APPENDIX 16

GEOTECHNICAL REVIEW

OF THE

RECLAMATION LANDFILL SUBSIDENCE AREA

POLARIS MINE

RESPONSE TO REGULATORS QUESTIONS REGARDING

SUBSIDENCE AT THE RECLAMATION LANDFILL

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September 30, 2003

EXECUTIVE SUMMARY

The Polaris Mine Decommissioning and Reclamation Plan, March 2001 (‘DRP’) identifies the Reclamation Landfill area as being influenced by significant subsidence referred to as a ‘Sinkhole’. The Approved plan is to ensure that there is at least a 1.8 metre cap over the landfill area. However, this does not address the concern that the area is continuing to actively subside which could present a public/wildlife safety issue.

Required in the letter of Approval of the operating protocols for the landfills at the site, and as a result of a site inspection by DIAND in September of 2003, Polaris was requested to review the geotechnical aspects of the ‘Sinkhole’ area. This report presents the currently available data for this area, an explanation of the subsidence mechanisms at work, and a proposed course of action to respond to the potential issues of concern.

The caving of the overlying strata into the 202 Stage III stope has resulted in substantial localized subsidence (‘sinkhole’) that is atypical of subsidence being experienced elsewhere at Polaris. Monitoring of subsidence at Polaris indicates that subsidence over the majority of the mine is not a concern in either the short or long term. However, in the area of 202 Stope, substantial subsidence has been occurring since 1999 as evidenced by the precise subsidence monitoring conducted while the mine was operating. The last precise subsidence survey was conducted in 2002 and the sinkhole area was still actively subsiding at that time.

The development of subsidence prediction and modeling is a well developed science in Europe due to the impact of coal mining in populated areas on civil structures. While the behaviour of subsidence not exactly the same in base metal mines, the rock mechanic principles and empirical application of them to base metal mines does give guidance in understanding the subsidence mechanisms at work. Typically in coal mines, the length of time that subsidence occurs is measured in relatively few years. Similar trends have been observed at Polaris over other areas of the mine. In the area of the sinkhole, significant movement at surface has been measured for several years prior to 2002. Conducting a precise level survey in 2004 will indicate whether the subsidence has entered the decelerating phase of the subsidence cycle. Once these measurements have been obtained, a better assessment of the current and future expectations for ground movement around the sinkhole will then be possible. At that time a more informed decision as to whether or not any future action or monitoring is required.

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RESPONSE TO REGULATORS QUESTIONS REGARDING SUBSIDENCE AT THE RECLAMATION LANDFILL

1. Introduction

Part H, Item 6 of Polaris's Water Licence requires an annual geotechnical inspection be conducted. Included in the approval of Polaris's Landfill Operating Protocol's, is the requirement 'That TCL provide assurance which demonstrates that the mine workings under the Reclamation Landfill have been sufficiently supported or backfilled to prevent further subsidence.' as part of the Annual Geotechnical Inspection.

The Department of Indian Affairs and Northern Development (DIAND) conducted a site inspection between September 8^{th} to 10^{th}, During the site visit, discussions were held with John Knapp (Site Manager) regarding ongoing subsidence over the underground mining area. The inspection report requested that the following issues be evaluated:

1. A description of the mechanism of subsidence
2. Thermal regime and ice conditions in the overburden
3. Thermal regime and need for installation of thermistors to monitor permafrost temperatures from the surface, around the underground opening
4. Impact of surface water pond on thermal regime and permafrost stability.
5. Impact of placing fill on the rate and amount of subsidence and the permafrost regime
6. Estimate of maximum extent and depth of subsidence zone
7. Assessment of physical stability and protection required
8. Recommendations for ongoing assessment and monitoring

This document will respond to all of the above comments although not in the order listed above.

2. Description of Mechanisms of Subsidence

2.1. Rock Mechanics and Subsidence Monitoring at the Polaris Mine

Monitoring and prediction of the stability of underground mine workings has been key to the successful mining of the Polaris ore body. The objective of recovering a mineral resource is to extract the maximum ore possible given safety and economic constraints. As such, mine planning attempts to maximize the volume of ore removed in a manner that minimizes the quantities of ore that must remain in place either because they are uneconomic or are required to support the ground around the mine workings (i.e. 'pillars').

Each underground mine is unique. The shape of the ore body, the composition of the ore and host rock, the depth of the ore body, its width, length and dip are all different. The types of rock underlying and overlying the mine differ from mine to mine. Faulting, weathering, ground water conditions, rock temperatures, faulting of the rock, and surrounding pre-mine ground pressures are all factors that affect the stability and behavior of the mine openings and surrounding rock masses. As a result of these and other variables, the prediction of subsidence is complex and reliant on site specific experience to develop an understanding of how the mining activities will influence subsidence at that site.

Pre-mining evaluations of mine designs are based on data collected at the exploration stage, through lab testing of the rocks to determine their physical characteristics, and experience of mining similar ore bodies at other locations. The development and refinement of mine designs evolve as experience and knowledge of individual ore bodies are gained during the mining process. As the mine is developed, rock mechanics instrumentation is utilized to monitor the physical conditions of the mine such as ground pressures, ground temperatures, and ground movements around the underground openings. At some mines, surface subsidence monitoring is an important aspect that is monitored. Visual observations by experienced mining personal are key in monitoring the immediate day to day stability of the ground surrounding the mine openings. Polaris Operations utilized graduate mining engineers (normally with at least one or more staff members registered as a Professional Engineer) to ensure competent planning and management of the mine design and monitoring process occurred.

At Polaris, early mining was done utilizing open stopes (i.e. areas where a volume of ore is removed is referred to as a 'stope') that were not re-filled (i.e. left 'open') after mining of that area was completed. For this method to work, the size of the stope was limited so that the ground surrounding the stope would stay intact. To allow for improved recovery of ore, and to provide for improved ground conditions (i.e. stable ground that was safe for personnel working in the area), the mine had to provide additional support to the mined out stopes by re-filling the void space in the stopes with fill ('backfill'). Initially the backfill consisted of waste rock with water added to increase the structural strength. The permafrost conditions in the mine caused the water in the rock to freeze adding strength to the backfill. The placement of backfill must be done soon after the stope is mined, before the rock surrounding the stope starts to fail (i.e. break up falling into the stope). While the use of frozen backfill was successful, it became apparent that a stronger backfill would provide additional support allowing for even better recovery of ore. It was determined that the use of backfill consisting of cement mixed with waste rock (i.e. Cemented Rock Fill or 'CRF') would provide superior backfill strength and the strength would be obtained in a shorter period of time. Although this was a very expensive process, the improved ground support and improved ore recovery justified the additional cost. The improved support for the stopes had the additional benefit that the amount of subsidence measured at surface was reduced.

2.2. Subsidence Mechanisms

There is substantial technical knowledge related to the process of mining induced subsidence. This technical expertise was initially developed in Europe where coal mining near populated areas created significant damage related to the subsidence of roads, pipelines, houses and other civil structures. Subsidence related to coal mining typically differs from metal mining ('hard rock mining') subsidence in a number of ways. Normally coal mining is occurs in relatively thin coal beds (several metres thick not tens of metres thick as with Polaris), with relatively substantial thickness of cover (relative to the ore body thickness), and the extraction of the coal beds occurs over large areas (often extending for miles) using relatively uniform patterns of extracted areas and adjacent areas where ground has been left intact for support (‘pillars’). These configurations allow for relatively accurate mathematical predictions of amounts of subsidence, timing of subsidence, and amount of surface strains (i.e. surface cracking). Initial planning is done using information from similar mines/ground conditions documented in reference materials but as site specific empirical data is collected, the accuracy of the predictions are refined.

The following explanation is simplistic to give the reader an understanding of the subsidence mechanism coal mines. Typically, the subsidence is caused by the strata overlying the mining area bending uniformly as mining progresses. The overlying stratum behaves like a beam that sags as support is removed from beneath it (i.e. by the mining removing coal or other mineral). As there is less rock to support the weight of the overlying strata, the remaining rock (‘pillars’) must support increasing loads. At some point, the pillars are not capable of holding the amount of weight they are exposed to and they begin to fail. As the pillars crumble, the overlying strata subsides. The debris from the failed pillars (and roof over the mine openings) starts to partially fill the mine openings. As this process of crushing the pillars progresses, at some point, support for the overlying strata is gradually regained and the subsidence slows and eventually ceases. The surface of the ground appears to gradually and uniformly subside. Some coal mines (but not most), place fill into the areas where they have removed the coal to provide additional support and to reduce the amount of subsidence. The backfill must be placed soon after mining or else the area will start to fail before the backfilling is completed. If the coal seam is very thick and/or if the seam is close to surface, or if there are irregular patterns to the mine layout, or if the overlying strata if more brittle, different mechanisms of subsidence may occur and the resulting subsidence may not be uniform.

The mechanisms of surface subsidence are usually different for metal mines. While the same physical principles apply, the conditions surrounding metal mines are often very different from coal mines. The ore body is often much thicker so that mining open creates high stopes with tall, slender pillars between the stopes. Often, the distance to surface relative to the height of the stope is less that in a coal mine. The rock types are often much harder and more brittle in nature. If the width of the stope is narrow enough and the pillar adjacent to it is strong enough, the stope can remain stable over a very long period of time and there is no disturbance of the surface. If the stope is wider or the adjacent pillar is not strong enough, the roof of the stope or the pillar itself may fail in a brittle manner. As the failure progresses, series of rock pieces or larger blocks of rock from the roof and/or the pillar break up and fall into the stope. Broken rock occupies more space than solid rock due to the void spaces between the broken pieces. As failure of the surrounding rocks progress further and further from the opening, the area affected above the stope typically becomes wider (i.e. similar to the shape of an ice cream cone). As the failure of the overlying strata progresses further and further upward, the volume of broken rock continues to increase so that at some point it occupies enough space that the broken rock starts to provide support again until the remaining strata overtop of it is adequately supported and becomes stable (if the distance is far enough to surface). This mechanism can result in several different subsidence effects on surface. If the volume of the stope is small relative to the volume of rock overlying it, the overlying strata may bend so that at surface subsidence is similar to the example of the coal mine. Alternately, if the volume of the stope is substantial relative to the distance to surface, then failure of the overlying rock can progress through to surface causing a more localized area of subsidence where the surface subsides with steeply dipping angles (i.e. a 'sinkhole'). In extreme cases an open hole extending from surface down into the stope can occur (this would generally only occur when the volume of rock overlying the collapsing stope is relatively small compared to the volume of rock required to fill the stope, typically when the stope is very near surface). As ore bodies are not usually uniform, consequently mine designs are also not normally uniform. As a result, subsidence over the mine may be a mixture of the above subsidence mechanisms. Subsidence at Polaris is primarily smooth and uniform due to the use of backfill. Early in the mine life, there was one area (the 202 Stage III stope) where premature failure of the stope before it could be backfilled has resulted progressive failure of the overlying strata resulting in a 'sinkhole' type of subsidence to occur. The failure of this area emphasized the need to backfill stopes and was the standard procedure adopted for stopes after 202 Stope was mined This procedure has prevented other areas from experiencing excessive subsidence.

Empirical monitoring of subsidence at Polaris has been a useful tool in predicting the behaviour of the ground in response to mining. Monitoring of subsidence at Polaris has been done both utilizing precise survey measurements of the bedrock surface, and through visual observations of indications of subsidence. A network of monitoring pins anchored to bedrock was established over the mining area in the 1980's. While mining was active (until 2002), these monitoring stations were surveyed twice per year with adequate precision to detect small changes in pin elevations. These measurements have identified the expected maximum angle of draw of the subsidence zones (i.e. the angle from the extracted area to surface affected by subsidence) to be approximately 40 degrees. This information is useful predicting the ultimate boundaries of subsidence at surface. The length of time subsidence is active is influenced the area being mined, the depth of mining and the angle of draw. Appendix A shows a graph of subsidence over time at a typical coal mine (Subsidence Engineers' Handbook, National Coal Board). The graph illustrates the relationship between these factors and indicates that typical duration for subsidence to be active in a typical coal mine is up to 5 years. While these charts are not directly applicable to base metal mines, it does indicate that subsidence occurs over a relatively short period of time.

3. Estimate of Maximum Extent and Depth of Subsidence Zone

Subsidence progresses through a series of phases over time starting from no movement, to accelerating vertical movement, to decelerating rate of movement, and finally to little or no movement. A typical graph of the amount of subsidence compared to time is presented in the Subsidence Engineers Handbook and is also included in Appendix A. At Polaris, while the time frames for subsidence to occur will be different from the example in the Handbook, the process will be similar showing the same series of phases of changing rates of subsidence over time. Appendix B contains the following figures:

- Location Plan of Subsidence Monitoring Stations and Outline of Mine Workings
  This drawing shows the outline of the mine workings in plan view indicating the locations of the subsidence survey monitoring stations. The majority of these stations are no longer required due to little on-going ground movement and have been

destroyed intentionally as part of re-contouring the site as part of the reclamation activities, through substantial ground movement (in the sinkhole area) or by accident. Our contractor has been instructed to save key monitoring stations around the sinkhole area for future monitoring requirements.

