODERATE HABITAT PRODUCTIVITY
🟪	HABITAT COMPENSATION SITES
▨	HIGH HABITAT PRODUCTIVITY
▨	INTERTIDAL HABITAT
▨	RIPARIAN HABITAT
▨	HABITAT INVENTORY (NULL)
▨	SENSITIVE RIPARIAN HABITAT
▨	AGRICULTURAL AREA

REFERENCES

FRASER RIVER ESTUARY MANAGEMENT PROGRAM (FREMP) ATLAS ONLINE AND LOCATIONS OF HABITAT INFORMATION ARE APPROXIMATE ONLY.

APPROXIMATE SCALE 1:10,000

0 100 300 500m

DILLON CONSULTING

DATE SEPTEMBER 2008

PROJECT TERASEN GAS SOUTH FRASER ARM SEISMIC UPGRADE PROJECT

TITLE POTENTIAL ENVIRONMENTAL SENSITIVITIES & IMPACTS ON SOILS

PROJECT NO. 08-9162

FIGURE NO. 1

FileName: g:\cad\089162-terasen fraser hdd\089162-terasen_potential_soil_impacts.dwg

Mitigation strategies

Based on the results of the environmental screening and agency liaison completed to date, Terasen expects that all potential environmental, agricultural, and archeological impacts associated with this project can be mitigated through implementation of standard mitigation protocols and Best Management Practices (BMP's). Mitigation measures for potential impact on soils and soil production are detailed within the Madrone Environmental Service report and include mitigation strategies for soil compaction, alteration, and erosion.

Regulatory Permits, Notifications, and Approvals

The proposed project will be subject to review or notification by several regulatory bodies including Fisheries Oceans Canada, FREMP, FRPA, Transport Canada and the Oil and Gas Commission. The specific actions required for approval from each regulatory body are outlined in detail below.

Fisheries and Oceans Canada

From a planning perspective, the proposed design package will be subject to review by Fisheries and Oceans Canada (DFO). All waters classified as fish habitat are protected by the federal *Fisheries Act*, which is administered by DFO. DFO (Brian Naito, DFO Fish Habitat Biologist) has requested direct notification of the HDD activities and any other proposed works within the Project Area that may affect potential fish-bearing watercourses. DFO will review the notification and determine at that time whether the activities associated with the HDD should be referred to the Fraser River Estuary Management Program (FREMP) for project review or simply submitted under DFO's "Operational Statement". DFO's Operational Statements are designed to streamline regulatory review of activities considered to be of *low-risk to fish and fish habitat*. Under this initiative, horizontal directional drilling is identified as one of twelve low-risk activities in BC. As such, Terasen Gas is only required to submit *a 14-day notification* to DFO subject to incorporation of a series of measures and conditions into their plans. The HDD Operational Statement outlines measures and conditions for avoiding the harmful alteration, disruption or destruction (HADD) to fish habitat in compliance with Section 35(1) of the *Fisheries Act.*

The Operational Statements are adapted in each DFO Region to complement existing Provincial legislation, standards and specific environmental conditions. Under this Operational guideline, Terasen Gas can proceed with HDD activities *at any time* subject to adherence to the following conditions**:**

- There is a low risk of frac-out, supported by a geotechnical assessment;
- An emergency frac-out response plan is in place that outlines the protocol to monitor, contain and clean-up a potential frac-out event; and
- Terasen Gas incorporates the Measures to Protect Fish and Fish Habitat into the EPP plan (as outlined in the Operational Statement).

DFO will also review any potential instream work requirements associated with the proposed ground improvements and either issue a Letter of Advice or a Section 35(2) Authorization (in the unlikely event that a HADD can not be avoided). Timing windows for these activities may also apply depending on the nature of the works and the watercourse classification, which are outlined in the previous section on Potential Impacts.

The timeline for DFO review and potential referral of HDD activities to FREMP is expected to be relatively brief (*i.e.*, 30 to 60 days). Review and approval timelines for the terrestrial-based works *(i.e.*, drill string laydown) will vary depending on the degree of impact (if any) to environmentally-sensitive areas within the Project Area.

Fraser River Port Authority

Notification to the FRPA will be required in support of the proposed HDD. The FRPA may decide to process the notification via their “Track 1” process (given that the HDD activities are of a predictable nature with little or no impact). Please note: the possibility exists that the FRPA would submit a referral to FREMP for their consideration and review.

Fraser River Estuary Management Program

FREMP uses a two-track process to review projects in the Fraser River Estuary. Track 1 projects are dealt with by the FRPA (as above). Track 2 projects (projects of a more complex nature with potential impacts) are reviewed by the FREMP environmental review committee. Track 2 project reviews typically take 30-days to complete (may vary depending on project complexity).

