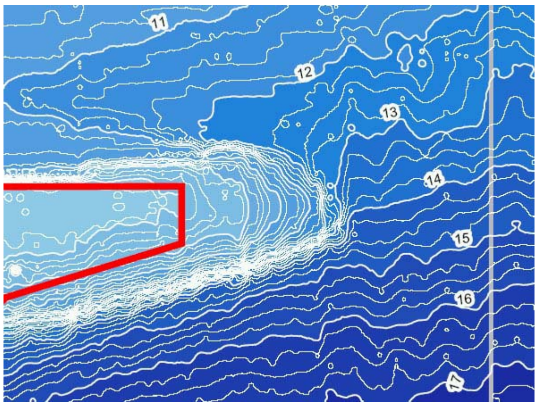
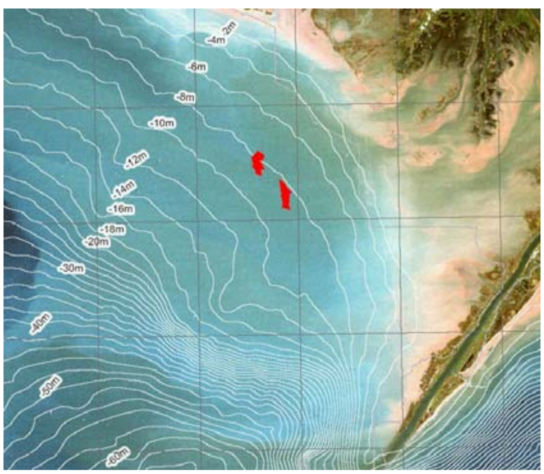
OCS STUDY
MMS 2004-019

Preliminary Infrastructure Stability Study, Offshore Louisiana





PREPARED FOR:
U.S. DEPARTMENT OF THE INTERIOR
MINERALS MANAGEMENT SERVICE

MMS U.S. Department of the Interior
Minerals Management Service

OCS Report
MMS 2004-019

Preliminary Infrastructure Stability Study, Offshore Louisiana

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DISCLAIMER

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1.0 INTRODUCTION

The Minerals Management Service (MMS) requested a preliminary evaluation of the potential impacts of dredging to existing oil and gas infrastructure (primarily pipelines) on the Outer Continental Shelf offshore Louisiana. Specifically, the investigation focused on the proposed 2004 dredging for South Pelto (or New Cut) and Sandy Point Borrow areas. Recommendations are required on a provisional buffer to avoid impact to the pipelines either directly or indirectly. This report describes the findings of this investigation.

The methodology for the investigation consisted of the following steps:

1. Collect available information on the most recent bathymetry for the two deposits and infrastructure and import to GIS.
2. Develop a provisional buffer between the limit of dredging and existing infrastructure to minimize the risk of erosion in the area of existing infrastructure. This buffer will consider positioning accuracy of dredging operations together with a stable slope allowance (i.e. considering that the initial dredge cut slope will slump and evolve with time to achieve a flatter stable slope and this has the potential to impact infrastructure indirectly).
3. Place the buffers in the GIS with bathymetry to show the area available for dredging and comment on implications to removing the required dredge amounts for 2004, if any.
4. Complete a report describing methodology and results to be delivered in hard copy and digital form (including GIS files).

The remainder of the report is divided into the following sections:

2.0 Background

3.0 Analysis

4.0 Conclusions and Recommendations.

2.0 BACKGROUND

This section includes a description of the proposed dredging, regional context for the two sites, and an introduction of the buffer zone concept.

2.1 Proposed Dredging

There are plans to remove up to approximately 12,000,000 cubic meters (m^3) of medium sized sand from the South Pelto and Sandy Point Borrow Areas commencing in May 2004. The sand will be used for land reclamation and beach nourishment projects.

The water depths range from 7 to 10 m at the South Pelto Borrow Site and 10 to 11 m at the Sandy Point Borrow area. The placement sites are located approximately 15 to 25 kilometers (km) from the borrow areas. It is likely the depth of cut would be somewhere in the range of 1 to 3 m. These conditions are ideally suited to Trailing Suction Hopper Dredges (TSHDs) and possibly Cutter Suction dredges (though the latter is less likely). TSHDs do not dredge to a slope at the edge of the cut and instead cut at the toe and a slope develops with each deepening pass of the drag head.

A concern with the proposed dredging is the potential for impacts to existing oil and gas infrastructure that exists in the same areas. The focus of this investigation has been on pipelines in the area. At the time of original installation most of the pipelines would have been buried with a cover of 3 feet (ft) or approximately 1 m.

2.2 Overview of Borrow Deposits

A description of the conditions at the borrow deposits and for the surrounding region has been developed through the acquisition of the following information:

1. GIS information on the location and characteristics of pipelines in the vicinity of the borrow deposits was obtained from the website of the MMS, Gulf of Mexico Region, Geographic Mapping Data in Digital Format page (http://www.gomr.mms.gov/homepg/pubinfo/repcat/arcinfo/index.html). The spatial datasets (ArcInfo GIS versions) downloaded included pipelines, platforms, active leases, fairways, federal lease blocks, lease term lines, and protraction polygons. The pipeline database version was updated 17 November 2003, and the platforms database was updated 2 December 2002;

2. Regional images of the adjacent land are from Landsat 7 images, acquired from the Louisiana GIS CD (version 2.0) and from the University of Maryland's Global Land Cover Facility. This satellite provides 30 m resolution images that show the borrow areas in relation to features like the Mississippi River delta.

3. Regional bathymetry with 2 m contour intervals was obtained from Louisiana Oil Spill Coordinator's Office (Louisiana Offshore Bathymetry, Geographic NAD83, LOSCO (1999)). This dataset was not used for any analysis, only as a large-scale visual reference.

4. Local and more detailed bathymetry for each borrow area was obtained from multiple sources. Historic hydrographic surveys were obtained from the National Oceanic and Atmospheric Administration, via the Geophysical Data System for Hydrographic Survey Data DVD, version 4.1.18, distributed by the National Geophysical Data Center (NGDC). Historic hydrographic surveys were found only for the South Pelto borrow area, none were found for Sandy Point borrow areas. The South Pelto historic surveys consisted of three 1936 surveys, from maps at 1:40,000-scale, the original survey lines are spaced at 500-600 meters with samples taken at 150-280m intervals, and are identified as NGDC numbers 03071006, 03071036, and 03071111. Also at South Pelto, a 1994 hydrographic survey (NGDC# 03091126) was available that covers the west half (approx. 60%) of the borrow area. Current bathymetry at South Pelto is represented by an August 2003 survey by C & C Technologies of Lafayette, Louisiana referred to as '4037'. Current bathymetry at Sandy Point borrows is represented by a July 2003 survey conducted by Coastal Planning & Engineering of Boca Raton, Florida. Only 1-foot interval contours were available from this survey. No other bathymetry datasets for the Sandy Point borrows area were found or provided.

5. The outline boundaries of the proposed borrow deposits were created by entering coordinate values taken from documents received at Baird. The South Pelto polygon was from a document produced by the Louisiana Dept. of Wildlife and fisheries and Louisiana DNR Coastal Restoration Division. The two Sandy Point borrow areas were from Coastal Planning & Engineering Inc., Pelican Island Restoration (BA-38-1) CWPPRA Project Sandy Point. These features were defined using Louisiana South State Plane coordinate system in feet, NAD 1983 datum. To support analysis and comparison with all of the MMS datasets that are natively defined using NAD 1927 datum, the Borrows dataset was projected from NAD83 to NAD27 using ESRI's ArcGIS ArcToolbox 8.3 Project Wizard software.

6. Isopachous coverage of Ship Shoal, as constructed from the available vibracore data and high-resolution seismic profiles, was extracted from the Ship Shoal: Sand Resource Synthesis Report (Kulp et. al., 2001). The isopach contours were used to construct a surface that was clipped to the South Pelto Borrow Area extents and used to derive a total sand volume estimate.

7. The use of a 1000-ft setback distance from infrastructure is described in the draft of the MMS Negotiated Noncompetitive Lease for Sand, Gravel and Shell Resources on the Outer Continental Shelf, Lease number OCS-G 25379, for the removal of materials from within the Sandy Point Northwest and Sandy Point Southeast Borrow Areas: "STIPULATION NO.5 – Avoidance of Oil and Gas Structures – During all dredge operations, a minimum "no dredge" setback distance of 1000 ft will be established from existing pipelines and all other oil and gas-related infrastructure."

The location of the South Pelto and Sandy Point Borrow Areas relative to the coast of Louisiana is shown in Figure 2.1.

The South Pelto Borrow Area is located at the east end of Ship Shoal as shown in Figure 2.2. Ship Shoal is a relict submerged barrier island. The Sandy Point Borrow Areas are located immediately on the west side of the main delta of the Mississippi River (see Figure 2.3). The shallower water on the west side of the delta suggests this is the location of a former distributary mouth of the Mississippi River.

Figures 2.4 and 2.5 show the existing pipeline areas and the designated borrow areas (the latter determined from geophysical investigations) for the South Pelto and Sandy Point Borrow areas, respectively. Five individual borrow cells are created by the pipeline network at South Pelto while the two smaller Sandy Point Borrow Areas are not bisected by existing infrastructure.

2.3 Concept of Buffers to Protect Infrastructure

In a recent project for MMS, buffer requirements for archeological resources were reviewed (see Research Planning, Inc. et al., 2004). Buffer zones are also stipulated to protect hard bottom habitat from dredging impacts. There are several reasons that buffers or avoidance/exclusion zones need to be stipulated and these fall into two groups: a) to avoid direct impact of the dredge with the resource; and b) to avoid indirect impacts related to subsequent changes to the sea bed and the possibility of erosion or scour at the resource. These same reasons also apply to the oil and gas infrastructure and are described below:

Avoidance of Direct Impacts

- To address the possibility of position inaccuracies by the dredge vessels and the drag arm or cutter head (although these are low at +/- 5 m);
- To allow for the possibility of power loss, influence of storms or human error in the navigation and operation of the dredge vessel;
- Possible inconsistencies related to common geographic coordinates for the infrastructure and the dredge vessel position.

Avoidance of Indirect Impacts

- The slope at the edge of the borrow area (which will generally become 1 to 3 m deeper than the surrounding areas outside the borrow area) will adjust with time usually becoming flatter than the initial slope, thus potentially expanding the area of bed lowering;
- If dredging occurs on either side of a pipeline (such as the case may be at South Pelto – see Figure 2.4) a berm may develop with a potential height of 3 m above the adjacent sea

bed. It may be possible that this berm (which is left in place to protect the pipeline) could begin to migrate, eventually exposing or undermining the pipeline.

- The sea bed in these depths is dynamic and particularly the South Pelto Borrow Areas at the east end of Ship Shoal. Therefore, there will be natural erosion and accretion with time. It is possible that the dredged borrow areas may change the natural morphodynamics (patterns of sea bed change).

Direct impacts to the infrastructure would result in damage or breakage of the infrastructure, such as pipelines. Indirect impacts could result in uncovering or undermining (creation of spans) of pipelines. Therefore, a buffer is required to address the potential for direct dredge impacts mostly associated with potential errors in the relative position of the dredge and infrastructure in addition to a buffer to address the indirect changes to the sea bed. The two buffers are not additive as the indirect changes will develop with time. The larger of the two buffers is selected.

In the MMS Archeological Survey (Research Planning, Inc. et al., 2004) several dredging companies in the US and Europe were canvassed for their recommendations on buffer strips. Generally, the dredging contractors recommended buffers of 100 to 300 m.