- Graph of Surface Subsidence Versus Time Along Section 1500 E.
  This graph indicates the total subsidence over time for a series of monitoring stations that extend in a North – South line at about the 1500 E section line. The chart shows that subsidence is in the deceleration phase at the south end (Station Sub-5), is still undergoing substantial subsidence just north of the sinkhole (Stations Sub 20 and Sub 22), and has substantially decreasing rates of subsidence as you move further north from the sinkhole (as the amount of mine workings under the stations decrease).
- Graph of Surface Subsidence Versus Time for 2150 N Section – East
  This graph shows the subsidence compared to time for stations east of the sinkhole area. As can be seen from the plan drawing, the location of these subsidence monitoring stations start at the edge of mining and extend out over un-mined areas. The amount of subsidence of these stations is relatively small and subsidence is nearing completion.
- Graph of Surface Subsidence Versus Time for 2150 N Section – West
  This graph shows the subsidence compared to time for stations near the sinkhole area and extending to the west. The stations closest to the sinkhole area are still undergoing significant subsidence and the stations further west are still subsiding significantly but at reducing rates the further away from the sinkhole area. All of the stations in this graph are located over top of mining areas with substantial extraction and that have experienced continuing mining activity throughout the monitoring period. With the cessation of mining, subsidence rates in these areas will start to decrease. The data in this graph is current as of the summer of 2002.

The 'sinkhole' area of subsidence is located directly over top of 202 Stage III stope. A cross section of the stopes in this area relative to the surface identifies the location of this ground failure (Appendix B). Golder Associates Ltd., a mining/rock mechanics engineering consulting firm reviewed this problem as part of their report 'Site Visit to Cominco Ltd.s' Polaris Mine' dated February 1994. This report indicates that a block over top of this stope failed and moved downward in excess of 3.5 metres at the 850 Level (report Section 5.3, Appendix C). The report includes several generalized sketches indicating the observations of the block failure as evidenced underground. Referring to Section 3.3 of Golder Associates' 1995 site visit report (Appendix C), makes a number of observations:

a) Most subsidence monitors at the mine are maintaining constant velocity or de-accelerating.
b) Monitoring data suggests an angle of draw of about 40 degrees.
c) 'At Polaris, the ore is both shallow and thick, and various coal subsidence formula become difficult to apply.'
d) 'A recent review by Golder Associates ….found that published information on subsidence over base metal mines was extremely limited and mainly referred to caving. Thus, there is little precedent which can be used to assess future subsidence (North Keel and Ocean Zone) at Polaris. More or less sole reliance will be on the

> information currently being gathered and mine derived relationships (assisted, for example, by numerical modeling).'

The Golder report has photographs of the surface tension cracks which are also included in Appendix C.

Monitoring in the active area of the sinkhole is difficult as the ground movements are large enough that the survey stations have been destroyed and subsequently buried as fill has been placed into the sinkhole. Maximum vertical movement in the area is estimated to be in the order of 10 metres. Subsidence west of the sinkhole is active but more moderate. The area west of the sinkhole is also over areas where thick sections of ore have been mined. However, relative to the horizontal distances involved the change in surface contours are more modest and are not of any concern. A drawing titled '2150 Section Through Sinkhole Area' (Appendix B) indicates the approximate surface over this area and shows the changes to surface contours as a result of subsidence up until relative total subsidence to July of 2002. As there is data missing within the most active area of the sinkhole, the drawing does not necessarily accurately represent the area in the middle of the sinkhole.

As previously identified, most of the monitoring stations have either been destroyed through ground movement or were removed in 2003 as part of the reclamation re-contouring activities. However, key subsidence stations related to the sinkhole area are being retained so that they can be re-surveyed in 2004. It is anticipated that the 2004 survey will indicated decreasing rates of subsidence.

A simple method of observing subsidence is from visual observations. At the boundaries of subsidence where the slope of the surface ground changes, the ground surface is placed into tension causing cracks to form in the surface soils. During the snow free months, recording the locations of new tension cracks is a practical method of monitoring if the area of subsidence is expanding. These observations have been mapped on a regular basis with the results plotted on a surface plan (refer to Appendix B). This data was last updated in 2002. As the ground surface was being re-graded during 2003 during reclamation activities, no observations of surface cracks were made. It is planned to identify and map any new cracks during the summer of 2004.

4. Impact of Placing Fill on the Rate and Amount of Subsidence and the Permafrost Regime

4.1. Impact of Placing Fill on the Rate of Subsidence

As referred to in Section 2.2 above, the Subsidence Engineers' Handbook states that the length of time that subsidence is active is a function of mining depth, draw angle and the rate of extraction, and that the time to complete subsidence is measured in years. While the time frames are extended at Polaris, it still indicates that the time frame for active subsidence to be occurring is limited.

The Handbook also indicates that increasing the depth of cover increases the length of time for subsidence to finish (Appendix A). In the area of the Sinkhole, there is approximately 150 metres of cover, so even if 10 or 15 metres of fill were added, the relative change in cover thickness is small and would have little effect on subsidence rates.

4.2. Impact of Fill on the Permafrost Regime

Placing fill in the sinkhole area is no different from placing fill anywhere else on the island. Permafrost will be established in the fill over a relatively short period of time. The thicker the fill, the more time it would take for the permafrost to be fully re-established. The primary purpose of placing fill in the sinkhole area to restore previous elevations of the ground surface in this area. Whether or not permafrost is reinstated in the new fill in several months or in a few years has no impact on the ground surface elevation which is the primary issue of concern.

5. Thermal Regime at the Polaris Mine Site

5.1. The Need for Installation of Thermistors to Monitor Permafrost Temperatures from the Surface and/or Around Mine Workings

There is an extensive history of ground temperature monitoring related to the mine workings at the Polaris Mine. The mine has measured rock temperatures in and adjacent to mining areas for mining planning purposes. Some examples are:

a) Ground Stability of Mine Workings Due to Thermal Regime
   Prior to developing mine workings in an area, mine engineers needed to be confident that the planned workings would be in an area where the ground is frozen. Thermistors were installed in drill holes that were drilled from surface into the ground ahead of mining. Additional thermistors were placed into drill holes that were drilled from underground workings to confirm the temperature forecasts provided by the surface drill holes. Figure 7 in Volume 1 of the Decommissioning and Reclamation Plan (March 2001) was developed though the collection of this data.

b) Ground Stability of Mine Workings Due to Summer Air Temperatures – the stability of the ground immediately surrounding the underground mine workings was key to providing safe working conditions for personnel working underground. Mines utilize high horsepower fans to force large volumes of fresh air underground to provide fresh air for diesel equipment and to provide clean air for personnel. Experience has shown that if the surfaces of the rock around the tunnels underground are allowed to thaw (in summer when air temperatures are above freezing), that localized sections of rock become unstable (referred to as 'Loose') and are a hazard to personnel working in the area. Thermistors were commonly placed into drill holes in the walls and roofs of the tunnels to monitor rock temperature changes related to local mining activities and seasonal temperature changes. This data indicates that warming of the rock face underground is affected within only a few metres of the mine openings during the warm summer months. It is important to note that after the completion of placing contaminated soils underground in 2004, all of the entrances to the mine will be sealed preventing any air flow in the mine so that the warming effect by air during the summer months will no longer be a factor.

c) Performance of Backfill – as indicated earlier in this report, the mine utilized a water/waste rock backfill to increase the stability of most stopes once mining had been completed. It was important from an operational stand point to determine how quickly the water/rock backfill froze as it would not provide adequate strength until this occurred. Thermistors were placed into this fill and into the adjacent pillars to confirm that the fill had frozen and that the surrounding ground did not thaw as a result. Monitoring of the fill indicated that up to two years was required for fill in large stopes to completely freeze. An individual stope could have upwards of 110,000 tonnes of fill placed that would be frozen as a result of the surrounding ground temperatures. The thermal mass of the surrounding ground is immense. Disturbing the thermal regime by placing materials in the mine is very localized and temporary.

Given over 20 years experience monitoring temperatures in and around the mine during on-going mining and backfilling of openings has clearly demonstrated that there are no concerns with the thawing of the ground at that depth. There is no need to verify this by additional monitoring using thermistors.

5.2. Thermal Regime and Ice Conditions in the Overburden

Temperature monitoring of surface and near surface ground temperatures has been conducted at Polaris for a number of years. Near surface permafrost conditions are a consideration for civil structures at the site such as Garrow Lake Dam and the Operational Landfill. Starting in 2004, monitoring of the Little Red Dog Quarry Landfill will be initiated and continue until 2011. Monitoring of the Garrow Lake dam and the Operational Landfill clearly demonstrates that large quantities of fill placed on surface quickly freeze and within a short period of time, only a relatively shallow active layer (less than 1.5 metres deep) temporarily thaws during the summer season. The effects of global warming were reviewed to determine the effect in the thickening of the active layer related to the landfill cover designs proposed in the DRP. Conservative forecasts indicate on slight increases in the thickness of the active layer (refer to the Polaris Mine Decommissioning and Reclamation Plan, Volume 2, Landfill Closure Report).

The rate of subsidence in the sinkhole area is expected to continue at a decreasing rate over the next few years. Past experience has shown that water pooling over this area during the summer months can infiltrate into new surface cracks caused by ongoing settlement. The depth that this water penetrates the strata overlying the mine has not been investigated. The immense thermal mass of the frozen overburden and bedrock freezes the water before it penetrates into the mine workings (refer to the Conclusion section of the memorandum prepared by Trevor Feduniak titled ‘Subsidence Analysis’ attached in Appendix D). Once the subsidence in the sinkhole area slows, there will be no new surface cracking and no new conduits for water to flow into the overburden will be created. Existing cracks will be ice filled in a self healing process. Any water penetrating cracks in the near surface strata adds to the strength of the strata as it freezes (a ‘healing’ process).

5.3. Impact of Surface Water Ponding on Thermal Regime and Permafrost Stability.

During the DIAND site inspection in September 2003, the option of allowing water to pond rather than placing fill into the Sinkhole was discussed as a method of filling any holes caused by subsidence of the sinkhole. It is felt that making this decision is premature at this time until further subsidence data can be collected in 2004.

6. Assessment of Physical Stability and Protection Required

The following is a listing of the types of conditions that if formed by the subsidence referred to as the 'sinkhole' area, could represent a hazard to the public and/or wildlife:

1. If the surface of the ground is unstable it could present a danger to the public/wildlife walking or the public operating motorized equipment over the sinkhole area. The potential danger is that subsidence of the bedrock continues to occur while the overlying soils form a bridge overtop of it. If the activities of people or wildlife were to break the bridging, then the soils could potentially suddenly slump into the underlying void causing harm to those overtop of this area.
   - This area has in the order of 10 to 20 metres of overburden soils overlying the bedrock. During the initial period of active subsidence in this area, heavy mobile equipment has operated adjacent to it and over top of it, placing fill and re-contouring the area without incident. There has never been any evidence of this occurring.
   - As the rate of subsidence decreases, the risk is further reduced as the ground surface has more time to react (i.e. settle).
   - The potential for unexpected, sudden subsidence caused by people or wildlife walking over this area or from operating light motorized equipment is considered remote based on previous experience (at Polaris as well as at other Teck Cominco mine sites) although one can not say categorically that it would never occur.

2. If the slope of the ground is excessively steep, this could represent an unexpected hazard to persons operating motorized equipment in the area. Also at some point, if the slopes are too steep, wildlife could also become trapped in the sinkhole area:
   - The slope of the ground in the area is relatively smooth with low slopes so that there is no concern of thus type of problems at the current time.
   - While there was no survey conducted during 2003, visual observations did not identify localized movement in the Sinkhole area.

- The area will be inspected (and surveyed) in 2004 and if significant subsidence has occurred by that time, adjacent slopes could be re-contoured as there will still equipment available on site.
- Beyond 2004, the rate of subsidence is expected to be decreasing so that the potential for steep slopes forming is a decreasing risk. A survey review in 2004 will be required to confirm this and to forecast future subsidence rates.

3. If the surface contours are altered so that water collects in the low areas creating a pond, there is a potential that the public and/or wildlife could drown in the water.
    - This is not considered a hazard any more or less than any other pond or lake on the island.
    - If ponding of water were to occur, it is not anticipated that any action would be required from a public/wildlife safety perspective.

7. Recommendations for On-going Assessment and Monitoring

As previously discussed the precise surveying of subsidence monitoring stations installed in the surface bedrock were established to provide information for mine planning and design activities. Vertical subsidence movements as little as 0.01 metres were monitored. Now that mining has been completed, the need for this level of accuracy of monitoring is not required. The purpose of monitoring subsidence is now one of public safety which requires a much coarser level of survey accuracy. Once the 2004 precise survey has been completed, subsidence rate curves will be updated and a forecast of future subsidence trends will be more definitive.

Inspection of the mine area will be conducted to determine if there are any new tension cracks in the soils. If there are, these will be surveyed and plotted onto the surface plans to identify any trends indicating changes in the subsidence boundaries. This monitoring can be conducted post 2004 as part of the annual site inspections.

In preparation for longer term monitoring of the site, a topographical survey was completed in 2003. Apart from a final precise survey of the remaining subsidence monitoring stations in 2004, future subsidence monitoring should consist of topographical monitoring of the soil surface to identify potential changes of drainage patterns and for public safety (i.e. settlement causing hazards to the public riding on quads or snow mobiles) purposes. A copy of this survey is included in Appendix E. As with monitoring of the tension cracks, it is recommended that some key locations are surveyed as part of the annual site inspections.