In the event that FREMP receives the notification (triggered by either FRPA or DFO), and provided there is no significant disturbance to near shore or foreshore areas of the Fraser River, it is likely that they will simply require a list of Best Management Practices (consistent with the DFO Operational Statement BMPs) be applied to the proposed HDD works.

Oil and Gas Commission

It is anticipated that an application for approval under Section 9 of the provincial *Water Act* must be submitted to the OGC (Chris Wagner, Kamloops Office). Chris Wagner has confirmed that the project review would be brief (*i.e.*, 30 days) given the low-risk nature of the proposed activities.

Transport Canada

It is anticipated that an approvals submission to Transport Canada (Navigable Waters Protection Division) will also required for this project. The timeline for project review is anticipated to be less than 45-days.

Ministry of Environment

The works will also be subject to consideration under the provincial *Wildlife Act*. Section 34 of the act prohibits the disturbance of nests that are occupied by birds, eggs or fledglings during the bird nesting window (April 1 to July 31 in the Lower Mainland). If drill string or reservoir pit construction is proposed for this window and there is a potential to disturb bird nesting habitat as a result, assessment of impacted vegetation will be required immediately prior to initiation of works (B.C. Ministry of Environment 2008).

Closure

Although the environmental resources sustained within the Project Area have been impacted by past industrial and agricultural practices, the area still provides some intrinsic value as both terrestrial and aquatic habitat. The implementation of appropriate mitigation during the site preparation, such as adhering to the appropriate timing windows mentioned in this report, will minimize any potential impact and will ensure that these values are protected in the long term. From a planning perspective, the proposed project will be subject to review by Fisheries Oceans Canada, FREMP, FRPA, Transport Canada and the Oil and Gas Commission.

This report was prepared exclusively for the purposes, project, and site location outlined in the report. The report is based on information provided to, or obtained by Dillon as indicated in the report, and applies solely to site conditions and the regulatory and planning frameworks existing at the time of the site investigation.

This report was prepared by Dillon for the sole benefit of Terasen Gas. The material in this report reflects Dillon's best judgment in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibilities of such third parties. Dillon accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Should you have any questions about any part of this letter, please do not hesitate to contact the undersigned at 604-278-7847.

Regards,

DILLON CONSULTING LIMITED

Chris Dane	Matt McKinnon
Project Manager	Project Biologist

cc. Mujib Rahman, Terasen Gas
Jennifer Robertson, Terasen Gas
Dillon ISO File

References

B.C. Ministry of Environment. 2008. Best Management Practices – Land Development. Online at http://wlapwww.gov.bc.ca/vir/pa/bmp_dev2.htm. (Accessed on May 21, 2008)

B.C. Ministry of Environment. 1996a. Water Act. Online at http://www.qp.gov.bc.ca /statreg/stat/W/96483_01.htm. (Accessed on May 21, 2008)

B.C. Ministry of Environment.1996b. Wildlife Act. Online at http://www.qp.gov.bc.ca /statreg/stat/W/96488_01.htm. (Accessed on May 23, 2008)

Fraser River Port Authority. (2005). Information. Online at http://www.fraserportauthority.com/pdf/FRPA_ENVIRONMENT_05.pdf. (Accessed on May 23, 2008).

Freshwater Fisheries Society of BC.(FFSBC). 2008. Fish Wizard database. On-line at http://www.fishwizard.com. (Accessed on May 6, 2008).

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Transport Canada (2005). Navigable Waters Protection Act. Online at http://www.tc.gc.ca/acts-regulations/GENERAL/n/nwpa/regulations/001/nwpa003 /nwpa3.htm. (Accessed on May 21, 2008.

Appendix 9

Altamira

Archaeological & Historic Resource Consulting

June 23, 2008

Stephanie Braig
Dillon Consulting Limited
Suite 130 - 10691 Shellbridge Way
Richmond BC
V6X 2X8
Tel: 604-278-7847
sbraig@dillon.ca

Dear Stephanie Braig:

Re: Archaeological Overview Assessment Terasen Gas – South Fraser Arm Seismic Upgrade Project

At the request of Dillon Consulting Limited, an Archaeological Overview Assessment (AOA) was undertaken for the Terasen Gas Fraser Arm Seismic Upgrade Project (Figures 1 & 2). The Terasen Gas Fraser Arm Seismic Upgrade Project consists of a river crossing using directional drilling crossing the South arm of the Fraser River in the area of Tilbury Island. The entry/exit points are approximately 300 meters (+/- 10-20 meters) from the north bank and 240 m (+/- 10-20 m) from the south bank. The only other type of disturbance would be from construction traffic and drill string layout on either side of the crossing (Richmond (north side) and Delta (south) side). The disturbance or impact zones lie within previously disturbed lands on either side of the river.

Review of the existing archaeological inventory indicates that there are no previously recorded archaeological sites in the project area. There are two previously recorded archaeological sites (DgRs-17 and DgRs-39) recorded near the project area (Figure 1), but both are clearly located well away from the project impact zone. (Ham 2004: Branch File 24600-85/FREMP; Ham 2004b: FREMP File CPR-0407F057).