3.0 ANALYSIS

3.1 Application of Buffers and Volume Analysis

The analyses performed for this preliminary assessment consisted of developing some reasonable and conservative buffers and applying these to the two borrow areas to determine the implications to the size and yields (in terms of quantities) of the borrow areas. In addition, the eventual form of the sea bed topography was evaluated to assess the potential for indirect impacts, and particularly migration of berm features along the pipeline corridors.

3.1.1 Discussion of Three Buffer Widths Considered

Three different buffer widths were applied to the pipelines in the vicinity of the borrow areas: 150 m (corresponding to the 500 ft buffer presented in a EIS for an OCS Lease Sale in the Gulf of Mexico), 200 m (corresponding to the suggested 630 ft buffer by the MMS Gulf of Mexico Region a recent dredge test lease issued by MMS within South Pelto Block 13), and 300 m (the upper end suggested by dredging contractors and consistent with the Draft Stipulations for the Sandy Point Borrow Areas). The largest buffer of 300 m also corresponds to an excavation of 3 m with a potential ultimate slope of 1:100 (vertical:horizontal) at the edge of the borrow area or 1:300 with a 1m excavation – which are relatively conservative and would likely take many years to develop.

The sea bed gradients have been calculated at a variety of positions representing steepest gradients and existing gradients perpendicular to proposed protective berm corridors along pipelines and range from 1:285 to 1:1,800. These slopes are all flatter than our recommended assumption of 1:100 to develop a buffer for a 3m excavation or 1:300 for a 1m excavation. Therefore, in the long term, based on slope alone, the assumption of a 1:100 to 1:300 slope is not overly conservative.

3.1.2 Volume Analysis

Figure 3.1 illustrates the dredge cells created by a buffer width of 300 m for the South Pelto deposit. An initial slope of 1:3 was assumed to be created at the dredge boundary, ultimately forming a 1:100 slope in the long term. (Interestingly, the slope of 1:3 creates a slope volume to total volume ratio constant of 0.00374.) Table 3.1a presents the quantities of sand available from each of the created blocks in the South Pelto Borrow area for dredge cuts of 1, 2 and 3 m corresponding to a 300 m buffer on either side of the pipelines, with the first set of values representing the maximum volume assuming an equivalent dredge depth, and then a second set of values incorporating the allowance of an initial 1:3 slope at the dredge cell boundaries. Tables 3.1b and 3.1c present the quantities for buffers of 200 m and 150 m, respectively, and are presented for comparison to the 300 m buffer to show the comparative volumes. For the largest 300 m buffer, the five South Pelto cells yield approximately 15,000,000, 31,000,000 and 46,000,000 m^3 for dredge cuts of 1, 2 and 3 m, respectively.

It is interesting to note that the assumed total reserve of the South Pelto Borrow Area, without consideration for the need to protect infrastructure, is estimated to be 67,500,000 m^3. This was calculated based on the information presented in the Ship Shoal: Sand Resource Synthesis Report (Kulp et al., 2001), specifically Figure 19 which depicts an isopach map of the entire Ship Shoal sand body at an estimated map scale of 1:500,000. According to the report, the isopach contours were "constructed from the available vibracore data and high-resolution seismic profiles." For the South Pelto Borrow Area, the isopach described in the report has a thickness of up to 4 m across an east-west ridge at the north of the Borrow Area, diminishing to a thickness of at least 1 m across the southern portions of the Borrow Area.

The isopach contours defined by Kulp et al. (2001) were used to construct a surface that was clipped to the South Pelto Borrow Area extents (as shown in Figure 3.2) and used to derive a sand volume estimate (that incorporates the initial slope of 1:3), also presented on the right-side of Table 3.1a. These volumes incorporate an allowance for the initial slope of 1:3 using a slope volume to total volume ratio constant of 0.00374 that was derived from values in the earlier step of slope volume allowance. Incorporating these estimated isopach limits, the volume potentials are reduced for the deeper cuts as the depth of sand is limited:

1 METER – There is at least 1 m sediment thickness over the entire Borrow Area, resulting in no volume reduction and the same value of approximately 15,000,000 m^3.

2 METER – At the 2 m thickness, about half of cell SP-A is not available, resulting in a volume estimate of 23,200,000 m^3, compared to 30,565,000 m^3 before accounting for sediment thickness limitations.

3 METER – At the 3 m thickness, only portions of cells SP-B, SP-C & SP-D have any significant coverage, resulting in only an additional 3.5 million m^3 of material, totaling 26,704,000 m^3, significantly less than the 45,848,000 m^3 as would be available if 3 m thickness was available over the entire 5 cells.

Figure 3.3 shows a 300 m buffer for the Sandy Point Borrow Areas and Table 3.2 presents the corresponding quantity of dredge material for 1:3 slope down to a cut depth of 45 ft below the original surface. The irregular outline shape of the Sandy Point Borrow Areas (not rectangular like South Pelto), and the significantly deeper dredge depth, meant that the slopes would meet opposite facing slopes at narrow areas of the borrow. To accurately represent this surface, a series of 14 concentric internal buffers were created. Incorporating these factors, the combined quantity of dredge material available at the two Sandy Point Borrow Areas is 8,634,000 m^3.

3.2 Topographic Change

As noted in Section 2.3, there is concern for possible indirect impacts related to shifting of created sea bed features (such as berms created by dredging along either side of a pipeline) and related to changes to the natural morphodynamic development that may be caused by the dredging.

The first step required to investigate these possibilities is to evaluate the historic change in the areas of proposed dredging. At the South Pelto Borrow Area, both historic and recent bathymetry data were available to facilitate a bathymetric change analysis. Insufficient data were available to complete a similar analysis at Sandy Point.

As indicated earlier, the South Pelto site is located at the east end of the Ship Shoal feature. Ship Shoal features a steeper shoreward slope and flatter seaward slope and this asymmetry typically indicates that the feature is migrating shoreward in the long term (see Figure 3.4). Due to the size of Ship Shoal (even at this extreme east end of this feature the "crest width" of the feature is 1.5 to 3.0 km which is large compared to the height of the feature of approximately 5 m above the surrounding sea bed) landward migration rates will be very slow. Figures 3.5 and 3.6 show comparisons of bathymetric change between 1936 and 1994, and 1994 and 2003, respectively.

Figure 3.5 shows erosion on the seaward flank and accretion on the shoreward flank that is compatible with slow long-term shoreward migration of the shoal, although this might be exaggerated as a result of the limits of the 1936 hydrographic surveys. The two individual 1936 hydrographic surveys that contributed to this surface are pretty sparse (lines spaced at 500-600 m, samples taken at 150-280 m intervals) so there are some artifacts of the surface interpolation process that show circular patterns in the contour lines at the bottom of the shoreward slope, and a closer inspection reveals north-south linear troughs in the top face seaward slope of the shoal (as evident in the 0.25 m contour lines). This figure also shows widespread erosion of the crest of the feature in the range of 0.25 to 1.25 m between 1936 and 1994 (which may be related to a vertical datum discrepancy – the 1936 vertical datum is "mean low water" while the 1994 vertical datum is "mean lower low water" and "aveTide = 0.4").

Figure 3.6 shows comparisons of bathymetric change between 1994 and 2003, illustrating accretion in some areas (up to 0.5 m) and erosion in others (up to 0.75 m – the accretion value of 1.25 m is the result of a shallow spike data anomaly in the 1994 survey). Looking at the 1994 surface, a much more dramatic and distinctive north-south ridge in the bathymetric map is visible, with a subtle rise in the surface measuring about 1 km across and with depths about 0.5 m shallower than the areas to the west. This cannot be a result of surface interpolation because the 1994 survey is much more dense than the 1936 survey. It is likely a trough has formed in the middle of the 1994 survey, but not visible in the other surveys (1936 or 2003). This makes visible a distinct band of high erosion at the easterly limit of the 1994-2003 comparison area as the 0.5 m subtle rise is eroded away.

Figure 3.7 illustrates the data anomalies of the 1936 and 1994 hydrographic surveys.

As a general comment, these are significant changes both in comparison to the depth of burial of the pipelines (approximately 1 m) and relative to the proposed dredge cut depths (1 to 3 m). It is possible that the pipelines may have been exposed in places by this degree of erosion depending on when they were constructed. More information is required on the current depth of burial and whether there are any existing instances of spanning. This information may result in a revision to the recommended buffer requirements.

With regard to the potential impact of dredging on the stability of the east end of Ship Shoal, the shoal only extends about 5 m above the adjacent seabed (from –12 m up to –7 m). Therefore, the removal of 3 m would essentially significantly lower the feature. However, with the stipulations of buffers to protect pipelines, only part of the feature will be lowered significantly. The influence of the buffering is discussed in the remainder of this section.

With all five cells at South Pelto dredged to 3 m deep with 300 m buffers along the pipelines, the resulting form of the shoal is shown in Figure 3.8. This extent of dredging would yield of 46,000,000 m^3 sediment (but only 26,700,000 m^3 after including limits of the isopach estimates). A perspective view of one of the berms (between cells A and B- see Figure 3.1) is shown in Figure 3.9. With a dimension of 3 m in height and 600 m wide, these berms would be susceptible to landward migration, similar to Ship Shoal. This would be particularly true for those berms with an east-west axis (i.e., between A and B and D and E). Numerical modeling would be required to determine the potential rate of migration.

If only 1 m were removed from each of the five cells the berms created by the buffers would be very subtle features and likely not susceptible to migration. As noted in Section 3.1.2 this would yield 15,000,000 m^3 of sediment. At this time this would appear to be the best option to provide the sediment required. It would result in the least change to the feature and produce relatively subtle berm features. However, one implication of initially limiting the dredge depth to 1 m is that this would influence the efficiency of large cutter suction dredges that have a full production cut depth of 1.6 to 2 m. There would be no negative implications to the operations of trailing suction hopper dredges. If it is important to have a project that is suitable to both cutters and hoppers (e.g., broadening the market for the project) then another possibility would be to allow 1.5 to 2 m dredge cut in Cell A only producing a little over 12,000,000 m^3. This would avoid the creation of isolated berms along the pipeline corridors. However, this option should be further investigated with numerical modeling.

At the Sandy Point Borrow Area, the removal of 3 m would create pits on the sloping shelf off the southwest flank of the delta. While this may not be an issue with respect morphologic change, it may become a water quality issue and/or these pits would fill with fine sediment discharged from the Mississippi River. It is likely this area of the delta is a depositional area.

Generally underwater stable slopes are around 1:3 immediately following dredging. However, the ultimate stable slope will depend upon many influencing factors such as sediment size, sediment transport, wave climate, etc. A 1:3 slope is relatively steep considering the existing grades in the Sandy Point Borrow Area are around 1:1,500.

How the slope adjusts and evolves after dredging depends on the local sediment transport patterns. There is anticipated to be preferential deposition of regional suspended sediment (from the significant loads of the Mississippi River) into deeper pits, reducing the affect of the slopes eroding and/or slumping to a gentler stable slope and thereby reducing the risk of impacts to infrastructure. Post-dredge slope evolution of a 6 m (20 feet) dredge pit could develop under the following three scenarios (as illustrated in Figure 3.10):

A. No infilling of the dredge pit occurs and the slope continues to erode back towards the pipeline infrastructure. This would require eroding back some 318 m to ultimately create a slope of 1:53.

B. Eroded slope material settles into the dredge pit, creating a complete balance of the sediment locally. This mid-depth scenario would create an ultimate slope of 1:106.

C. Infilling of pit will be heavily influenced by sediment loads transported from the Mississippi River. If we assume 3 m of infilling and slope adjustment from the point where the infill intersects the original 1:3 slope, then the ultimate slope that would interact with the pipeline would be 1:106 again. What is unclear without further analysis is the timeline for infilling of the pit.