Yours truly,

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APPENDIX A

1. **Time / Subsidence Relationships – Subsidence Engineers' Handbook, National Coal Board, 1975**

2. **Time – Subsidence Curve – Subsidence Engineers' Handbook, National Coal Board, 1975**

Subsidence Engineers' Handbook

NCB

National Coal Board
Mining Department 1975

Time/Subsidence Relationship

Permanent repairs should not normally be carried out if a damaged property is due to be undermined again in another seam or by another face in the same seam lying within the critical area. First-aid repairs are often satisfactory for short periods, but discretion is necessary when long intervals are likely to occur between successive excavations or when the property is going to be in an unstable state over a long period.

If the stability of a building is affected and the site is required for development, an estimate should be made of the earliest date when building could safely commence. This should be done by plotting a development curve or a time/subsidence curve and usually ignoring any possible residual subsidence period, which in any case would probably be covered by the site preparation period.

The nomogram in Fig. 33 may be used for this estimation of total time for a single face working. Starting at the depth line, the limit angle is next chosen and this gives the diameter of the critical area (2R). The value for the rate of advance of the face is next intersected to give the total time on the right-hand half of the base line. In the example the broken line shows that for a seam 450 m deep and an angle of draw of 35°, the width of the critical area is 630 m. With a face advance of 1400 m per year the time taken to work the panel is about 6 months.

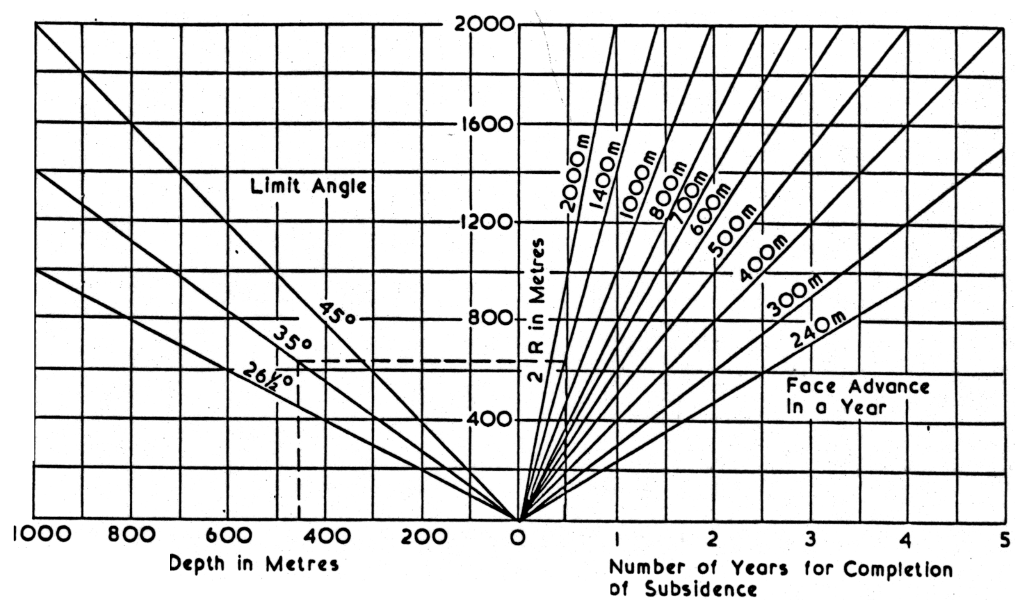

Fig. 33 Nomogram for estimating duration of subsidence.

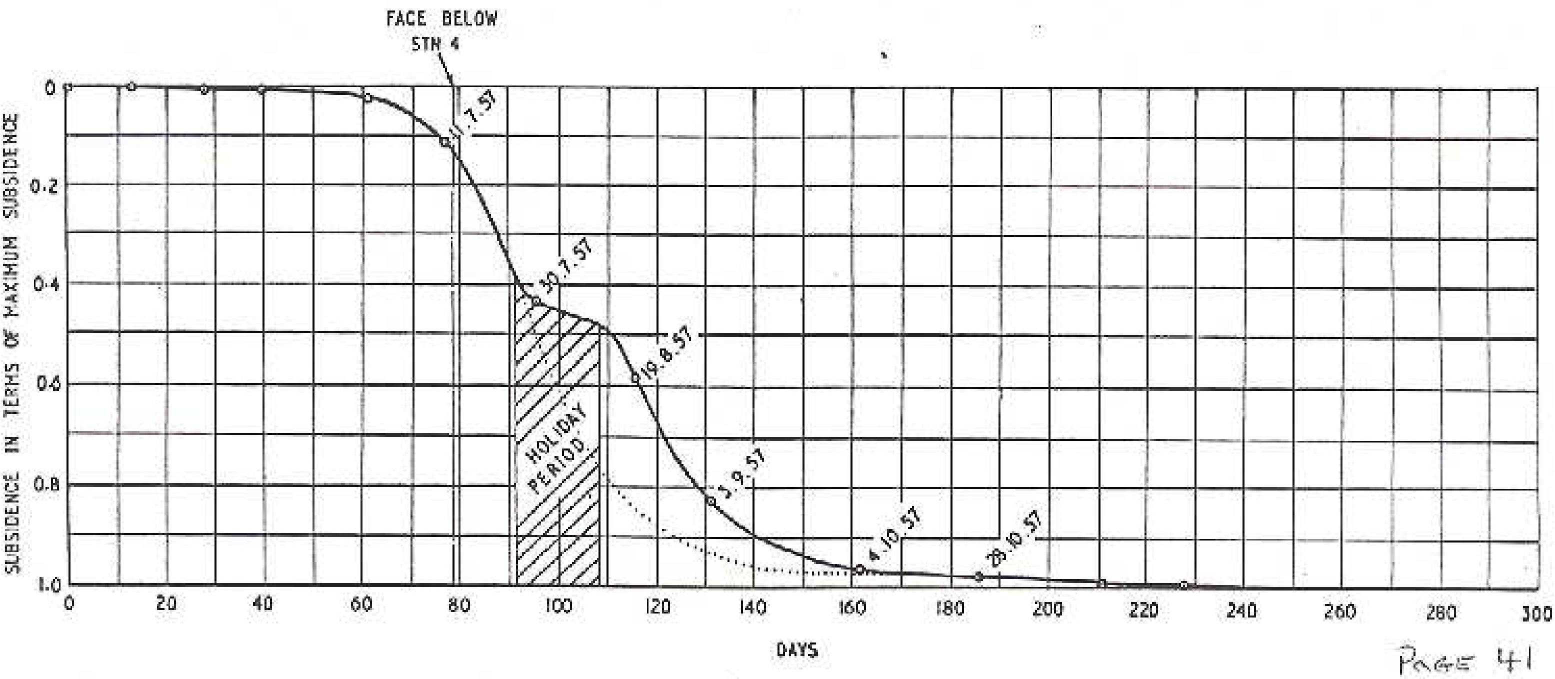

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Fig. 30 National Case No. 9—time-subsidence curve.

APPENDIX B

1. **Plan of Subsidence Monitoring Stations and Outline of Mine Workings**

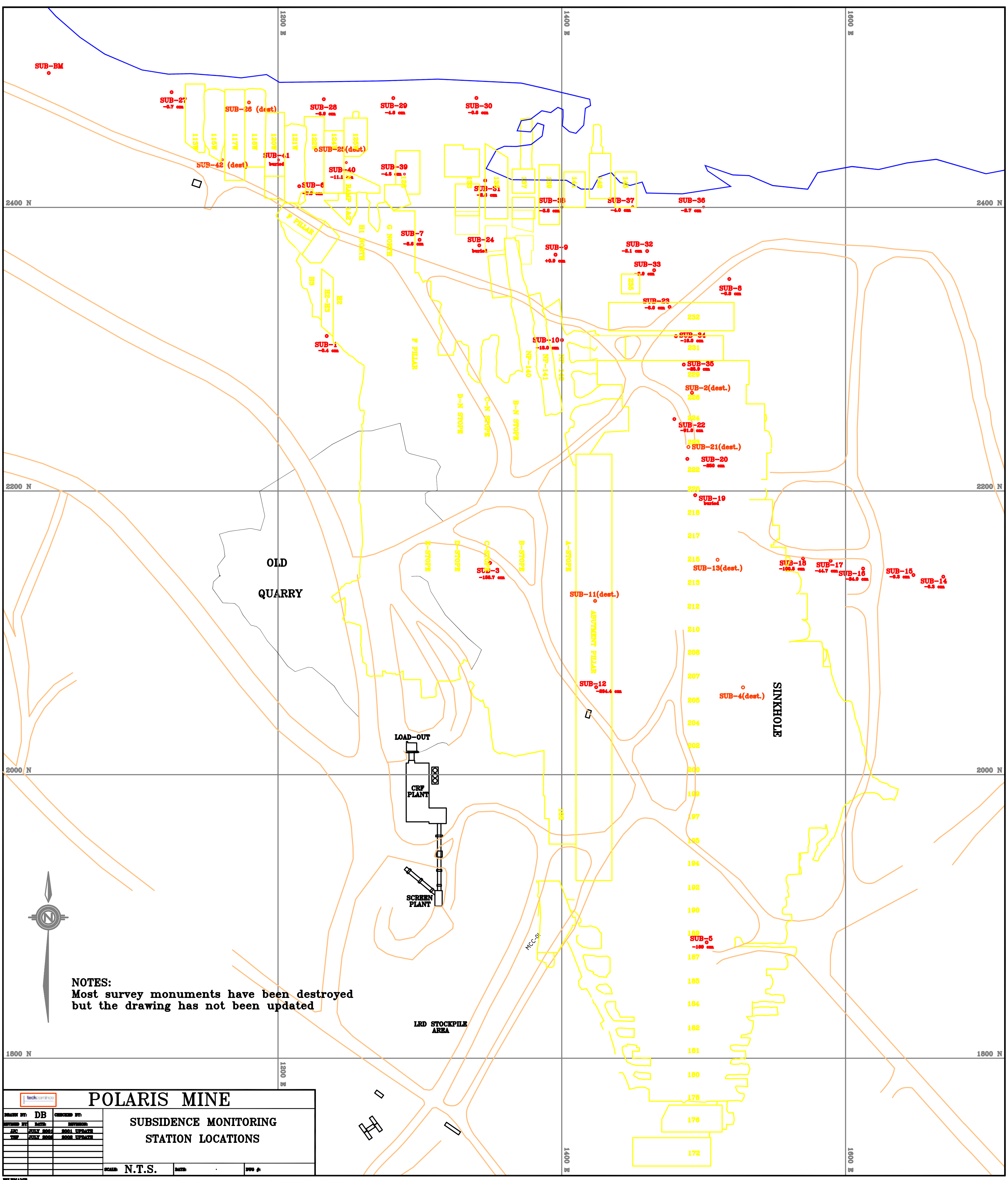
2. **Graph of Surface Subsidence Versus Time Along Section 1500 E**

3. **Graph of Surface Subsidence Versus Time for 2150 N Section – West**

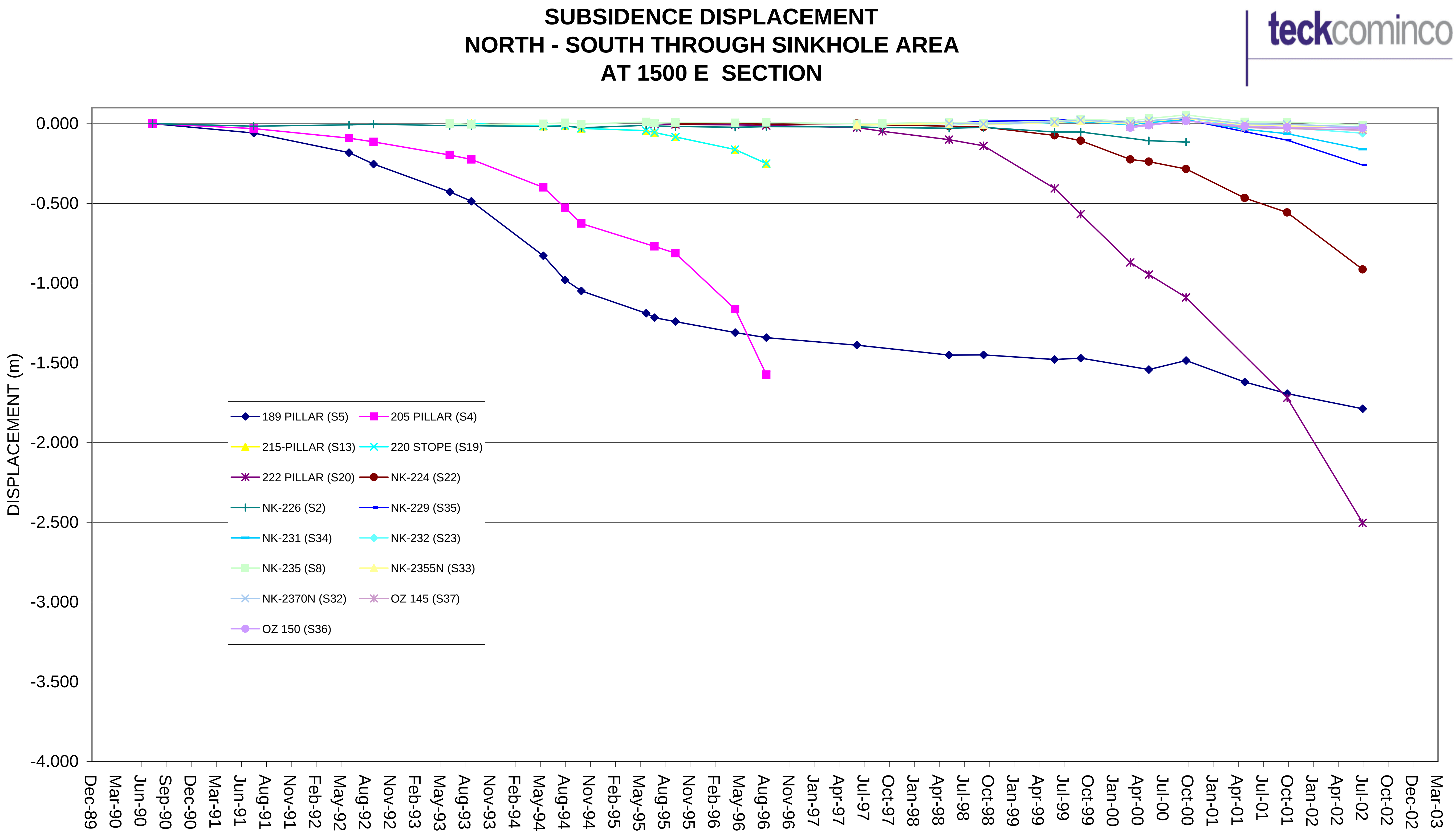
4. **Graph of Surface Subsidence Versus Time for 2150 Section – East**