It is the conclusion of this report that there is no potential for archaeological sites to be adversely affected by the Terasen Gas Fraser Arm Seismic Upgrade Project and that further concern for archaeological sites is not warranted.

It is recommended that the Terasen Gas Fraser Arm Seismic Upgrade Project proceed as planned without further concern for archaeological sites.

Yours truly,
ALTAMIRA CONSULTING LTD

Bruce F. Ball *BA, MA, RPCA*
Director

pc. Dr. Leonard Ham, 1141 Walalee Drive, Delta, B.C.

Member: British Columbia Association of Professional Archaeologists
Candian Archaeological Association
Director: Canadian Association of Professional Heritage Consultants

attachments

Maps

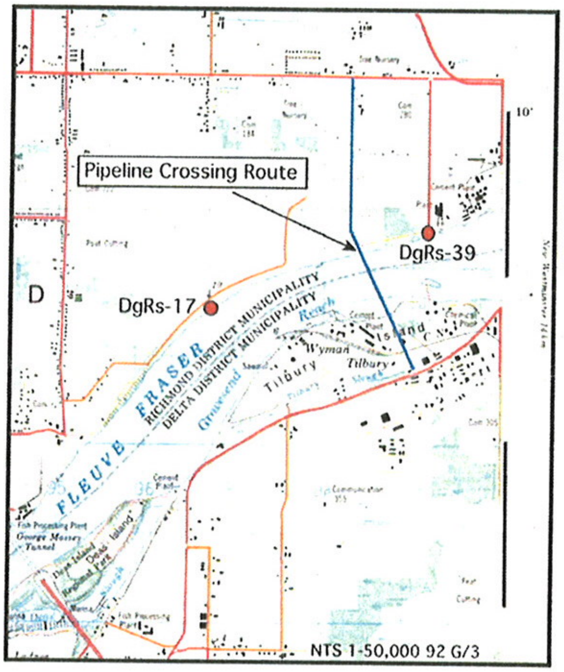

Figure 1. Map showing the location of the pipeline route across the south Fraser from Delta to Richmond and recorded archaeological sites DgRs-17 & 39 (from NTS 1-50,000 92G/3).

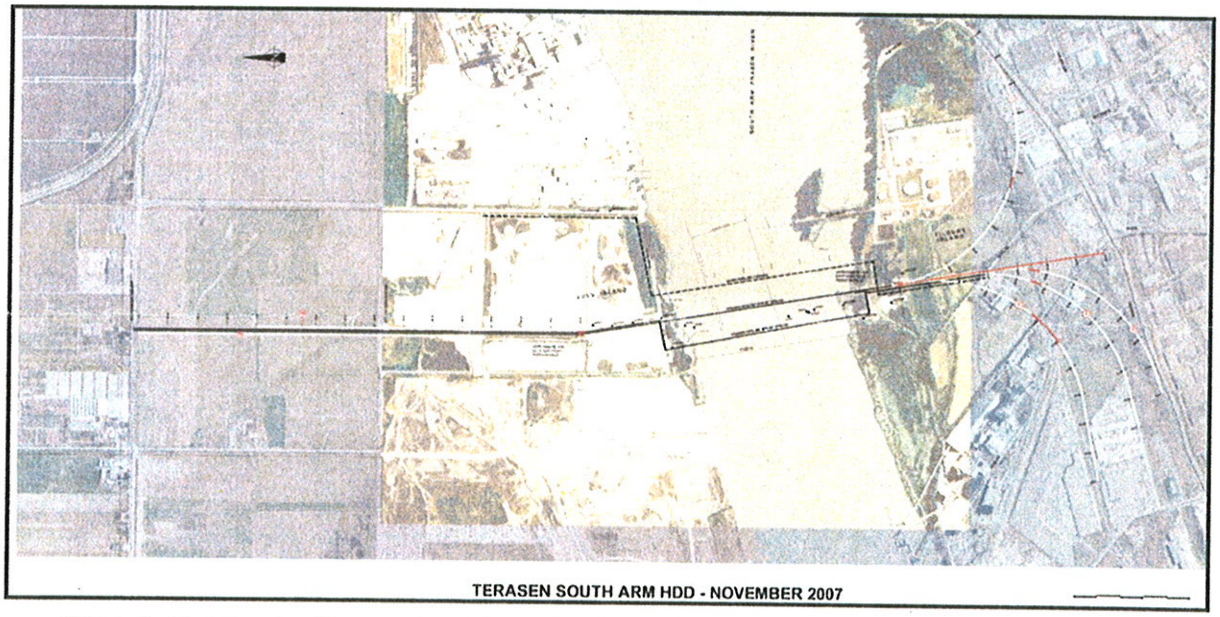

Figure 2. Map showing Terasen South Fraser Pipeline project route.