The question is "Do slopes of 1:53 to 1:106 give an adequate margin?" While it is not overly conservative, the erosion and evolution of the dredge slope would be a slow process, possibly spanning many years (though this needs to be confirmed by modeling), which would allow time for monitoring. This long time scale of adjustment would allow for mitigating efforts to be implemented, in response to the results of monitoring, such as filling the dredge pit well before any adverse impacts to the pipelines.

The removal of 15 m, the deepest proposed cut, would result in more rapid infilling. The rate of infilling could be estimated through additional analysis or numerical modeling. The rate of pit infilling will influence the ultimate slope development beyond the dredge area. With no pit infilling and with a 15 m cut plus 300 m buffer, the ultimate slope for scenario A would be 1:23 from edge of pipe to toe of pit, which is considerably steeper than average slopes in the area. Therefore, with no pit infilling a larger buffer would be prudent for a 15 m cut. It is possible that this additional buffer could be applied as a berm at the 20 ft cut depth if a deeper dredge cut was planned as a second phase (see Scenario D in Figure 3.10). If it is necessary to dredge to 20 m (45 ft) immediately, we would recommend a buffer of 600 m.

4.0 CONCLUSIONS AND RECOMMENDATIONS

A preliminary assessment of the potential impacts to oil and gas pipelines of dredging the South Pelto and Sandy Point was completed.

With respect to buffer widths, at this time 300 m on either side of the pipeline is proposed. This buffer width is more than sufficient to prevent any accidental direct impact due to positional errors of the dredging operation but is required to prevent indirect impacts related to subsequent sea bed changes.

At the South Pelto site it is recommended that the dredging depth be limited to 1 m in any of the five cells at this time. An implication of this stipulation is that large cutter suction dredges would not be able to operate at full production rates (i.e., because a cut of 1.6 to 2 m is required), thus narrowing the market on tendering the project. As a less desirable alternative to allow both cutters and trailers to work the project at South Pelto, dredging could be restricted to the largest

Cell A with a 2 m maximum cut depth. For either this second alternative or subsequent consideration of increased dredge depths, a numerical modeling assessment of the stability of the shoal and the created berms should be undertaken. It is also recommended that the conditions of the pipelines around and through the proposed borrow areas be evaluated with respect to existing cover and invert elevations and, specifically, for any existing instances of spanning.

Of the two Sandy Point Borrow Areas, only the northwest deposit is trimmed by the implementation of 300 m buffers. Here the only concern with a 3 m dredge cut is the potential for the pits to fill with fine sediment, possibly becoming anoxic. While these changes do not have morphologic implications they may have implications to the change of habitat. Three scenarios for infilling of a 6 m cut show that slumping and sedimentation would create slopes of 1:53 to 1:106 over a 300 m buffer that could take many years to develop (the slope evolution should be closely monitored). A 15 m cut would result in a very deep pit that fills in quite rapidly (the rate of infilling could be estimated through additional analysis). The rate of infilling would need to be determined to evaluate the eventual slope development beyond the dredge cut area and impact for pipelines. Without the benefit of numerical modeling a 600 m buffer is recommended for a 15 m cut adjacent to pipelines. For both the 6 m and the 15 m cut plans additional analysis is required to better understand slope evolution processes at this site and to develop a site specific monitoring plan.

All of these recommendations have been developed on the basis of limited investigation and are therefore preliminary in nature. However, it is noted that in the event that the slopes evolve more quickly than expected (i.e. towards the pipelines), mitigation measures are possible and could consist of filling in the pits through dredging. These recommendations have also assumed that the pipelines are currently buried and that there are no significant spanning problems at present.

5.0 REFERENCES CITED

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Research Planning, Inc., Tidewater Atlantic Research, Inc., and Baird & Associates Ltd., 2004. Archaeological Damage from Offshore Dredging: Recommendations for Pre-Operational Surveys and Mitigation During Dredging to Avoid Adverse Impacts. U.S. Department of the Interior, Minerals Management Service, Sand and Gravel Unit, Leasing Division, Herndon, VA. OCS Report MMS 2004-005, 75 pp. + appendices.