5. **Cross Section Titled '2150 Section Through Sinkhole Area'**

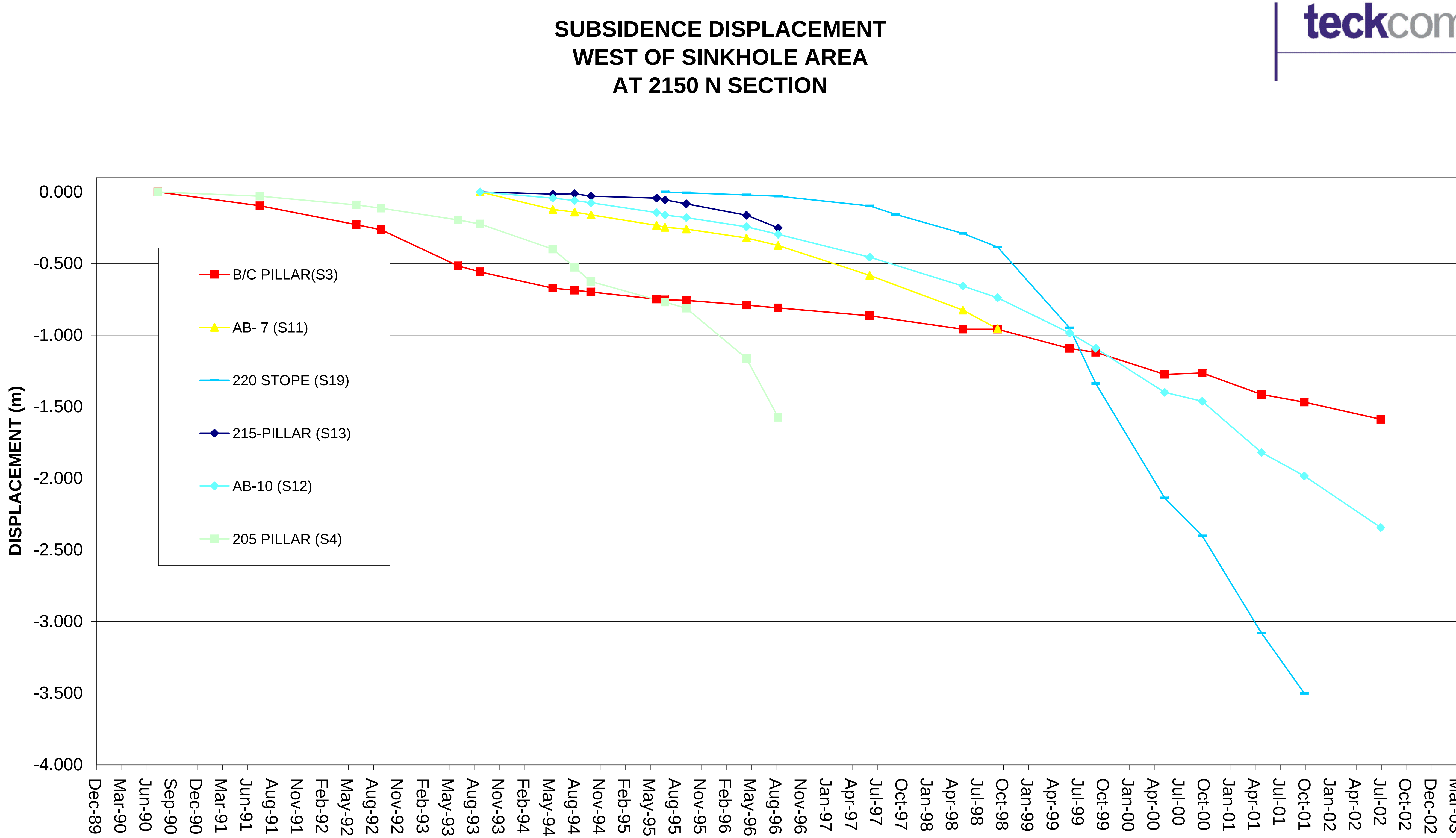
6. **Plan View of Mine Area Identifying Locations of Surface Tension Cracks**



POLARIS MINE
SUBSIDENCE MONITORING
STATION LOCATIONS
DB
N.T.S.
NOTES:
Most survey monuments have been destroyed
but the drawing has not been updated
OLD
QUARRY
SINKHOLE
LOAD-OUT
CRF
PLANT
SCREEN
PLANT
LRD STOCKPILE
AREA
2400 N
2200 N
2000 N
1800 N
1200 E
1400 E
1600 E
SUB-BM
SUB-27
SUB-26 (dest)
SUB-28
SUB-29
SUB-30
SUB-41
SUB-42 (dest)
SUB-25 (dest)
SUB-40
SUB-39
SUB-6
SUB-31
SUB-38
SUB-37
SUB-36
SUB-7
SUB-24
SUB-9
SUB-32
SUB-33
SUB-8
SUB-23
SUB-1
SUB-10
SUB-34
SUB-35
SUB-2(dest.)
SUB-22
SUB-21(dest.)
SUB-20
SUB-19
SUB-13(dest.)
SUB-18
SUB-17
SUB-16
SUB-15
SUB-14
SUB-3
SUB-11(dest.)
SUB-12
SUB-4(dest.)
SUB-5



SUBSIDENCE DISPLACEMENT
NORTH - SOUTH THROUGH SINKHOLE AREA
AT 1500 E SECTION
teckcominco
DISPLACEMENT (m)
0.000
-0.500
-1.000
-1.500
-2.000
-2.500
-3.000
-3.500
-4.000
Dec-89
Mar-90
Jun-90
Sep-90
Dec-90
Mar-91
Jun-91
Aug-91
Nov-91
Feb-92
May-92
Aug-92
Nov-92
Feb-93
May-93
Aug-93
Nov-93
Feb-94
May-94
Aug-94
Nov-94
Feb-95
May-95
Aug-95
Nov-95
Feb-96
May-96
Aug-96
Nov-96
Jan-97
Apr-97
Jul-97
Oct-97
Jan-98
Apr-98
Jul-98
Oct-98
Jan-99
Apr-99
Jul-99
Oct-99
Jan-00
Apr-00
Jul-00
Oct-00
Jan-01
Apr-01
Jul-01
Oct-01
Jan-02
Apr-02
Jul-02
Oct-02
Dec-02
Mar-03
189 PILLAR (S5)
205 PILLAR (S4)
215-PILLAR (S13)
220 STOPE (S19)
222 PILLAR (S20)
NK-224 (S22)
NK-226 (S2)
NK-229 (S35)
NK-231 (S34)
NK-232 (S23)
NK-235 (S8)
NK-2355N (S33)
NK-2370N (S32)
OZ 145 (S37)
OZ 150 (S36)