Appendix 10

MADRONE
environmental services ltd.

1081 Canada Avenue
Duncan, BC V9L 1V2
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F: 250.746.5850
www.madrone.ca
info@madrone.ca

September 5, 2008

Dillon Consulting Ltd.
Suite 130 – 10691 Shellbridge Way
Richmond BC V6X 2W8
Attention: Mr. Matt MacKinnon

Potential Impacts on Soils:
Terasen Gas - South Fraser Arm Seismic Upgrade Project

Dear Mr. MacKinnon:

Introduction

At the request of Dillon Consulting Ltd. (Richmond), I conducted a field review of soils on the Gilmour Farm. The purpose of this letter is to assess and summarize potential impacts on soils and soil production, as well as to recommend measures to mitigate those impacts. I visited the site on August 21, 2008 assisted by Mr. Matt MacKinnon of Dillon Consulting Ltd.

Location

Gilmore Farm is located in Eastern Richmond, South of Westminister Highway and East (and adjacent too) Number 8 Road.

Nature of Disturbance

I understand that the disturbance will consist of traffic by heavy machinery (tracked and wheeled) and above-ground laying of pipe. No excavation or pipe burial is planned.

Terasen Gas has indicated that pipe lengths will be supported by wooden cradles with a plywood base designed to reduce compaction. The nature of the impact on soil productivity is likely to be mainly compaction and to a lesser extent rutting and soil structural alteration. Surface erosion is unlikely to be a significant issue due to the very gentle slopes. Wind erosion and dust may constitute a localized impact.

The disturbance footprint will consist of a narrow strip about 20 m wide, extending from south to north for a total length of approximately 800 m. The total area therefore is roughly 16,000 m^2 or 1.6 ha. I assume that traffic by heavy machinery will be extensive within this footprint. The tentative construction schedule is for two weeks in June 2009.

Regulatory Context

This development will not result in the placement of fill from a different property, nor will it require the removal of soil. It therefore does not contravene Section 20(4) of the Agricultural Land Commission Act, or similar restrictions contained in local government by-laws.

This work will be done along an existing pipeline corridor, which has been covenanted to allow for utility use. I assume that the covenant has been properly issued under the Land Title Act, and has been duly approved by the Agricultural Land Commission.

Parent Materials and Texture

The soils in the disturbance footprint are derived from deltaic silts deposited by the Fraser River in a prograding estuarine environment. Soil textures are consistent along the strength of the footprint, consisting of 80% to 90% silt with smaller amounts of fine and very fine sand. The soils are essentially free of coarse fragments.

Drainage

Drainage ranges from imperfect to (more commonly) poor. All soil profiles exhibited distinct or prominent mottling, reflecting fluctuating water tables and periods of saturation between late fall and early spring.

Three ditches drain water, between fields, to the east, where they discharge into a larger north-south outlet ditch. The ditches are approximately 1.5 m deep. They were mainly dry at the time of my field review in August but likely contain water between late fall and early spring.

Classification

The most common soil encountered was Orthic Gleysol. These soils have a weakly to moderately well developed surface horizon enriched in organic matter (Ah or Ap), above a massive gleyed horizon (Bg). In places within the hay field, the Ah horizon is sufficiently well developed, in which case the classification is Orthic Humic Gleysol.

In all soil profiles, boundaries between horizons were gradual or diffuse. Subsoils, deeper than 30 cm, were uniformly firm in consistence or in a few cases, very firm. These deeper horizons contained very few, very fine or fine roots.

Mapped soils series

Soils in the footprint conform most closely to the Delta soil series as described by Luttmerding (1980). He mapped this area as Delta soils, complexed in places with Kitter soil series. Kitter soils are similar to Delta, but slightly less poorly drained.

Topography

The fields are very gently undulating, with a total relief of 0.5 m to 1.0 m. Slopes range from 0% to 2.5%.

Land use

The footprint runs across four fenced fields. From south to north I have labeled them A, B, C, and D.

Field A supports a hay field with a well established sward of forage grass. This field is in good condition with few weeds.

Field B is another hay field, also in good condition but with slightly higher weed cover (1% – 2%).

Field C was planted to corn this year.

Field D is covered in hay but has been maintained. It has very high cover of weeds, out competing forage grass. The predominant weed is goosefoot (*Chenopodium album*). Potatoes have been planted in adjacent fields. Common crops in this part of east Richmond include blueberries and garden nurseries.

Potential Impacts

These soils have a silty texture with poor bearing strength. Because they tend to be wet or moist they are susceptible to compaction. If they are subject to wheeled traffic between late fall and early spring, they are likely to experience rutting and soil structure alteration.

However in late spring (May and June) watertables fall and the soils drain substantially. The date at which they become suitable for mechanized cultivation varies year to year, but in most years it is before mid-June (an interview with the farm operator would be helpful here).