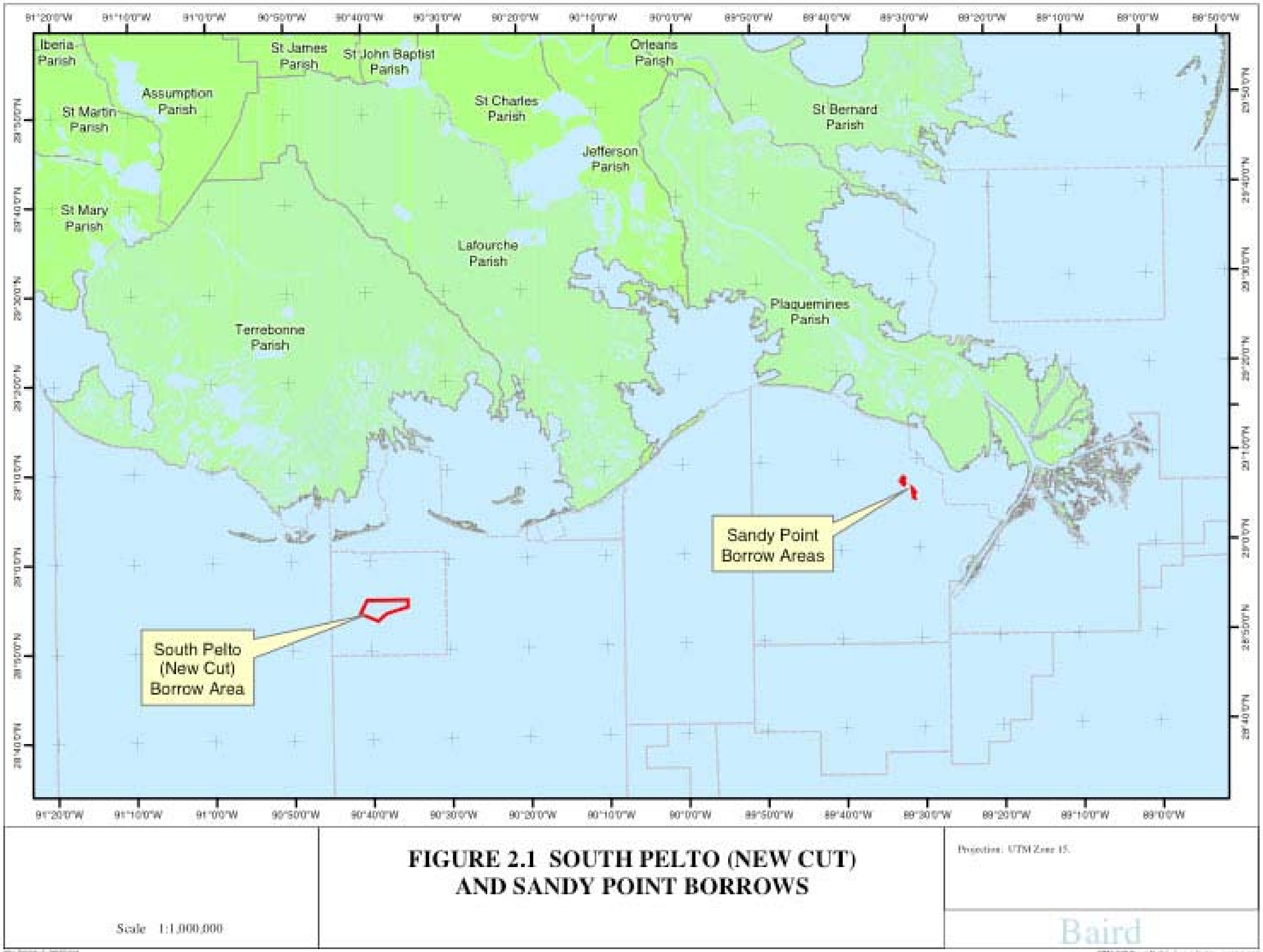

FIGURE 2.1 SOUTH PELTO (NEW CUT) AND SANDY POINT BORROWS

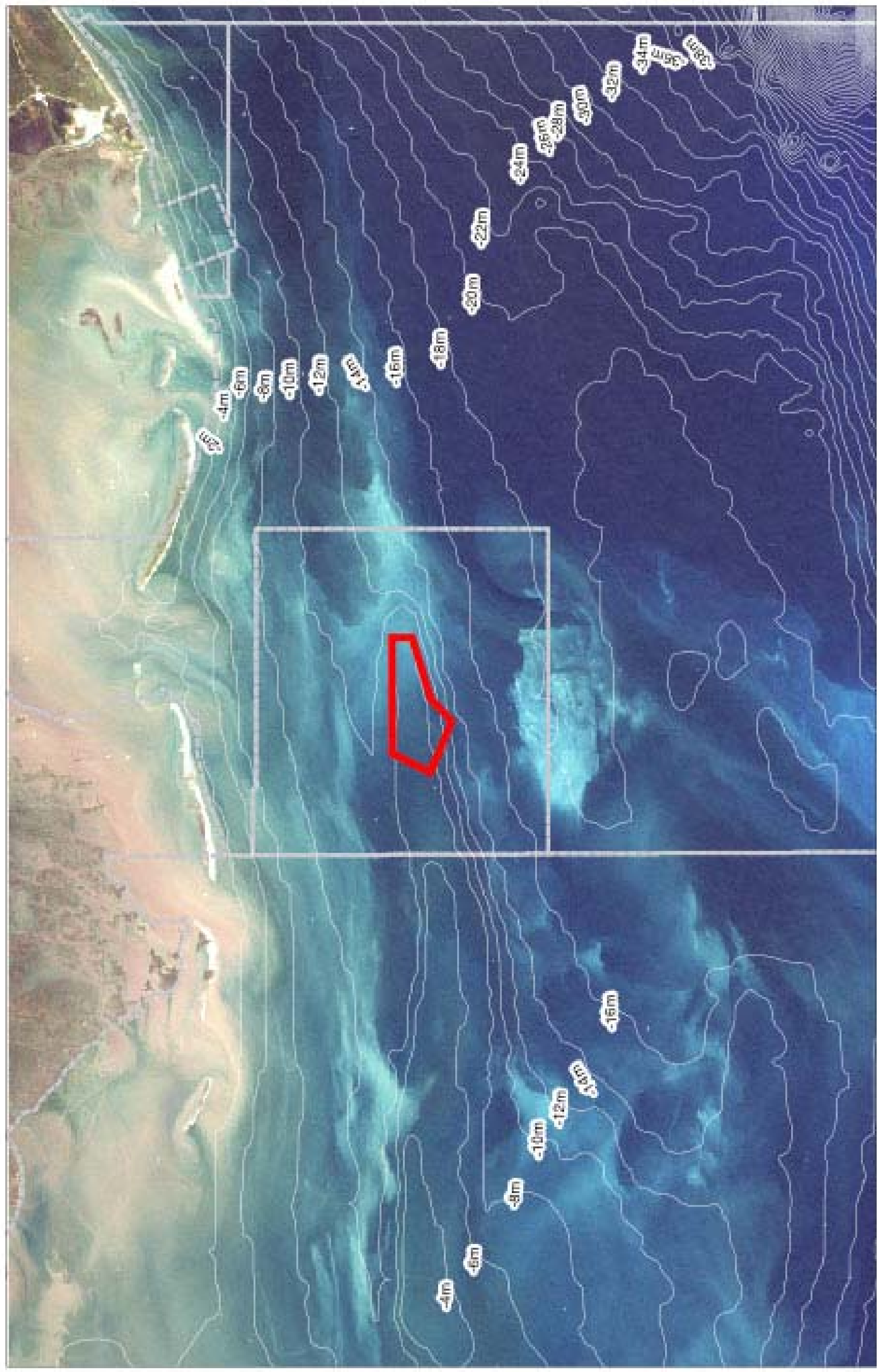

FIGURE 2.2 SOUTH PELTO BORROW REGIONAL BATHYMETRY

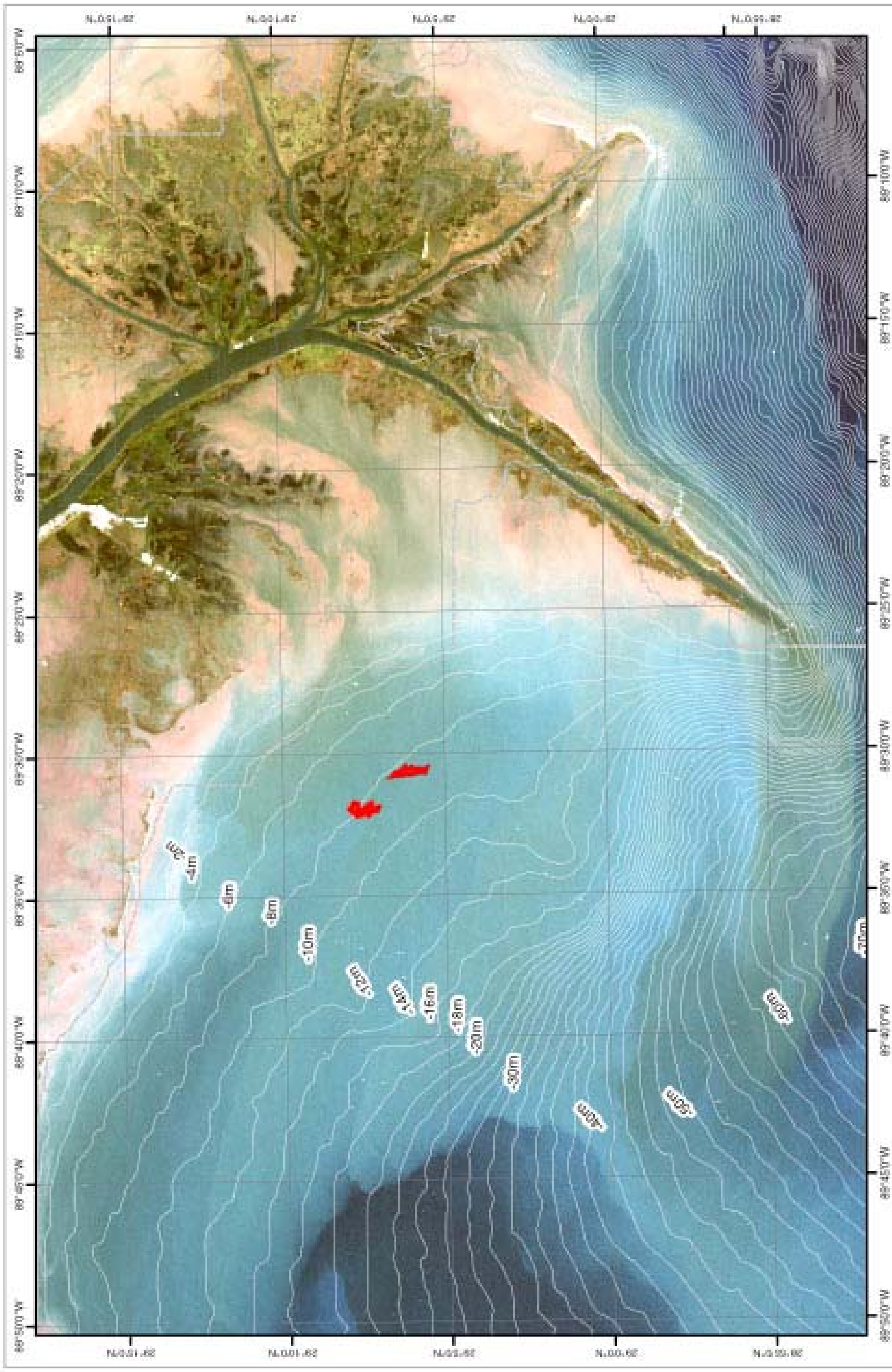

FIGURE 2.3 SANDY POINT BORROWS REGIONAL BATHYMETRY

Scale 1:300,000

Baird

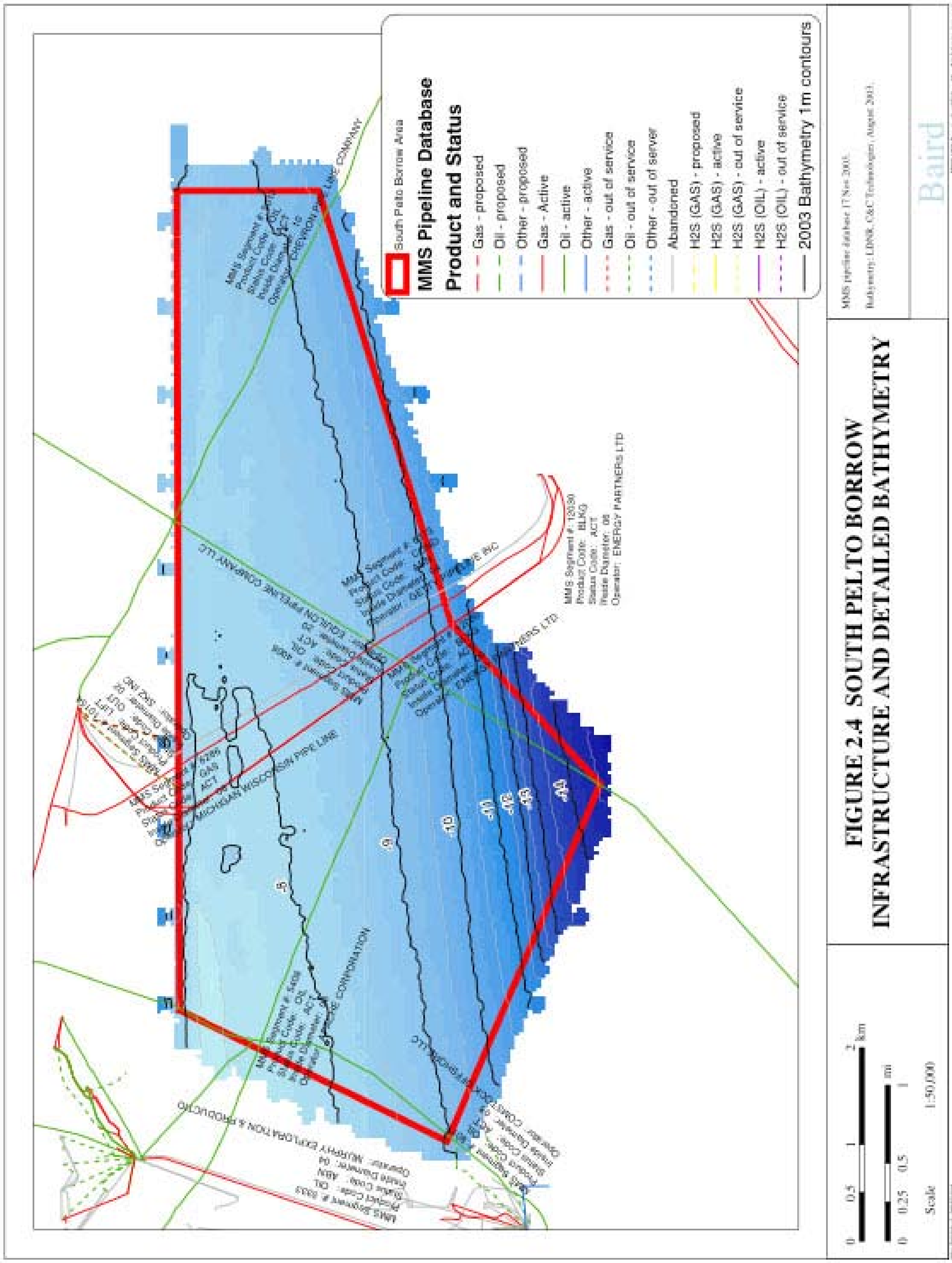

FIGURE 2.4 SOUTH PELTO BORROW INFRASTRUCTURE AND DETAILED BATHYMETRY

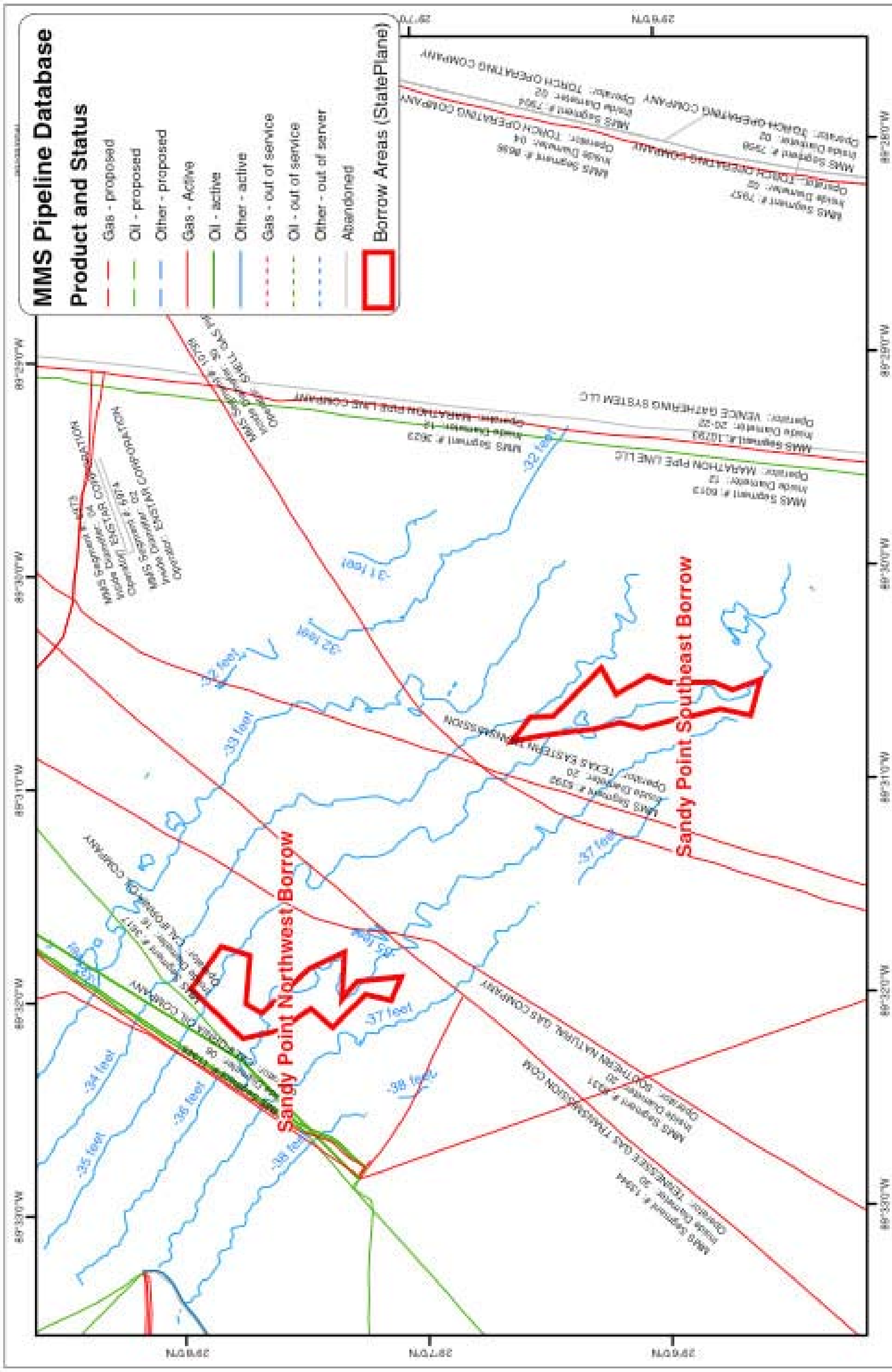

FIGURE 2.5 SANDY POINT BORROWS
INFRASTRUCTURE AND DETAILED BATHYMETRY

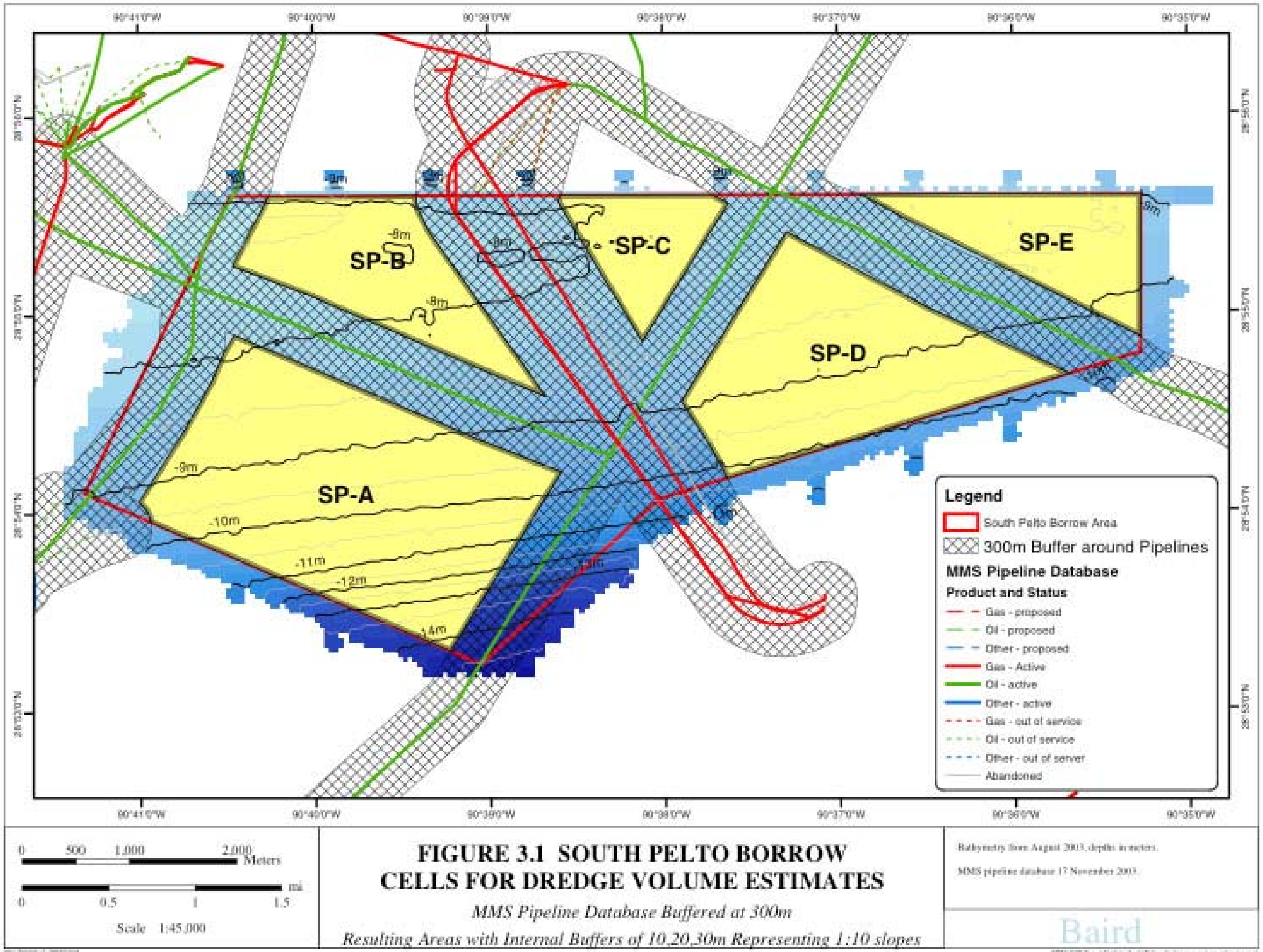

FIGURE 3.1 SOUTH PELTO BORROW CELLS FOR DREDGE VOLUME ESTIMATES