SUBSIDENCE DISPLACEMENT
WEST OF SINKHOLE AREA
AT 2150 N SECTION
DISPLACEMENT (m)
0.000
-0.500
-1.000
-1.500
-2.000
-2.500
-3.000
-3.500
-4.000
B/C PILLAR(S3)
AB- 7 (S11)
220 STOPE (S19)
215-PILLAR (S13)
AB-10 (S12)
205 PILLAR (S4)
Dec-89
Mar-90
Jun-90
Sep-90
Dec-90
Mar-91
Jun-91
Aug-91
Nov-91
Feb-92
May-92
Aug-92
Nov-92
Feb-93
May-93
Aug-93
Nov-93
Feb-94
May-94
Aug-94
Nov-94
Feb-95
May-95
Aug-95
Nov-95
Feb-96
May-96
Aug-96
Nov-96
Jan-97
Apr-97
Jul-97
Oct-97
Jan-98
Apr-98
Jul-98
Oct-98
Jan-99
Apr-99
Jul-99
Oct-99
Jan-00
Apr-00
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Jul-01
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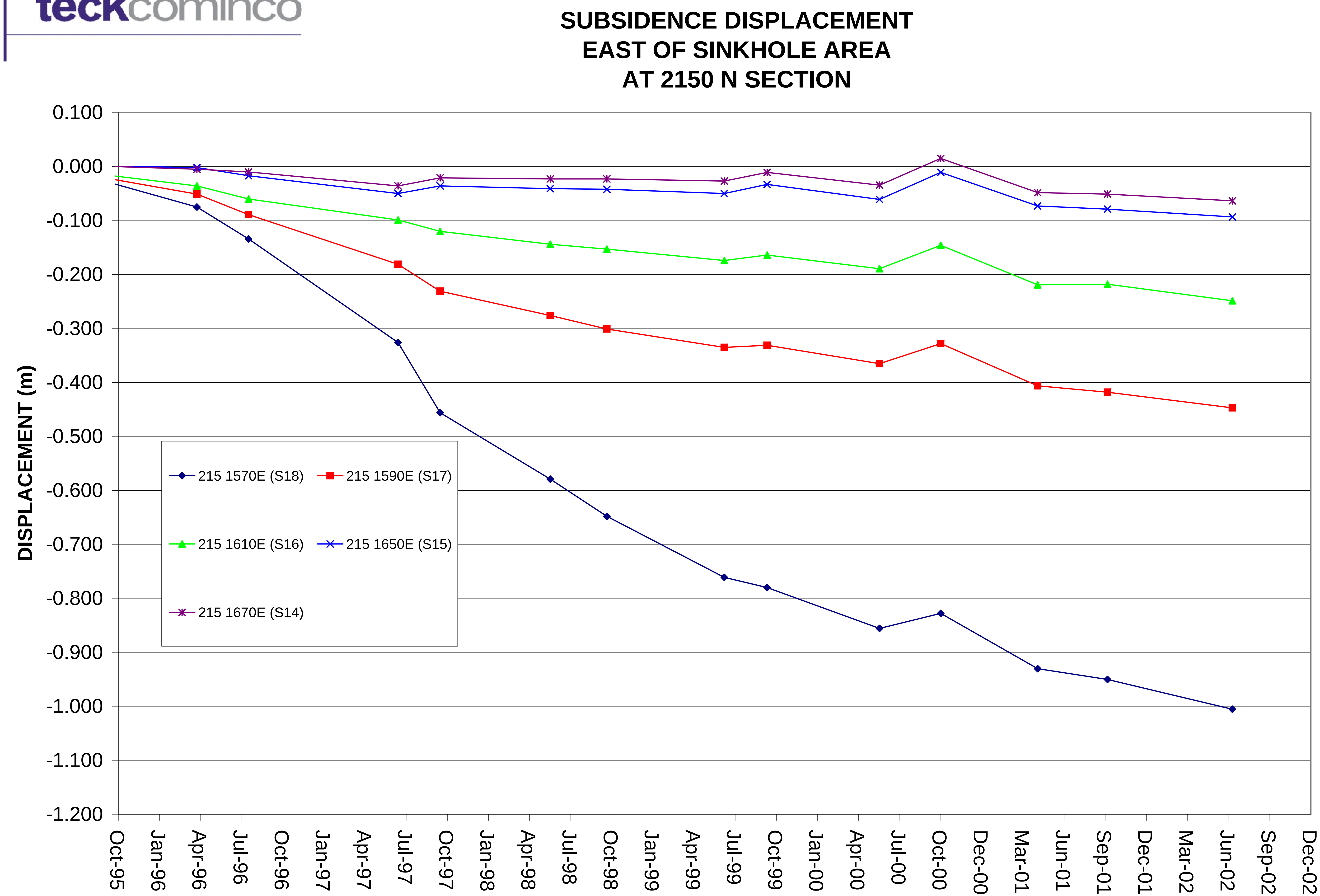
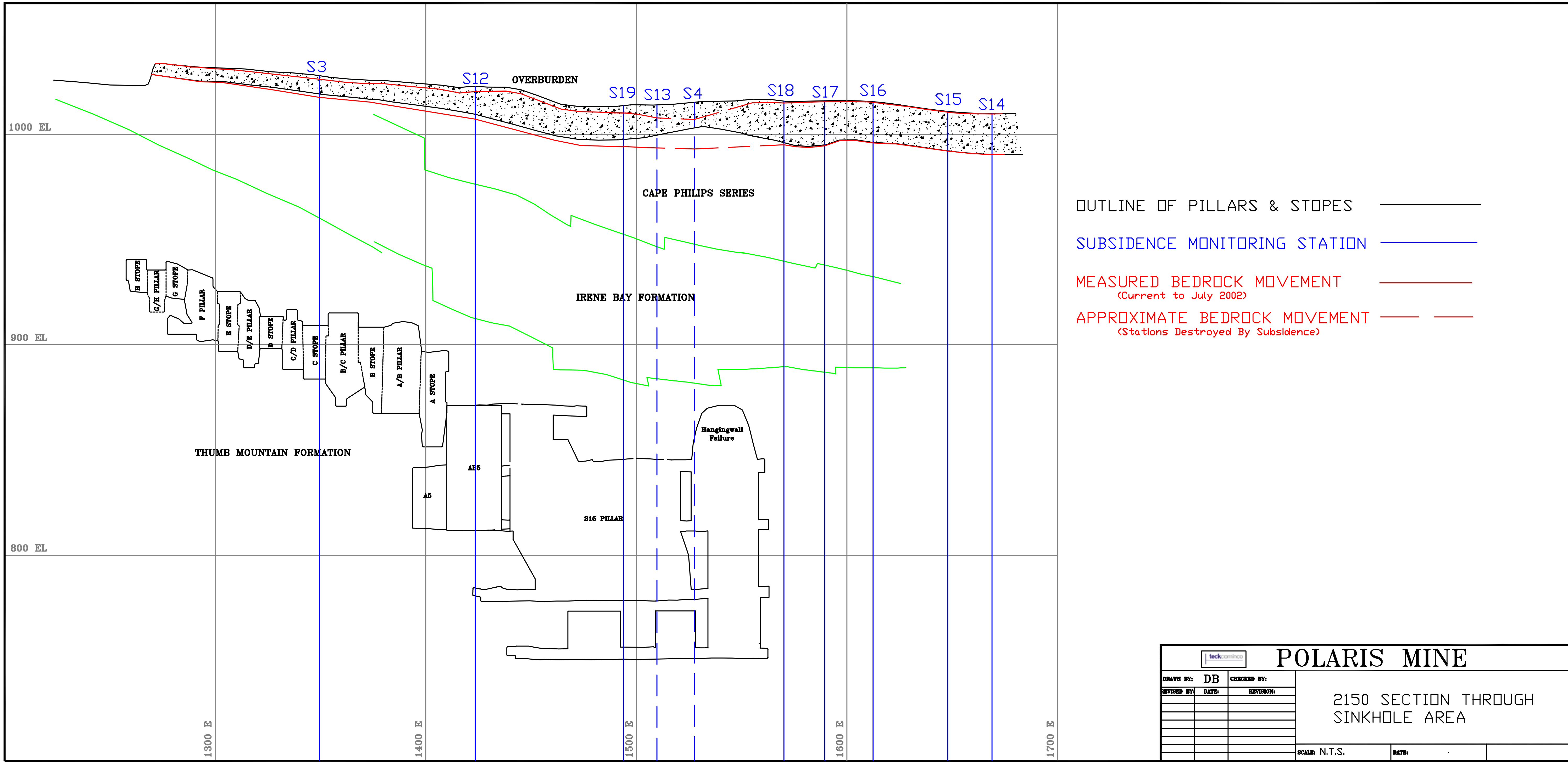
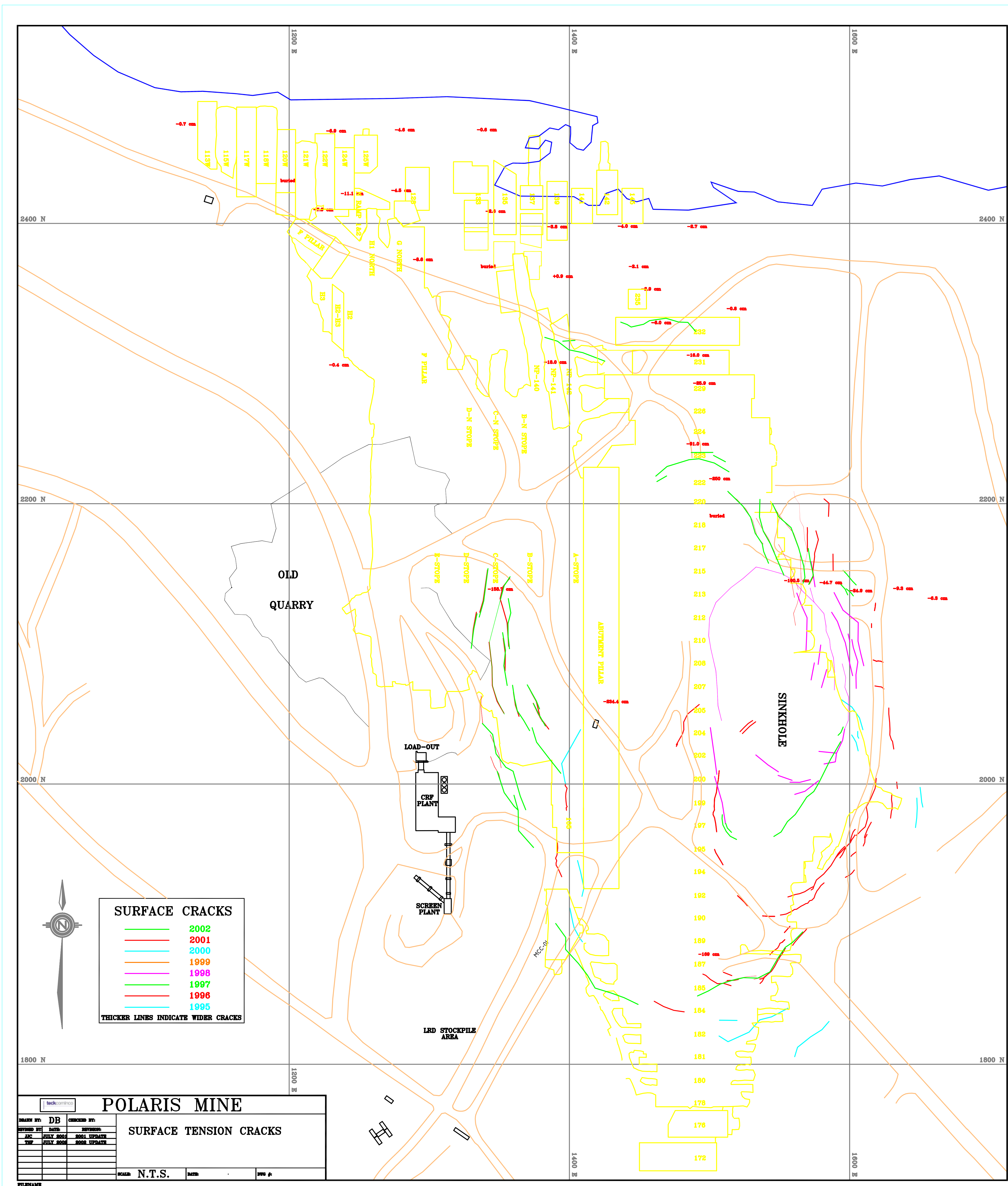
Jan-02
Apr-02
Jul-02
Oct-02
Dec-02
Mar-03


SUBSIDENCE DISPLACEMENT
EAST OF SINKHOLE AREA
AT 2150 N SECTION
DISPLACEMENT (m)
0.100
0.000
-0.100
-0.200
-0.300
-0.400
-0.500
-0.600
-0.700
-0.800
-0.900
-1.000
-1.100
-1.200
Oct-95
Jan-96
Apr-96
Jul-96
Oct-96
Jan-97
Apr-97
Jul-97
Oct-97
Jan-98
Apr-98
Jul-98
Oct-98
Jan-99
Apr-99
Jul-99
Oct-99
Jan-00
Apr-00
Jul-00
Oct-00
Dec-00
Mar-01
Jun-01
Sep-01
Dec-01
Mar-02
Jun-02
Sep-02
Dec-02
215 1570E (S18)
215 1590E (S17)
215 1610E (S16)
215 1650E (S15)
215 1670E (S14)


S3
S12
OVERBURDEN
S19
S13
S4
S18
S17
S16
S15
S14
1000 EL
900 EL
800 EL
CAPE PHILIPS SERIES
IRENE BAY FORMATION
THUMB MOUNTAIN FORMATION
H STOPE
G/H PILLAR
G STOPE
F PILLAR
E STOPE
D/E PILLAR
D STOPE
C/D PILLAR
C STOPE
B/C PILLAR
B STOPE
A/B PILLAR
A STOPE
AE5
A5
215 PILLAR
Hangingwall Failure
1300 E
1400 E
1500 E
1600 E
1700 E
OUTLINE OF PILLARS & STOPES
SUBSIDENCE MONITORING STATION
MEASURED BEDROCK MOVEMENT
(Current to July 2002)
APPROXIMATE BEDROCK MOVEMENT
(Stations Destroyed By Subsidence)
POLARIS MINE
DRAWN BY: DB
CHECKED BY:
REVISED BY:
DATE:
REVISION:
2150 SECTION THROUGH
SINKHOLE AREA
SCALE: N.T.S.
DATE:


SURFACE CRACKS
2002
2001
2000
1999
1998
1997
1996
1995
THICKER LINES INDICATE WIDER CRACKS
OLD
QUARRY
SINKHOLE
LOAD-OUT
CRF
PLANT
SCREEN
PLANT
LRD STOCKPILE
AREA
ABUTMENT PILLAR
F PILLAR
2400 N
2200 N
2000 N
1800 N
1200 E
1400 E
1600 E
POLARIS MINE
DRAWN BY: DB
CHECKED BY:
REVISED BY:
DATE:
REVISION:
JJC
JULY 2001
2001 UPDATE
TSF
JULY 2002
2002 UPDATE
SURFACE TENSION CRACKS
SCALE: N.T.S.
DATE:
DWG #:
FILENAME

APPENDIX C

1. **Excerpts from Report on ‘Site visit to Cominco Ltd.’s Polaris Mine’ by Golder Associates Ltd., February 1994**

2. **Excerpts from Report on ‘Visit to Polaris Mine November and December 1995’ by Golder Associates Ltd., May 31, 1996**

Golder Associates Ltd.

500 - 4260 Still Creek Drive
Burnaby, British Columbia, Canada V5C 6C6
Telephone (604) 298-6623
Fax (604) 298-5253

Golder Associates

REPORT ON

SITE VISIT
TO
COMINCO LTD.'S
POLARIS MINE

1994

Submitted to:

Cominco Ltd.
Polaris Operations
Polaris, NWT
X0E 0Y0

DISTRIBUTION:

3 copies -	Cominco Ltd. Little Cornwallis Island, NWT
3 copies -	Cominco Ltd. Vancouver, B.C.
2 copies -	Golder Associates Ltd. Vancouver, B.C.

February 1994

932-1510

- Movements on the 880 level were difficult to interpret due to erratic results.

Due to problems with maintaining convergence stations, the program was discontinued and is being replaced by a qualitative visual monitoring program.

4.3 Subsidence

Surface subsidence measurements continue over the Keel and Panhandle Zones. In 1993, an additional eight stations were added to the existing five. The locations of the monitoring points are shown in Figure 1. The new stations will provide information above the abutment pillar and northern stoping areas

Two measurements have been made since the December 1992 visit. Only three stations, B/C, 189 and 205 are showing significant movement. The movement recorded at these three stations is summarized in Table 1 and graphed in Figure 2.

Table 1

Summary of Subsidence 1990-1993 for B/C, 189 and 205 Stations

Station	Total Movement (mm)	1990-1991 Movement (mm)	1991-1992 Movement (mm)	1992-1993 Movement (mm)
B/C	558	97	167	294
189	486	58	195	233
205	224	30	84	110

Table 1 shows a yearly trend of increasing subsidence at the B/C and 189 stations. This corresponds to the nearly 100% extraction of the ore beneath these stations. The station above 205 is beginning to show the effects of the northward advance of the mining front.

4.4 Surface Extensometer

The two surface extensometer installations adjacent to the B/C and 189 surface subsidence stations have been monitored since 1988. Plots of cumulative movement of these two extensometers are presented in Figures 3 and 4. Total movement recorded for the B/C extensometer is 19 millimetres and for the 189 extensometer, 77 millimetres. These values are approximately 4% and 16% of total subsidence measured at that point.

Both extensometers record some minor separation at 40-60 metres depth. The disparity between the measured surface subsidence and the movement indicated by the extensometers indicates that the hangingwall may be moving as a relatively cohesive mass (or as a series of large blocks).