The Terasen operation will likely result in some soil compaction. Some localized rutting should be expected in depressional areas in the footprint. The extent and depth of compaction will be strongly dependent on the degree of drainage at the time of construction. I expect that for tracked vehicles (i.e., excavations) compaction would extend at most 30 cm in depth. However compaction of topsoils would detrimentally affect crop growth.

If soils are dry at any time during construction they will likely be subject to wind erosion. The extent depends on wind behaviour; if winds remain light, dust will remain in or near the footprint. Strong winds could generate substantial dust clouds which could settle on adjacent fields.

Mitigation

Compaction

To mitigate compaction of top soils, I recommend the following:

1. Strip top soils to a depth of 30 cm, using non-toothed buckets and stockpile in a berm alongside footprint strip. Place layer of sawdust or geotextile or other suitable separator on ground surface prior to stockpiling. Confine construction to stripped area.

2. When construction is complete, de-compact work area, using tines, discs, plows or rototillers. Ensure soil is decompacted to 30 cm depth. Soils should be reasonably dry at this time. If soils remain wet; delay the compaction until soils have suitably drained. Farm tractors or crawler-tractors can be used as prime movers.

3. Re-spread top soil. Use farm tractors to level and finely cultivate disturbed area.

4. At this point it may be too late to plant corn. It is imperative to work with the farm operator to re-establish the crop according to his objectives. Terasen should be prepared to assist in seeding fertilizing an irrigating to restore the area to original productivity.

Dust

Keeping the soil surface moist by spraying lightly though hot days will largely eliminate the dust problem.

Conclusion

Construction associated with the Terasen Gas South Fraser Arm Seismic Upgrade Project will disturb approximately 1.6 ha of productive soils in the Gilmore Farm.

Compaction of topsoils would likely result; this would probably have a detrimental effect on soil productivity and crop fields in the disturbance footprint.

This impact can be effectively mitigated by:

1. Stripping topsoils to a depth of 30 cm, and stockpiling in a berm parallel to disturbance area.

2. Decompacting the top 30 cm of stripped soils in disturbance area.

3. Re-spreading then fine-cultivate topsoils.

4. Work with farm operator to restore crop production.

Following these steps will likely result in a final soil productivity greater than that at present, although yields of shallow rooted crops such as corn and forage grasses may not be affected.

Construction may cause substantial dust clouds if weather conditions are dry and windy. Spraying water though out the day will mitigate this problem. Terasen should plan to have a water supply and spray equipment at the ready.

Sincerely,

BRITISH COLUMBIA INSTITUTE OF AGROLOGISTS
B.C.I.A.
Gordon Butt, P.Ag.
302

Sept 5, 2008

Gordon Butt, M. Sc., P. Ag., P. Geo.
Madrone Environmental Services Ltd.

References

Luttmerding, H.A. 1980. *Soils of the Langley Vancouver Map Area. REP #15, BC Soils Survey Volumes 1 and 2, Kelowna.*