MMS Pipeline Database Buffered at 300m

Resulting Areas with Internal Buffers of 10,20,30m Representing 1:10 slopes

Bathymetry from August 2003, depths in meters.

MMS pipeline database 17 November 2003.

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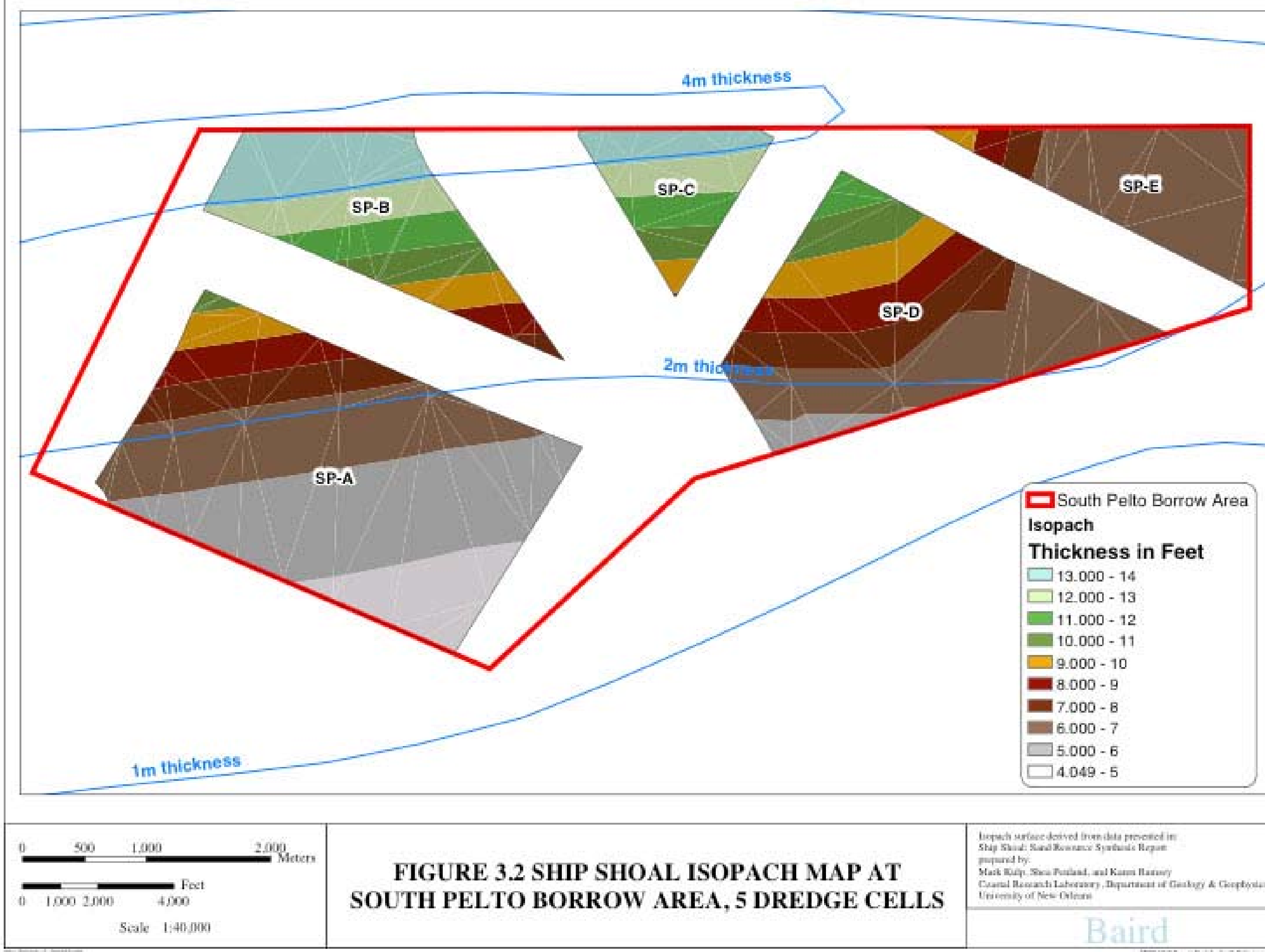


FIGURE 3.2 SHIP SHOAL ISOPACH MAP AT SOUTH PELTO BORROW AREA, 5 DREDGE CELLS

Isopach surface derived from data presented in:
Ship Shoal: Sand Resource Synthesis Report
prepared by:
Mark Kulp, Shea Penland, and Karen Ramsey
Coastal Research Laboratory, Department of Geology & Geophysics
University of New Orleans