5.0 KEEL PILLAR MINING

Pillar mining in the Keel Zone has rapidly become the primary source of ore at the Polaris Mine. Pillar ore now forms 72% of production tonnes versus 14% in 1988.

5.1 Review of Pillar Mining Experience

A considerable amount of information has been collected on the pillar mining carried out to date. This information was reviewed and will be applied to the analysis of future pillar mining operations.

5.1.1 Pillar Recovery

Table 2 presents experience with pillar mining to date. The percentage extraction of both tonnes and metal are included as well as comments on stability related issues.

Table 2

Summary of Keel Pillar Mining Experience

Pillar	% Tonnage Recovery	% Metal Recovery	Comments
180	-	60	Backfill problems
182	-	100	Back failure in Stage II
185	85	75	Backfill problems in Stage I, back failure in Stages II and III
189	105	95	
192	92	85	Backfill problems in Stage I Back failure in Stage IV
195 *	100	85	Back/hangingwall failure in Stage III, 90 metre high fill exposure
199 *	72	70	Significant ore loss in Stages I and III. Major back/hangingwall failure in Stage III
202-I	88	81	
202-II	102	99	Major failure of 820/850 block in Stage II

* Pillar not complete

The first pillars to be recovered tended to encounter problems with fill wall stability. However, with improved fill quality these problems appear to be resolved (for the fill wall dimensions currently being exposed). Recently there has been an increased incidence of back failures. These failures appear, in part, to be influenced by the various faults that traverse the orebody.

Recovered metal range from a low of 60% to a high of 100% with an average of 80%. Recovered tons range from a low of 72% to a high of 105%. The ratio of % metal to % tonnage is an average 0.92.

5.1.2 Backfill Performance

Backfill performance during pillar extraction is summarized in Table 3

Table 3

Summary of Exposed Backfill Stability*

Pillar	Stage	Maximum Height of Backfill Exposure (m)	Maximum E-W Span of Backfill (m)	Comments
185	II	50	24	
189	II	66	34	
192	I	65	33	Fail
192	II	65	25	
195	II	69	25	
195	III	71	26	
195	IV	95	22	
199	I	80	37	Fail
199	II	83	10	
199	III	87	28	Fail
199	IV	95	25	
202	I	51	26	

* Note: This table does not include early failures that were attributed to poor quality backfill.

Backfill stability would appear to be controlled by the following factors:

- The content and distribution of water in the fill;
- The time allowed for the fill to freeze;
- The height and width of exposed fill wall;

- The length of time between exposing a fill wall and backfilling of the pillar;

A reasonable amount of information is available on the water content and distribution within specific fill blocks. Where low moisture fill is anticipated, a "skin" of ore may be left to reduce the potential for fill dilution. The time required for the fill to freeze is also relatively well established and blocks are scheduled to allow sufficient time for ice formation. Stable exposure heights and widths have yet to be established. The data in the above table and in Figure 5 would indicate that the exposed width may play as big a role as the exposed height. This may be a result of the surfaces formed during fill deposition as shown in Figure 5.

5.2 Current Status of Pillar Mining in the Keel Zone

Active pillars in the Keel Zone are:

- 192 Stage III
  - Good recovery, no major problems to date.
- 195 Stage V
  - Mining block adjacent to major back failure, cable bolted back next to failure in good condition.

  199 Stage IV
  - Mining block adjacent to major back failure, some drilling problems on 850 level.
- 202 Stage II
  - Good recovery in 760/790 block, severe problems in 820/850 block with large ground displacements (see Section 5.3).
- 205 Stage I
  - Initial block development in place at eastern end.

5.3 202 Pillar Mining

The following outlines the sequence of events in mining of Stage II:

Mine and fill 760 to 790 level;

- Observed horizontal cracking and difficulty in maintaining blasthole integrity;

Mass blast 820 to 790 level;

- Continuous movement of the 850 to 820 block after the mass blast.

The block is bounded on the west by a steeply dipping structure and appears to be bounded by a similar structure on the eastern side. The top of the block is between 6 and 12 metres above the 850 Level. Figure 6 shows the approximate size of the block and the associated structures.

Total downward movement of the block is in excess of 3.5 metres on the 850 level (see Photographs 14 and 15). The block appears to be moving as a large mass and not rubblizing internally. **It is important to note that the total void space above the level must be equal to 3.5 metres.**

Important considerations in developing a plan to recover the block are as follows:

- 17,000 tonnes of ore from the 820/790 block remains on the 790 level;
- The 35,000 tonnes of ore in the 820/850 block is primarily from the high grade P1 horizon;
- Material above and to the east of the failure will be low grade or barren rock;
- The ultimate hangingwall on the 880 level has not been cable bolted;
- Significant back failures had occurred in both the 195 and 199 pillars.

From a geotechnical point of view it is important that any mining plan incorporate the following:

- Test holes towards the 199 pillar to establish the north-south extent of the back failure;
- Cable bolt the ultimate hangingwall on the 880 Level and, dependent upon the condition of the block below 880, cable bolt downwards to secure the ground above the sliding block. It must be recognized that due to the magnitude of the movements which have occurred that cable bolting may not be successful;
- Ensure that the drawpoint on 790 level is kept full to minimize the impact of any potential air blast should the sliding block fail suddenly;
- Development of a plan to fill the void should it become necessary;
- If an option is to mine Block III to induce failure of Block II then the size of Block III should be kept to minimum. This will reduce the size of the backfill exposure when both blocks are empty.

In evaluating a recovery plan it is very important to consider the risks associated with the plan and the consequences of both success and failure. The problem is 202 cannot be analyzed in isolation from the other stoping areas.

A number of controls exist that influence the course of action. These include:

- backfill disrupts float circuit and causes metal losses

- hangingwall dilution can slow the mill, but does not tend to cause metal loss
- the implication of these is that fill failure may be more costly ton for ton than hangingwall failure
- there is little flexibility in the overall extraction sequence (ie. few primary stopes remain that can be used to augment production when disruptions occur)

A number of potential recovery options were discussed. A final plan was developed at a ensuing meeting the week after the site visit.

5.4 General Pillar Mining Comments

5.4.1 Mass Blasting

A number of mass blasts have been undertaken during pillar recovery operations. Mass blasts are only considered when ground movements in the mining block become a potential safety concern or cause significant blasthole stability problems. Mining blocks of up to 40,000 tonnes have been mass blasted with large quantities of explosives assigned to a limited number of delays. Often, the blasts have had only minor void space.

Mass blasting has both positive and negative results.

Positive

- Efficiency gains through concentrated blasthole loading operations and reduced redrilling potential.
- Good fragmentation potential and therefore efficient mucking operations.

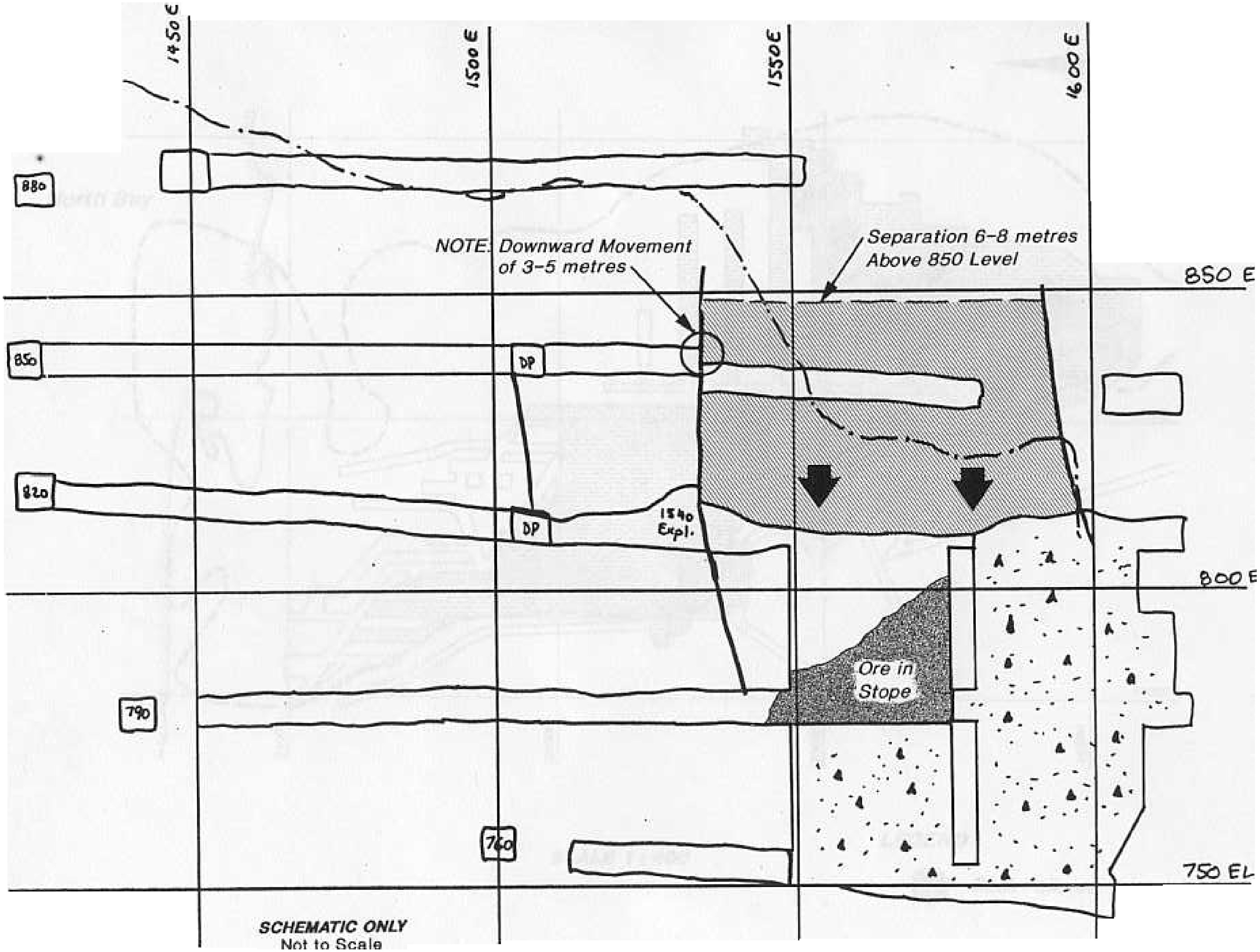
Negative

- High explosive quantities detonating over a short time period and small void ratio will result in high vibration and gas levels. This could potentially result in both new fracture creation, extension and opening existing fractures (blast damage).
- Large blast volumes will result in larger local stress redistribution and potentially more severe stress effects.

5.4.2 Size of Mining Blocks

When stability problems have been either identified through geologic mapping or encountered during pillar extraction, the post pillar location has been changed. In most cases the stage size has been increased to include the problem area.