Appendix 11

	A	B	C	D	E	F
1	**List of Agencies and Parties Contacted**					
2		Updated 6 November 2008				
3	**Agency/Party**	**Terasen Representative**	**Contact Information (i.e. phone, address,**	**Most Recent Date of Cont**	**Summary of Party's Response to Contact**	**Email**
4	**Communities**					
5	City of Richmond	AH, GAK, JL, MR, CC	Rob Gonzales, Director of Engineering 604-	September 4 2008	Meeting held September 4 with Robert Gonzales, Jim Young and Tom Stewart. Robert will write a paper in support of the project for City Council.	rgonzales@richmond.ca
6	City of Richmond	AH, AK	Public Works Committee	October 22 2008	Amy and Art presented to Public Works Committee. Response was positive, with the committee recommending a letter be written in support of the project.	mayorandcouncillors@richmond.ca
7	Richmond Chamber of Commerce	Amy Hennessy	Craig Jones, Executive Director, Richmond Chamber of Commerce	September 10 2008	Craig will include information we provided to him about the project in a mail out to his members.	craigj@richmondchamber.ca
8	Corporation of Delta	AH, JK	George Harvie, City Manager 604-946-3212	August 11 2008	Meeting held August 11 with George Harvie and Hugh Fraser.Delta has no major concerns with the project and offered to write a letter in support.	gharvie@corp.delta.bc.ca
9	Corporation of Delta	Amy Hennessy	Mayor and Council via George Harvie, City	September 16 2008	George recommends that we deal with staff on this project (Hugh Fraser). As the project gets closer, Hugh will give council a memo about the project.	mayor@corp.delta.bc.ca
10	Corporation of Delta	AH	Municipal Clerk's office	August 12 2008	Made request to make presentation to Mayor and Council. George Harvie, CAO of Delta, prefers to handle this as a staff matter.	clerks@corp.delta.bc.ca
11	Delta Chamber of Commerce	Amy Hennessy	Peter Roaf, Executive Director, Delta Chamber of Commerce	September 5 2008	Meeting held July 11. No issues identified. Peter sent out notification about the proposed project to his members the week of September 8.	execdirector@deltachamber.com
12	Metro Vancouver	AH, JK, AS, MR	Thomas Wu 604-451-6507	July 30 1008	Meeting held July 30 with Art Swenson, Mujib and Joel Lavers	thomas.wu@metrovancouver.org
13						
14	**First Nations**					
15	**Musqueam Indian Band**	Bruce Falstead	6735 Salish Drive, Vancouver BC V4N 4C4.	27/03/2008	phone call with Norman Point acting Band Band Manager, Fishers department would be interested as well	npoint@musqueam.bc.ca
16	Musqueam Indian Band	Bruce Falstead		23-Jun-08	Letter and map to Norman Point Band Manager	
17	Musqueam Indian Band	Bruce Falstead		July 29 2008	Phone conversation with Mr. Point followed by email. He is referring this information to Fran Guerin Land Manager	
18						
19	**Katzie First Nation**	Bruce Falstead	10946 Katzie Road, Pitt Meadows, B.C. V3Y	26/03/2008	phone call with Bill Chunick referred to Debbie Miller	katzie.treaty@shawcable.com
20	Katzie First Nation	Bruce Falstead		23-Jun-08	Letter and map to Debbie Miller	
21	Katzie First Nation	Bruce Falstead		July 16 2008	phone call left message for Debbie Miller	
22	Katzie First Nation	Bruce Falstead		July 21 2008	phone call left message for Debbie Miller	
23	Katzie First Nation	Bruce Falstead		July 29 2008	phone call left message for Debbie Miller	
24	Katzie First Nation	Bruce Falstead		July 29 2008	emailed June 23 2008 letter to Debbie Miller	
25						
26	**Tsawwassen First Nation**	Bruce Falstead	#131 N Tsawwassen Drive, Delta, B.C. V4M	23-Jun-08	Letter and map to Andrew Bak Manager Lands & Natural Resources	andrewbak@dccnet.com
27	Tsawwassen First Nation	Bruce Falstead		July 7 2008	Meeting scheduled with lawyer for Tsawwassen FN Arlene H. Henry, QC to review Tsawwassen First Nation and its Final Agreement	
28						
29	**Landowners**					

	A	B	C	D	E	F
1	**List of Agencies and Parties Contacted**					
2		Updated 6 November 2008				
3	**Agency/Party**	**Terasen Representative**	**Contact Information (i.e. phone, address,**	**Most Recent Date of Cont**	**Summary of Party's Response to Contact**	**Email**
30	Lehigh Cement (Dynacor Coatings-Lessee)	Art Swenson	7753 Berg Road, RR #7, Delta BC V4K 1B9	July 12 2008	Art Swenson met with Dynacor Owner - Brady McCulley on site to discuss project.	info@dynacorcoatings.com
31	Lantic (Belkorp Industries Inc.)	Art Swenson	Suite 900, 1508 West Broadway, Vancouver, BC V6J 1W8	July 8 2008	Art Swenson and Joel Lavers met with Belkorp Corporate Counsel-Randy Smith and their consultant Norman Laube of Omicron to discuss project.	rsmith@belkorp.com
32	Stork Craft Manufacturing Inc.	Art Swenson	7433 Nelson Road Richmond, BC V6W 1G3	July 11 2008	Art Swenson and Joel Lavers met with Stork Craft President-Jim Moore and property managers Ron Emerson and Herb Chan to discuss location of drill rig within Stork Craft parking lots	jim@storkcraft.com
33	Kingswood Industrial Park Property Management by Emerson Real Estate Group	Art Swenson	Suite 1180 - 625 Howe Street, Vancouver BC V6C 2T6	July 11 2008	Art Swenson and Joel Lavers met with Ron Emerson to discuss project within the Kingwood Industrial Park	rwemerson@telus.net
34	Kingswood Industrial Park Property Management by Canreal Management Corp.	Art Swenson	Nelson Square, Suite 409-808 Nelson St., Vancouver BC V6Z 2H2	July 11 2008	Art Swenson and Joel Lavers met with Herbert Chan to discuss project within the Kingwood Industrial Park	hchan@canreal.com
35	Gilmour Farms (Savage Farms - Lessee)	Art Swenson	4491 No.7 Road, Richmond BC V6V 1R6	July 15 2008	Art Swenson met at the Gilmour Farm on July 15th with Ray Aitcheson of Savage Farms, to discuss the impact of the pipeline assembly area, on their hay and corn crops . Phone call on Aug.15th to Jim Savage of Savage Farms for access to Gilmour farm for Terasen Consultants field inspection.	
36						
37	**Regulatory Agencies**					
38	Vancouver Fraser Port Authority	Amy Hennessy	Nures Kara, Environmental Manager -- River 604-665-9511	June 24 2008	Email/phone conversations. We will submit the application to Ports when we have the required information.	nures.kara@vfpa.ca
39	Provincial Dyking Authority	Amy Hennessy	Scott Cosman 604-582-5220	August 11 2008	Email communication regarding application and information. We will provide both when the information has been sufficiently developed.	scott.cosman@gov.bc.ca
40	Department of Fisheries and Oceans	Chris Dane (Dillon Consulting)	Brian Naito, 100 Annacis Parkway, Unit 3, Annacis Island 604-666-8190	May, 2008	Correspondence regarding proposed works, project timeline and regulatory approval requirements	NaitoB@pac.dfo-mpo.gc.ca
41	Oil and Gas Commission	Chris Dane (Dillon Consulting), Jennifer Robertson	Chris Wagner, 210 - 301 Victoria Street Kamloops 250-377-2157	August, 2008	Correspondence regarding proposed works, project timeline and regul	Chris.Wagner@gov.bc.ca
42						
43						
44						