Baird

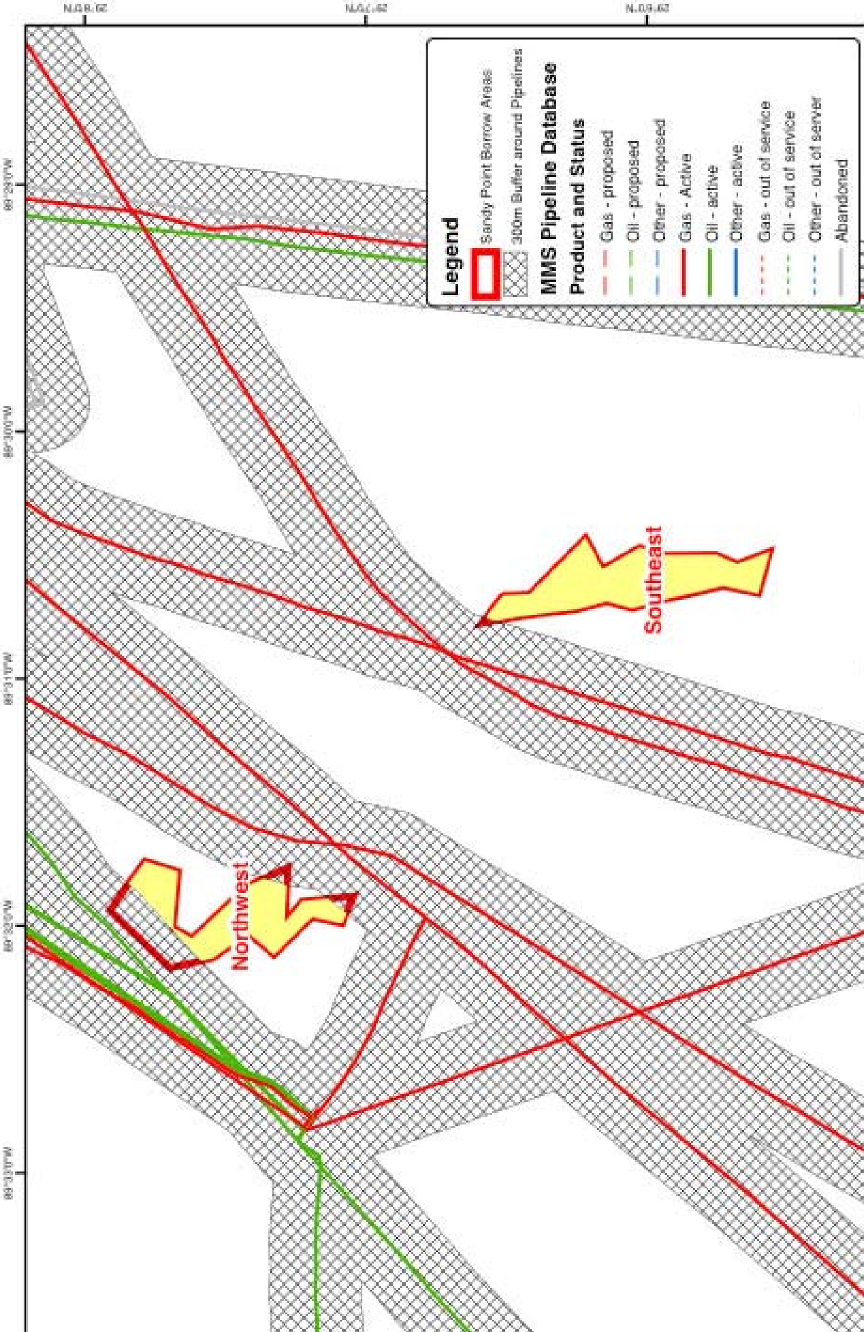


FIGURE 3.3 SANDY POINT BORROW CELLS FOR DREDGE VOLUME ESTIMATES

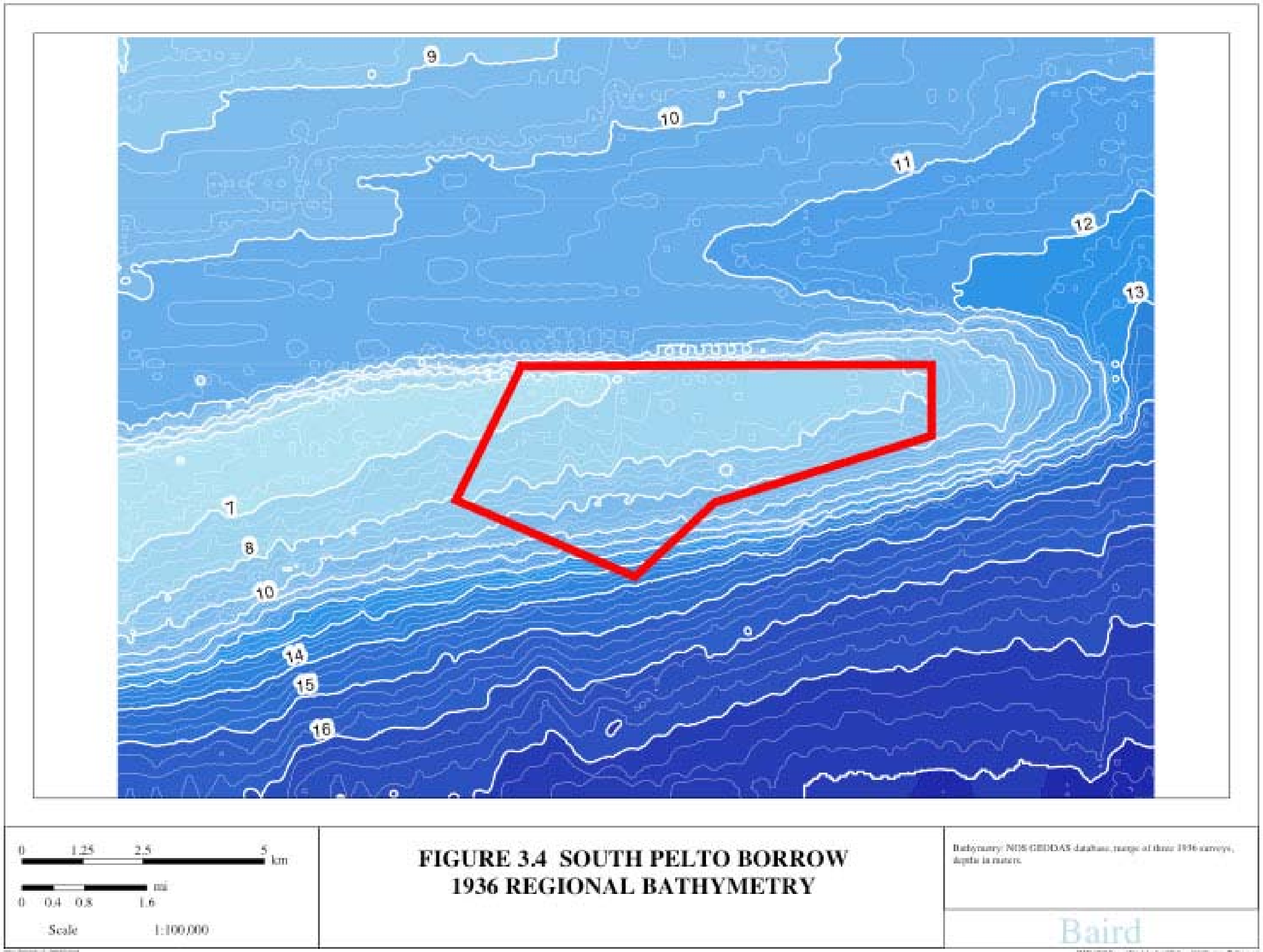


FIGURE 3.4 SOUTH PELTO BORROW
1936 REGIONAL BATHYMETRY

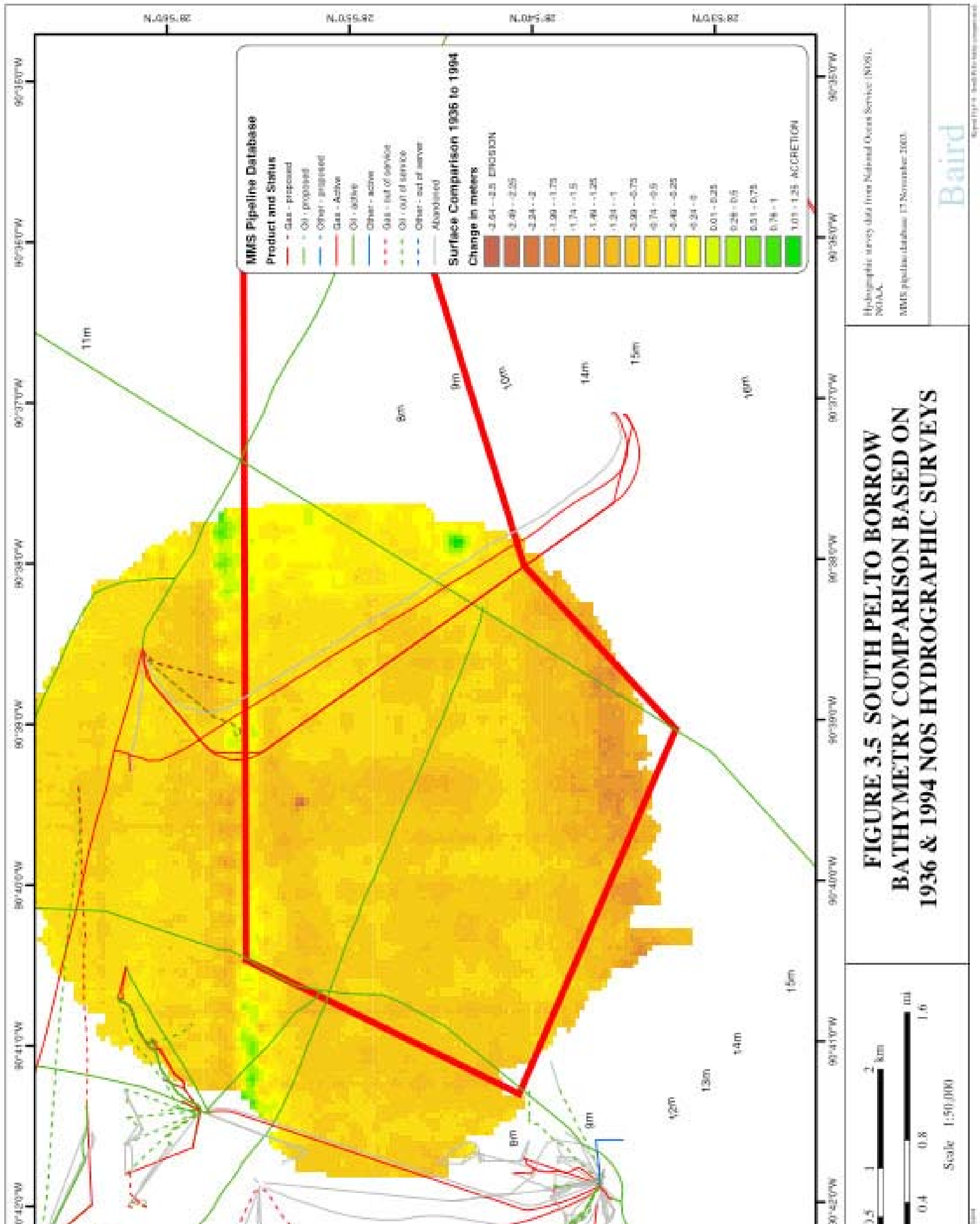
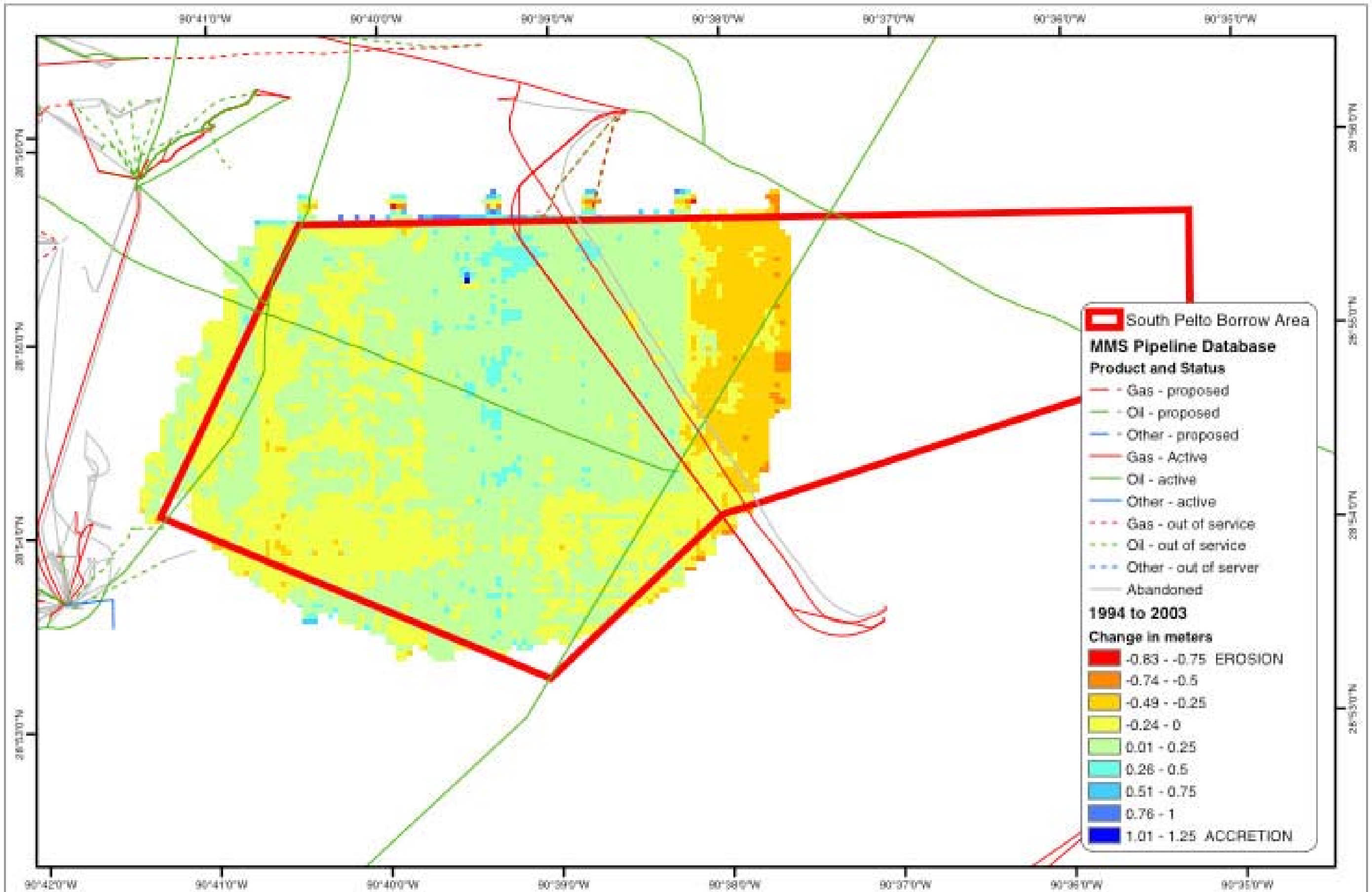