PROJECT NO DRAWN REVIEWED DATE

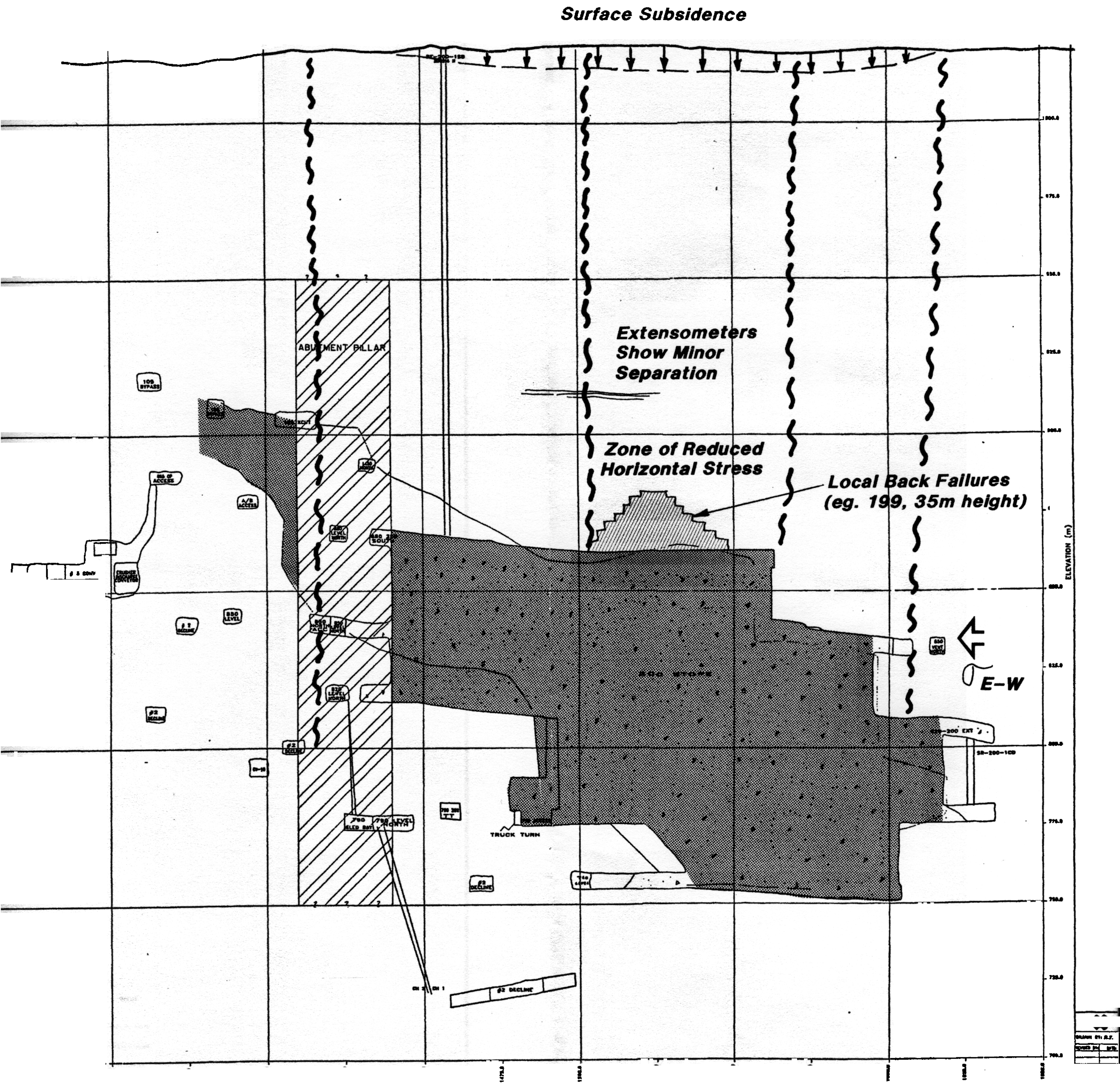


Golder Associates

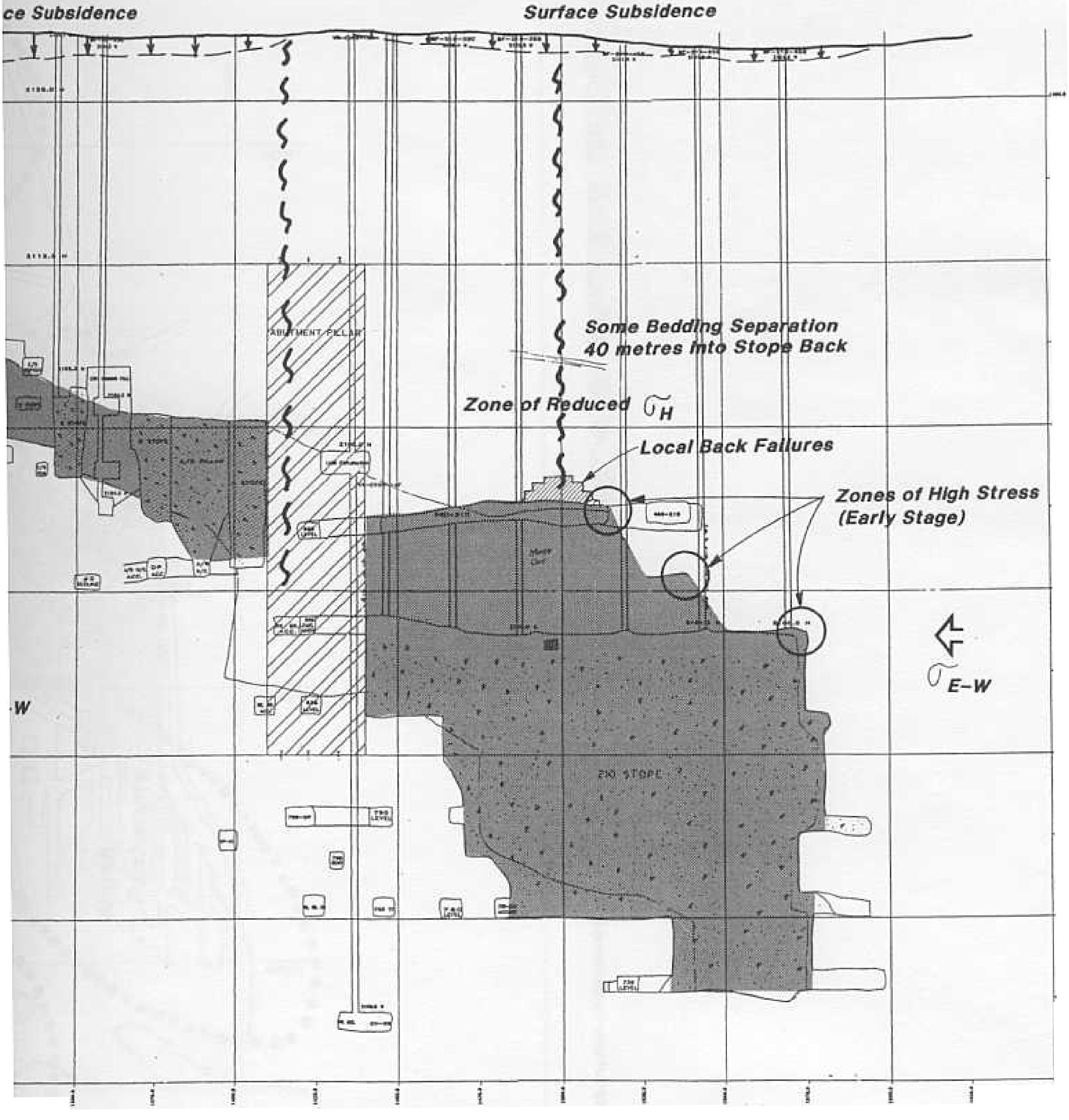
202 PILLAR SECTION

Figure 6

HANGINGWALL MODEL



HANGINGWALL MODE



Golder Associates Ltd.

500 - 4260 Still Creek Drive
Burnaby, British Columbia, Canada V5C 6C6
Telephone (604) 298-6623
Fax (604) 298-5253

Golder Associates

REPORT ON

VISIT TO POLARIS MINE
NOVEMBER AND DECEMBER 1995

Submitted to:

Cominco Ltd.
Polaris Operation
Polaris, NWT
X0E 0Y0

DISTRIBUTION:

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3 copies -	Cominco Ltd. Vancouver, B.C.
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May 31, 1996

952-1472

150 Area (see Photograph 28 and 29)

- **850L:** Stringer ore at fringes of main orebody will provide secondary ore source. Ground conditions rated as "fair". Back supported with Split Sets.

Lower S. Keel (see Photograph 30)

- **790L:** Stringer ore, secondary source. Back conditions rated as "good".

General

- Ground conditions do not appear to have substantially changed between the November and December visits. Overall, observed conditions were better than those during 1994 visit. In part, this is a result of more attention to ground support, both quality and timing of installation;

- Poorest observed ground conditions in abutment development were on the 880 mL;

- Poorest observed pillar conditions were along the 850 mL drill sub in the 208 and 212 pillars.

Support

- More screen is being installed. The quality of installation has improved substantially compared to the 1994 visit. In particular, screen is now being placed tight to the walls and back.

- A remote arm for placement of shotcrete has been built in the mine shops (see Photograph 20). Initial trials have indicated a number of problems with operating the arm and the quality of the placed shotcrete;

Subsidence

- Subsidence induced cracks have appeared on surface (see Photographs 44 to 48).

3.0 GROUND CONTROL

3.1 Current Ground Control Problems

Ground problems continue in the Keel Pillar stopes; for example, loss of access in the 208 pillar and wedging in the 212 pillar. These problems include:

hangingwall failures - Irene Bay;

wall slabbing in P1 ore;

wedging all north-south structure;

movement of ground in all stopes.

The cause of these problems has been discussed in previous visit reports. The important issue is, however, that problems will continue to occur as the highest, widest and weakest of the Keel Pillars are now being mined. The problems encountered in 208 can thus be expected in 212. Access will be lost (850/820), wedging will occur and re-drills will be necessary all leading to slower production and lower recovery.

As discussed in the following section, the majority of ground control problems appear to manifest themselves during Stage III stoping. This is due to a number of factors including thicker ore, weaker ground, etc. Improved support will mitigate against some of the problems. Other approaches include faster mining (with the aid of CRF) or a change in stage size. Observations, made by mine staff, that ground problems increase if a stage remains open for more than about 90 days, underline the benefits of faster mining.

3.2 Stoping Achievements

The mine has maintained a database on a number of key statistics on pillar mining. A review of this database indicates the following:

- Pillar recovery has decreased from approximately 92% of blasthole reserves in 1993 to approximately 82% of blasthole reserves in 1995, Figure 1a;
- Average daily production rates have been very variable (see Figure 1b), ranging from a high of 2,750 tonnes/da to less than 500 tonnes/da. Achievable daily production rates appear to be in the 500 to 750 tonnes/da range (see Figures 1b and 2). Discussions with mine staff indicate that production delays were largely associated with ground control problems;
- Average recoveries by stage were remarkably similar (see Figure 3a). However, the variation in recovery as measured by the co-efficient of variation (standard deviation/mean) clearly demonstrates the substantial risk of not meeting production targets during Stage II and Stage III mining (see Figure 3b);

- A typical section through a Keel pillar is given in Figure 4. This section illustrates that Stage III generally is tallest section and therefore weakest of the overall pillar; closest to the overlying, poor quality, Irene Bay; and contains the highest portion of high grade, weak ore. In addition, loss of access to the 850/820 drill subs leads to production delays due to increased support and poorer fragmentation;

3.3 Subsidence

The following summarises salient events regarding subsidence:

- Subsidence induced cracking has been observed at surface over and adjacent to the Keel mining area. The location of the cracks is shown in Figure 5.

- Surface cracking appears to be closely associated with those areas in the Keel where there has been 100% ore extraction. No cracking has been *observed* over the Panhandle mining area or over partially extracted areas of the Keel. The cracks appear to be located near vertically over the mined out outline on the 850/820 level.

  Surface monitoring shows continuing ground movement (see Figure 6). The maximum *measured* subsidence is approximately 1.25 m and is located over the 189 pillar area.

- Most subsidence monitors are maintaining constant velocity or de-accelerating.

- Analysis by mine staff of the monitoring data suggest an angle of draw of 40°.

- Given the location of the surface cracking, the angle of cave along the east and western sides of the orebody may be about 20° to 30°.

This information will assist in planning the North Keel and Ocean Zones where undue subsidence could lead to water inflow. A number of relationships exist for the prediction of surface subsidence. Unfortunately, these were generally developed for coal mining, where the ratio of depth to mined thickness (coal seam thickness) is high, often 50 or greater. At Polaris, the ore is both shallow and thick, and various coal subsidence formula become difficult to apply.

A recent review by Golder Associates (see Appendix II) found that published information on subsidence over base metal mines was extremely limited and mainly referred to caving. Thus, there is little precedent which can be used to assess future subsidence

(North Keel and Ocean Zone) at Polaris. More or less sole reliance will be on the information currently being gathered and mine derived relationships (assisted, for example, by numerical modelling).

3.4 Support

Improvements continue to be made in ground support practices. These include:

- screening and strapping of walls;
- installation of support prior to changes in ground conditions; and
- substantial reduction in backlog of support installation.

Salient comments are as follows:

Screening in the weak P1 ore should be to the sill. Bolts should be installed at the base of the screen. There may be some operational difficulties with this approach. It will enhance the effectiveness of the screen.

- The shotcrete arm should be modified in order to obtain a better application. Continued experimentation with shotcrete is required.
- The use of Split Set bolts instead of resin bar as a means of wall support has been proposed. From a purely ground control perspective, Split Set bolts can provide effective support. However, it is questionable whether the changes can be economically justified.

3.5 Cemented Rock Fill

The CRF plant is in the process of being commissioned. A number of start-up problems are being experienced which have been exacerbated by the extreme climate at Polaris.

The requirements and opportunities associated with CRF have been discussed in previous review reports and extensively by Polaris staff. The major impact of CRF with be the greater stoping control that can be realised and the faster stope cycle time that can be achieved. It is believed that this will be a significant factor in the mining of the abutment pillar.

PHOTOGRAPH 43

Surface subsidence cracks.

PHOTOGRAPH 44

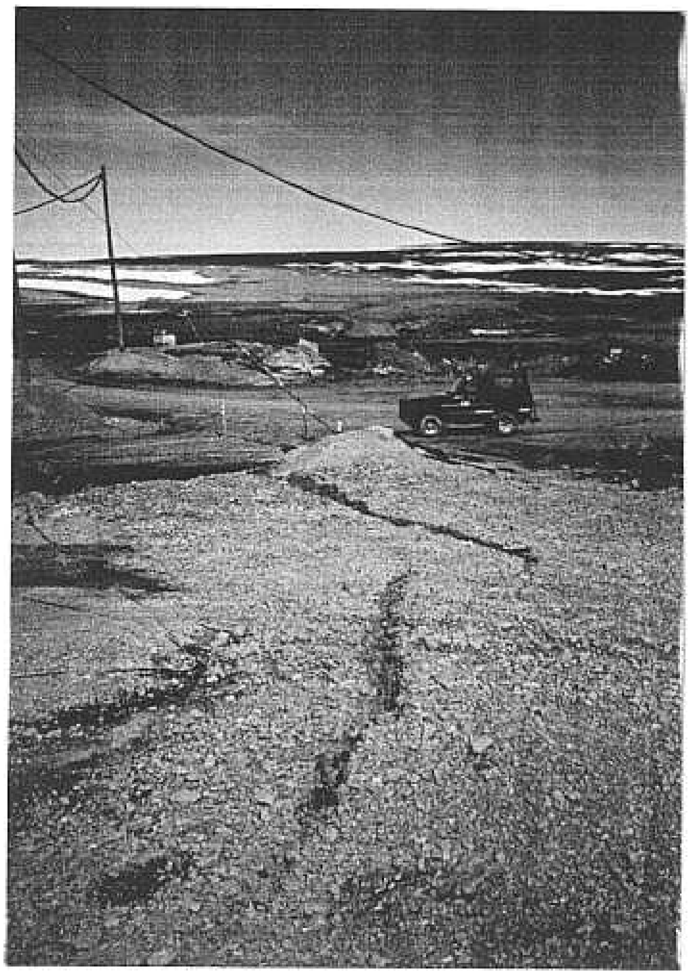
Surface subsidence cracks.