Terasen
Gas

16705 Fraser Highway
Surrey, B.C. V4N 0E8
Tel: 604-576-7000
Fax: 604-576-7677
Toll Free: 1-800-773-7001
www.terasengas.com

June 23, 2008

COPY

Tsawwassen First Nation
#131 N Tsawwassen Drive
Delta, B.C.
V4M 4G2

Attention: Councilor Andrew Bak, Manager, Lands and Natural Resources

Dear Councilor Bak:

Terasen Gas is proposing an upgrade of one of it's natural gas transmission pipelines crossing under the Fraser River. Since this project is within the territory of the Tsawwassen First Nation I would like share the project details with you and comply with any protocols the Tsawwassen First Nation may have in place around these types of projects.

The 20 inch natural gas transmission pipeline is 1.2 – 1.6 km in length and crosses between the cities of Richmond and Delta at Tilbury Island. Terasen will be seeking approval from the British Columbia Utilities Commission to replace the pipeline through horizontal directional drilling by the year 2010. At this point in time all planned work is expected to be taking place within Terasen's existing statuary right of way.

This project will ensure Terasen can deliver natural gas to Metro Vancouver after a design earthquake event. Natural gas service will be crucial for public safety and well-being as well as regional business resumption and economic recovery.

If this is of interest to the Tsawwassen First Nation it would be best to meet at your earliest convience and share detailed information. I will call you within the next few days.

Sincereley,

Bruce Falstead
Aborignal Relations Manager
Terasen Gas Inc.

Terasen
Gas

16705 Fraser Highway
Surrey, B.C. V4N 0E8
Tel: 604-576-7000
Fax: 604-576-7677
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www.terasengas.com

June 23, 2008

COPY

Mr. Norman Point
Band Manager
Musqueam Indian Band
6735 Salish Drive
Vancouver BC V6N4C4

Terasen Gas is proposing an upgrade of one of it's natural gas transmission pipelines crossing under the Fraser River. Since this project is within the territory of the Musqueam Indian Band I would like share the project details with you and comply with any protocols the Musqueam Indian Band may have in place around these types of projects.

The 20 inch natural gas transmission pipeline is 1.2 – 1.6 km in length and crosses between the cities of Richmond and Delta at Tilbury Island. Terasen will be seeking approval from the British Columbia Utilities Commission to replace the pipeline through horizontal directional drilling by the year 2010. At this point in time all planned work is expected to be taking place within Terasen's existing statuary right of way.

This project will ensure Terasen can deliver natural gas to Metro Vancouver after a design earthquake event. Natural gas service will be crucial for public safety and well-being as well as regional business resumption and economic recovery.

If this is of interest to the Musqueam Indian Band it would be best to meet at your earliest convience and share detailed information. I will call you within the next few days.

Sincerely,

Bruce Falstead
Aboriginal Relations Manager
Terasen Gas Inc.

Terasen
Gas

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Surrey, B.C. V4N 0E8
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COPY

June 23, 2008

Katzie First Nation
10946 Katzie Road,
Pitt Meadows, B.C.
V3Y 2G6

Attention: Debbie Miller

Dear Ms. Miller:

Terasen Gas is proposing an upgrade of one of it's natural gas transmission pipelines crossing under the Fraser River. Since this project is within the territory of the Katzie First Nation I would like share the project details with you and comply with any protocols the Katzie First Nation may have in place around these types of projects.

The 20 inch natural gas transmission pipeline is 1.2 – 1.6 km in length and crosses between the cities of Richmond and Delta at Tilbury Island. Terasen will be seeking approval from the British Columbia Utilities Commission to replace the pipeline through horizontal directional drilling by the year 2010. At this point in time all planned work is expected to be taking place within Terasen's existing statuary right of way.