FIGURE 3.5 SOUTH PELTO BORROW BATHYMETRY COMPARISON BASED ON 1936 & 1994 NOS HYDROGRAPHIC SURVEYS



0 500 1,000 2,000 Meters

0 4,000 8,000 Feet

Scale 1:50,000

FIGURE 3.6 SOUTH PELTO BORROW BATHYMETRY COMPARISON 1994 TO 2003

Original bathymetry from C&C Technologies, August 2003

MMS pipeline database 17 November 2003

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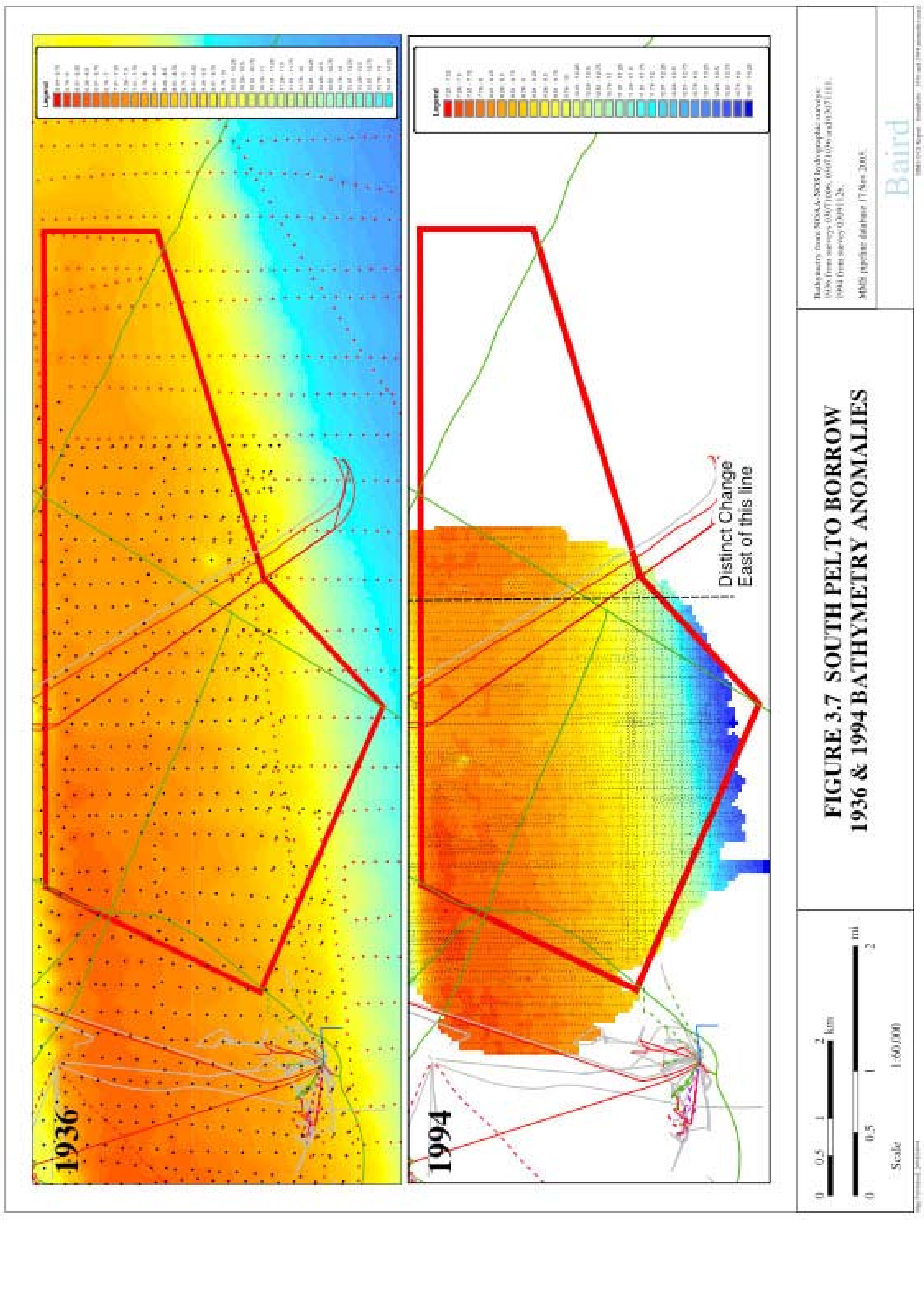


FIGURE 3.7 SOUTH PELTO BORROW
1936 & 1994 BATHYMETRY ANOMALIES

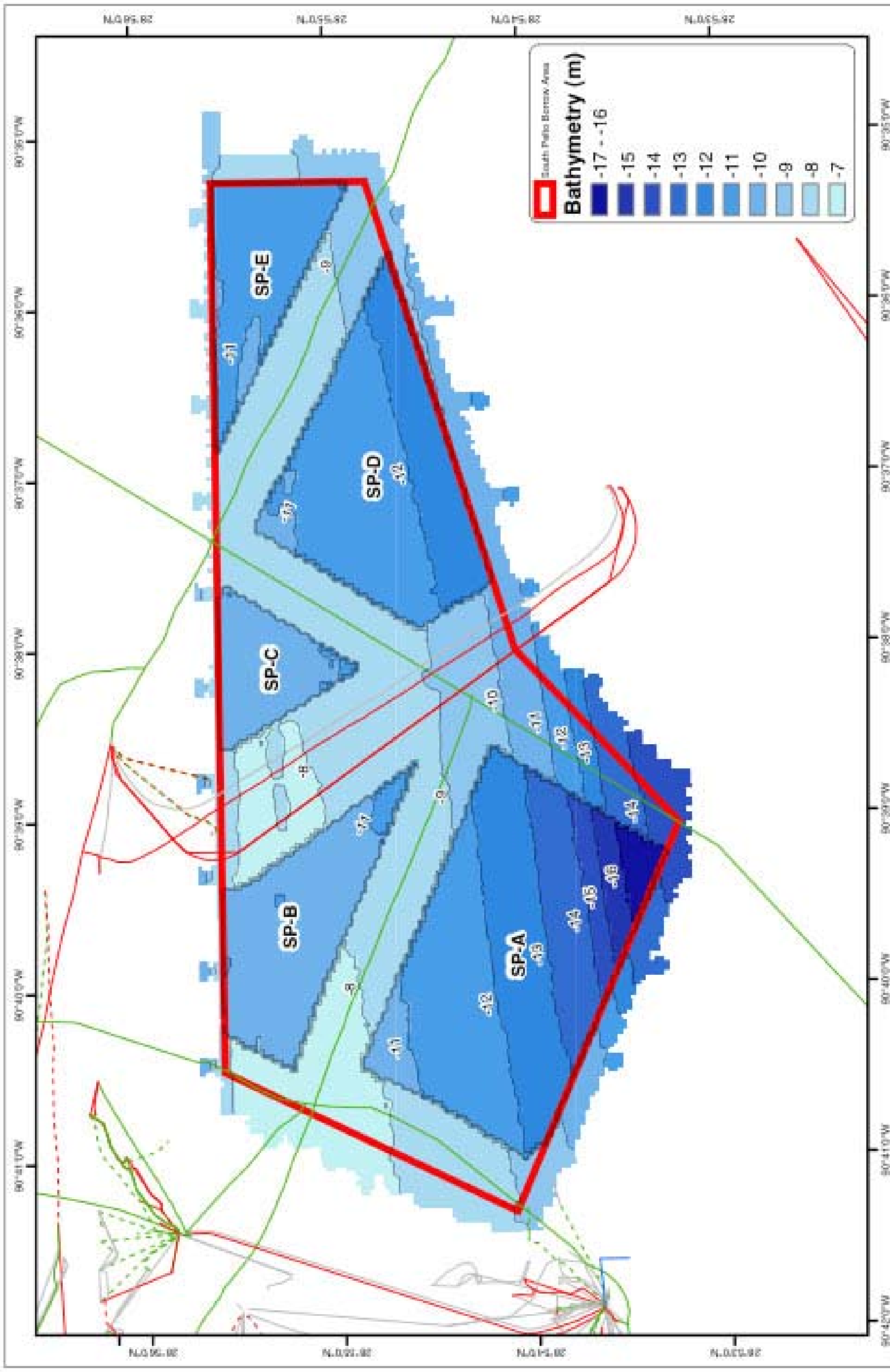
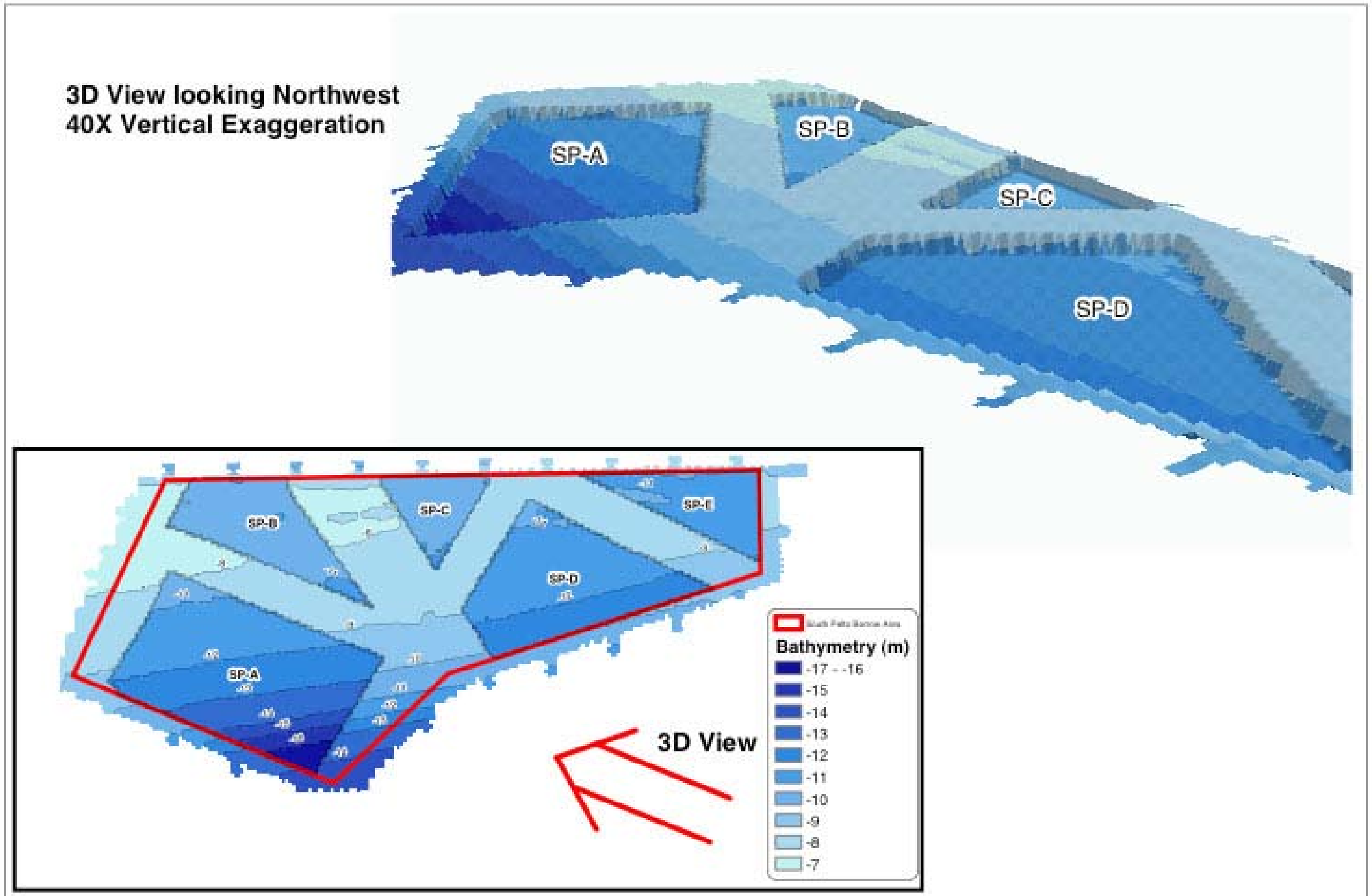