PHOTOGRAPH 46

Surface subsidence cracks.

PHOTOGRAPH 45

Surface subsidence cracks.



PHOTOGRAPH 47

Surface subsidence cracks.

PHOTOGRAPH 48

Surface subsidence cracks.

APPENDIX D

1. **Polaris Operations Internal memorandum – Trevor Feduniak (Senior Mine Engineer) to John Knapp (Manager) Regarding 'Subsidence Analysis', December 4, 2002**

teckcominco

Memorandum

To: John Knapp – Mine Manager

From: Trevor Feduniak – Senior Mine Engineer

Date: December 4, 2002

Subject: Subsidence Analysis

A surface subsidence analysis was conducted in the fall of 2002.

Measurement Method:

Subsidence at Polaris has been measured since 1990 by surveying the elevation of monitor posts at strategic locations. New posts have been added over the years to provide more detail, most recently in summer 1999. Some attrition has occurred; posts have fallen over due to large amounts of subsidence, and more commonly, posts have been damaged by surface mining activities.

The survey is done using a leveling instrument, using a benchmark post (located far from mining-influenced ground) as a reference. The posts are measured in sequence, and the loop is closed back at the benchmark. Closure error is distributed evenly among all measurements. In an effort to reduce the closure error, or at least distribute it more accurately, the surveys for the past couple of years were done as a series of sub-loops rather than one large loop of all stations. The results indicate that the new method increases our accuracy.

Typically only two measurements per year are practical, due to the leveling instrument's sensitivity to the cold weather and wind. This year, only one level loop was conducted (July). A measurement in September was not possible due to a decrease in manpower, a direct result of the scheduled completion of mining activities at the end of August.

Analysis:

Subsidence at Polaris is defined as a drop of greater than 50mm from original elevation, along with a downward trend observed over several readings. Closure accuracy, natural ground movement from freeze-thaw cycles, and heavy equipment activity nearby prevent us from defining mining-induced subsidence any more closely. It is important to observe the same post over a long period of time before drawing any conclusions.

The posts have been divided into several areas for convenience of analysis:

Sinkhole:

Located over the centre of the Keel mining zone, the Sinkhole has subsided more than 10 meters (a rough estimate). The Keel Zone was 120m top to bottom, and was mined without leaving posts or pillars. Hangingwall ground support in the stopes was limited to 8' swellex. Large-scale hangingwall caves at 880 level were induced in Pillars from 190 to 212, leaving large voids that were impossible to backfill. Tension cracks appeared on surface (see surface drawing for location).

There is comparatively little subsidence data on the Sinkhole area. Monitor posts were installed in ground that was likely already moving, and were destroyed or fell over quickly.

The attached graph of post movement near the sinkhole is at a different scale compared to the other areas to show the larger movements involved.

SUB-20, started to move in 1998, and has dropped 2.50m. We expect the deceleration phase to begin soon, and when this happens, we would probably be able to predict the final level of subsidence in this area.

SUB-22, continuing north, started moving in 1999. Currently down 0.91m, this post is still in the high velocity part of the expected curve.

SUB-3 is located west of the Sinkhole, over the Panhandle zone. This station has been moving at a fairly constant rate since 1994. Panhandle pillars have been mined during that time. Tension cracks in this area are quite pronounced and extend throughout the cement storage pad area. These cracks may be related to Abutment mining and were probably affected by the undercutting of A Stope late last year.

SUB-12 is right over top of the Abutment Pillar. This post showed some movement before Abutment mining began in 1997, but increased in velocity afterwards. It is down 2.34m. This station should enter the deceleration phase in the near future.

SUB-5 is at the south end of the Sinkhole. There has been very little mining at this end of the ore body in recent years, and the graph shows that this post underwent acceleration, rapid movement, and then deceleration. This station is currently at 1.69m, the same as a year ago. No further subsidence to the south is expected after backfilling 185 Stope during the reclamation phase.

Subsidence Front:

Immediately north of the Sinkhole, the Subsidence Front covers the northern limit of ground movement, and beyond that, posts that have just started to move. These posts are above the North Keel Zone, which has been mined differently than the Central Keel. The North Keel is 30m high, deeper underground, and is filled entirely with CRF. The entire hangingwall has been supported with 26’ or 40’ grouted cables.

SUB-23 passed the 50mm limit that defines subsidence, having been displaced 0.06m to date. This station is located directly above 232 Stope, our most northern large tonnage North Keel stope. This stope is completely filled with dry fill and is 80m from the shoreline.

SUB-33, 32, 36, 37 and 8 are located north of SUB-23 and none of these stations are defined as subsidence (>50mm). With little to no extraction in this area and no signs of major acceleration, large-scale subsidence similar to the sinkhole is not expected.

North:

These subsidence posts are located over the Ocean Zone and are beginning to trend downward; however, the movement isn’t characterized as subsidence. The Ocean Zone has been mined 30m high, with 4m rib pillars running north-south and 5m posts running east-west between pillar stages. The entire hangingwall has been supported with 26’ grouted cables. Mining of the Ocean Zone has spanned 4 years with no subsidence. No hanging wall failures have occurred and all stopes were completely dry filled. No major subsidence concerns are anticipated in the Ocean Zone.

Also in the northern end of the orebody is SUB-10. SUB-10 was installed to monitor the northern limit of the Panhandle, which is not part of the Ocean Zone. This station is located over NP-142 stope. This station has entered the high acceleration range due to the recent mining of NP141. This station has been displaced 0.18m and surface tension cracks have appeared on surface. The cracks run parallel to the extraction limits of the Panhandle, not the Ocean Zone. It is expected that the conservative mining method of the Ocean Zone will contain any major subsidence caused from mining in the southern part of the mine.

East:

Delineating the eastern limits of subsidence, this series of posts runs from the end of 215 Pillar (part of the Central Keel) towards the New Quarry.

SUB-18, closest to 215 Pillar, has subsided 1.05m. There was a large hangingwall cave in Stage 1 of 215 Pillar (the easternmost stage). The rest of the pillar was taken in smaller stages and filled with CRF, and no further hangingwall damage was incurred.

The rest of the posts show constant and diminishing movement as they get further from 215 Pillar, as expected. All stations are defined as subsidence with SUB-14 having been displaced 0.063m. Surface tension cracks have not extended further to the east and we predicted that this would also be true for major surface subsidence.

West:

Located over the West Panhandle, these posts have just moved into the classification of subsidence, with measurements ranging from 70mm to 110mm. We can measure these posts most accurately because they are closest to the Benchmark. Like the North Keel, the West Panhandle is filled with CRF and dry fill. The panhandle also has a few 5m posts and the hangingwall has been supported with 26' grouted cables. In 2002, mining in this area experienced high levels of activity with 35% of our total production from this Panhandle zone. Some subsidence was expected due to the high activity levels in this zone this past year.

Conclusions:

The principle reason to monitor subsidence is to predict the possibility of connecting the mine workings directly to the ocean via a large crack. The worst case scenario is a high volume failure flooding the mine before the completion of reclamation backfilling. A lesser problem would be flooding after closure.

From observations of the Sinkhole, tension cracks visible on surface form long before there is a route for large volumes of water to drain underground. It should be noted that we have never had surface water enter the mine workings, even with the existence of surface tension cracks and large seasonal runoff. We will continue to watch for the formation of surface tension cracks during the reclamation project. Underground, we have kept the hangingwall stable through intensive ground support measures and conservative recoveries by leaving large posts behind.

The extent of the subsidence limits is a direct footprint of the orebody with the exception of the Ocean Zone, which has not experienced any subsidence. The stability of the Ocean Zone can be attributed directly to the conservative mining extraction and extensive measures taken in ground support.

The different mining methods for the north end of the ore body will not induce subsidence similar to that experienced over the Central Keel; and there is no significant risk of an inflow of water.

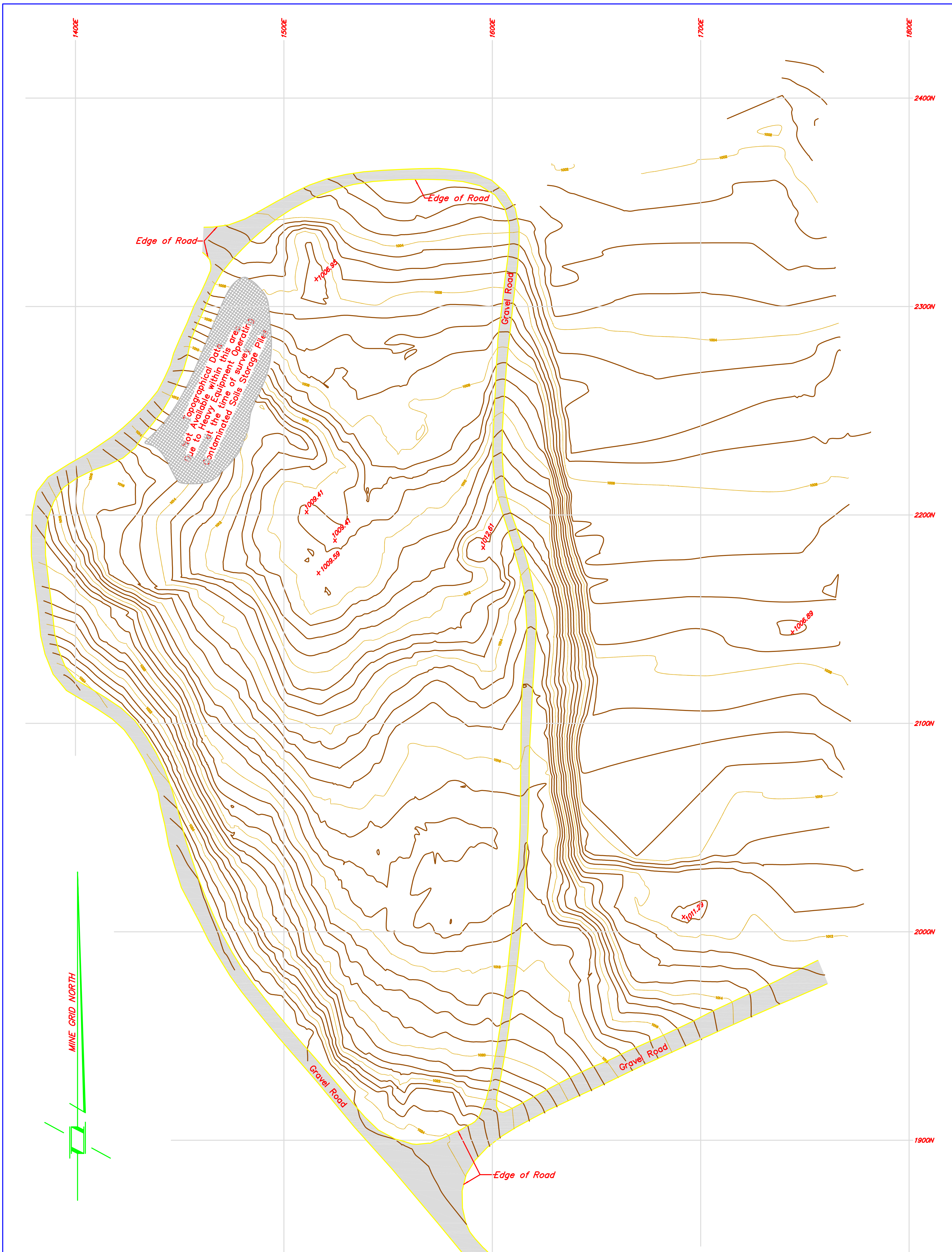
Trevor Feduniak, P.Eng.

Senior Mine Engineer

APPENDIX E

TOPOGRAPHIC SURVEY OF SIBSIDENCE AREA

By FOCUS SURVEYS



Indicates Surveyed Topo Point
DATE of SURVEY = August 29, 2003
CONTOUR INTERVAL = 0.5 m.
DATUM FOR ELEVATIONS IS C.P.#2 = 1065.34 m.

DATE	REVISIONS	DR/CK

TOPOGRAPHIC SURVEY
OF SUBSIDENCE AREA
POLARIS MINE
NUNAVUT

teckcominco

FOCUS
Focus Surveys
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Edmonton (780)466-6555
Calgary (403)269-2252
Grande Prairie (780)539-3222
Medicine Hat (403)527-3707
Regina (306)586-0837
Fort St.John (250)785-7776

DRAWN BY : KK	CHK'D BY : MT
DATE : SEPTEMBER 12/03	SCALE: 1:1000
JOB : 322789-00	FILE NO.
DWG : SUBSIDENCE TOPO.DWG	SHEET 1 OF 1