This project will ensure Terasen can deliver natural gas to Metro Vancouver after a design earthquake event. Natural gas service will be crucial for public safety and well-being as well as regional business resumption and economic recovery.

If this is of interest to the Katzie First Nation it would be best to meet at your earliest convience and share detailed information. I will call you within the next few days.

Sincerely,

Bruce Falstead
Aboriginal Relations Manager
Terasen Gas Inc.

Appendix 12

Appendix 12 - Fraser River South Arm Upgrade Project Cost of Service Impact ($000)

Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Incremental Mid-Year Rate Base	**$26,831**	**$26,493**	**$25,955**	**$25,417**	**$24,879**	**$24,341**	**$23,803**	**$23,265**	**$22,727**	**$22,189**
Incremental Cost of Service										
Depreciation Expense New Facilities	$538	$538	$538	$538	$538	$538	$538	$538	$538	$538
Avoided Depreciation Expense Retired Facilities	($42)	($42)	($42)	($42)	($42)	($42)	($42)	($42)	($42)	($42)
Income Tax Expense	($324)	($244)	($178)	($120)	($72)	($37)	($5)	$24	$50	$73
Earned Return on Rate Base	$2,007	$1,982	$1,941	$1,901	$1,861	$1,821	$1,780	$1,740	$1,700	$1,660
Total Cost of Service	**$2,179**	**$2,234**	**$2,259**	**$2,278**	**$2,285**	**$2,280**	**$2,271**	**$2,260**	**$2,246**	**$2,229**
Unit Cost of Service Impact										
Sales and Applicable Transportation Volumes (PJ/Yr)	155	156	157	157	158	159	160	161	162	163
Unit Cost of Service ($/GJ)	**$0.014**	**$0.014**	**$0.014**	**$0.014**	**$0.014**	**$0.014**	**$0.014**	**$0.014**	**$0.014**	**$0.014**

Year	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**
Incremental Mid-Year Rate Base	**$21,651**	**$21,113**	**$20,575**	**$20,037**	**$19,499**	**$18,961**	**$18,423**	**$17,885**	**$17,347**	**$16,809**
Incremental Cost of Service										
Depreciation Expense New Facilities	$538	$538	$538	$538	$538	$538	$538	$538	$538	$538
Avoided Depreciation Expense Retired Facilities	($42)	($42)	($42)	($42)	($42)	($42)	($42)	($42)	($42)	($42)
Income Tax Expense	$94	$114	$131	$146	$159	$171	$182	$191	$199	$206
Earned Return on Rate Base	$1,619	$1,579	$1,539	$1,499	$1,459	$1,418	$1,378	$1,338	$1,298	$1,257
Total Cost of Service	**$2,210**	**$2,189**	**$2,166**	**$2,141**	**$2,114**	**$2,086**	**$2,056**	**$2,025**	**$1,993**	**$1,960**
Unit Cost of Service Impact										
Sales and Applicable Transportation Volumes (PJ/Yr)	164	165	166	167	168	169	170	171	172	173
Unit Cost of Service ($/GJ)	**$0.013**	**$0.013**	**$0.013**	**$0.013**	**$0.013**	**$0.012**	**$0.012**	**$0.012**	**$0.012**	**$0.011**

Based on TGI current approved 64.99% - 35.01% debt equity structure, 8.62% ROE and 8% CCA rate.
Unit cost of service impact based on forcasted sales volumes and non-bypass transportation service volumes.
All costs presented in $2008

Appendix 13

Appendix 13

Fraser River South Arm Crossing Upgrade Project
Capital Cost Estimates

		Alternative 1	Alternative 2	Alternative 3	Alternative 4
	Description	NPS 20 & 24 HDD	NPS 24 HDD	NPS 20 HDD	NPS 30 HDD & Replacement
		Estimate ($2008 millions)	Estimate ($2008 millions)	Estimate ($2008 millions)	Estimate ($2008 millions)
1	Project Services	$ 4.9	$4.0	$4.0	$4.2
2	Land, Temporary Workspace	$ 1.8	$1.1	$1.1	$2.5
3	Pipe & Coating Materials	$ 3.6	$1.9	$1.4	$5.6
4	River Crossing HDD Installation	$ 11.6	$7.0	$6.6	$8.3
5	Pipeline Tie In Construction	$ 2.5	$1.2	$1.0	$3.4
6	Pipeline Commissioning	$ 0.6	$0.3	$0.4	$0.5
7	North Bank Dike Improvements Allowance	$ 1.0	$1.0	$1.0	$1.0
8	Subtotal	$26.0	$16.5	$15.5	$25.1
9	Retirement Costs	$ 0.4	$ 0.2	$ 0.3	$ 0.2
10	AFUDC	$ 0.9	$ 0.6	$ 0.6	$ 0.9
11	**Total Project**	**$27.3**	**$17.3**	**$16.4**	**$26.6**