FIGURE 3.8 SOUTH PELTO BORROW
BATHYMETRY AFTER 3 METER DREDGE

Original bathymetry from C&C Technologies, August 2003
MMS pipeline database 17 November 2003

Baird

Scale 1:50,000



0 750 1,500 3,000 Meters

0 2,500 5,000 10,000 Feet

Scale 1:75,000

FIGURE 3.9 SOUTH PELTO BORROW
3D VIEW OF BATHYMETRY
AFTER 3 METER DREDGE

Original bathymetry from C&C Technologies, August 2003

3D view is vertically exaggerated 40X to emphasize the dredge cuts.

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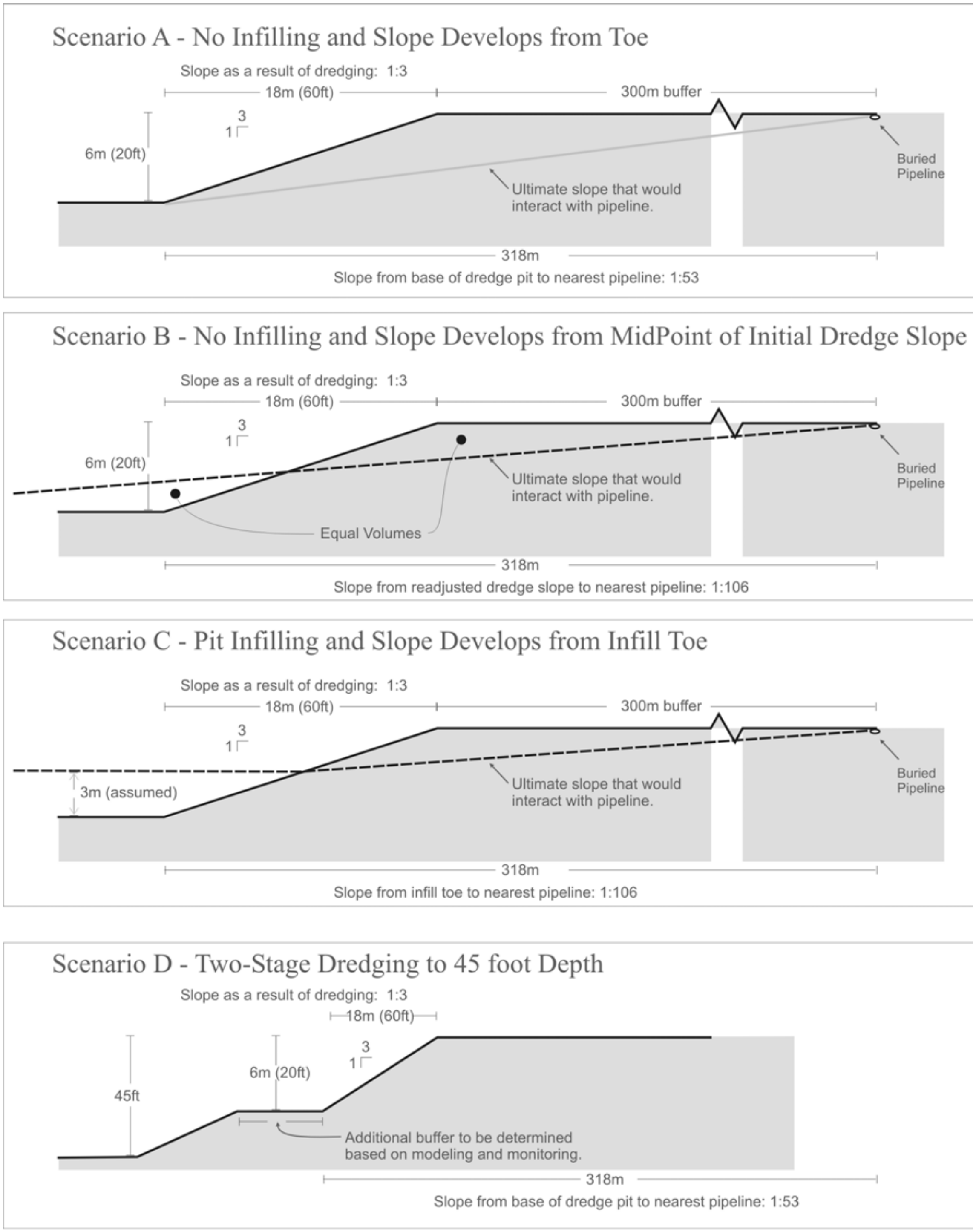

Figure 3-10 Sandy Point Post Dredge Slope Evolution

Table 3.1a South Pelto as 5 Dredge Area Cells

300m Buffer from Pipelines

Cell Name	Area, Feet^2	Area, Meters^2
SP-A	66,483,098	6,176,482
SP-B	24,806,912	2,304,638
SP-C	12,118,921	1,125,885
SP-D	43,003,618	3,995,167
SP-E	18,701,967	1,737,470
Total Area:	**165,114,517**	**15,339,641**

Assumed Equivalent Dredge Depth

Cell Name	**Dredge Depth Meters**	**Potential Volume Meters^3**
SP-A	1	6,176,482
SP-B	1	2,304,638
SP-C	1	1,125,885
SP-D	1	3,995,167
SP-E	1	1,737,470
Total		**15,339,641**
SP-A	2	12,352,964
SP-B	2	4,609,275
SP-C	2	2,251,769
SP-D	2	7,990,334
SP-E	2	3,474,939
Total		**30,679,281**
SP-A	3	18,529,446
SP-B	3	6,913,913
SP-C	3	3,377,654
SP-D	3	11,985,501
SP-E	3	5,212,409
Total		**46,018,922**

Incorporate Initial 1:3 slope at Perimeter

Area Feet^2	**Area Meters^2**	**Volume Meters^3**	**Total Volume Meters^3**
332,390	30,880	15,440	*6,161,042*
241,472	22,433	11,217	*2,293,421*
150,600	13,991	6,996	*1,118,889*
288,851	26,835	13,418	*3,981,749*
220,445	20,480	10,240	*1,727,230*
		57,310	***15,282,331***
664,020	61,689	30,845	*12,322,119*
481,807	44,761	22,381	*4,586,894*
300,402	27,908	13,954	*2,237,815*
576,747	53,582	26,791	*7,963,543*
439,620	40,842	20,421	*3,454,518*
		114,391	***30,564,890***
994,885	92,428	46,214	*18,483,232*
721,002	66,983	33,492	*6,880,421*
449,407	41,751	20,876	*3,356,778*
863,685	80,239	40,119	*11,945,381*
657,516	61,085	30,543	*5,181,866*
		171,243	**45,847,678**

Incorporate Isopach Limits

1m thickness is available over the entire area	
Area, feet^2	165,114,516
Volume, meters^3	15,339,640
Account for slope, m^3	-57,310
Volume at 1m cut:	**15,282,331**
2m thickness is available over about half the area	
Area, feet^2	85,546,805
Volume, meters^3	7,947,558
Account for slope (0.00374), m^3	-29,724
volume from 1m thick	15,282,331
Volume at 2m cut:	**23,200,165**
3m thickness is limited to portions of SP-B, SP-C & SP-D	
Area, feet^2	37,852,783
Volume, meters^3	3,516,639
Account for slope (0.00374), m^3	-13,152
volume from 1+2m thick	23,200,165
Volume at 3m cut:	**26,703,651**

Table 3.1b South Pelto as 5 Dredge Area Cells

200m Buffer from Pipelines

Cell Name	Area, Feet^2	Area, Meters^2
SP-A	74,140,578	6,887,885
SP-B	31,676,426	2,942,836
SP-C	15,695,249	1,458,136
SP-D	49,299,020	4,580,029
SP-E	21,821,843	2,027,316
Total Area:	192,633,117	17,896,202

Assumed Equivalent Dredge Depth

Cell Name	**Dredge Depth Meters**	**Potential Volume Meters^3**
SP-A	1	6,887,885
SP-B	1	2,942,836
SP-C	1	1,458,136
SP-D	1	4,580,029
SP-E	1	2,027,316
Total		**17,896,202**
SP-A	2	13,775,770
SP-B	2	5,885,673
SP-C	2	2,916,273
SP-D	2	9,160,058
SP-E	2	4,054,631
Total		**35,792,404**
SP-A	3	20,663,655
SP-B	3	8,828,509
SP-C	3	4,374,409
SP-D	3	13,740,087
SP-E	3	6,081,947
Total		**53,688,607**

Table 3.1c South Pelto as 5 Dredge Area Cells

150m Buffer from Pipelines

Cell Name	Area, Feet^2	Area, Meters^2
SP-A	79,493,665	7,385,203
SP-B	35,169,089	3,267,315
SP-C	17,888,867	1,661,930
SP-D	52,761,167	4,901,673
SP-E	23,563,924	2,189,160
Total Area:	208,876,711	19,405,281

Assumed Equivalent Dredge Depth

Cell Name	**Dredge Depth Meters**	**Potential Volume Meters^3**
SP-A	1	7,385,203
SP-B	1	3,267,315
SP-C	1	1,661,930
SP-D	1	4,901,673
SP-E	1	2,189,160
Total		**19,405,281**
SP-A	2	14,770,406
SP-B	2	6,534,631
SP-C	2	3,323,860
SP-D	2	9,803,346
SP-E	2	4,378,320
Total		**38,810,563**
SP-A	3	22,155,609
SP-B	3	9,801,946
SP-C	3	4,985,790
SP-D	3	14,705,018
SP-E	3	6,567,480
Total		**58,215,844**

Table 3.2 Sandy Point as 2 Dredge Area Cells

300m Buffer from Pipelines

Cell Name	Area, Feet^2	Area, Meters^2
Northwest Borrow	*3,571,489*	331,802
Southeast Borrow	*4,953,933*	460,235
Total Area:	*8,525,422*	***792,038***

Assumed Equivalent Dredge Depth

Cell Name	Dredge Depth Meters	Potential Volume Meters^3
Northwest Borrow	1	331,802
Southeast Borrow	1	460,235
Total		**792,038**
Northwest Borrow	2	663,604
Southeast Borrow	2	920,471
Total		**1,584,075**
Northwest Borrow	3	995,406
Southeast Borrow	3	1,380,706
Total		**2,376,113**
	(Depth of 20 feet)	
Northwest Borrow	6.096	2,022,666
Southeast Borrow	6.096	2,805,595
Total		**4,828,261**
	(Depth of 45 feet)	
Northwest Borrow	13.716	4,550,998
Southeast Borrow	13.716	6,312,590
Total		**10,863,588**

Incorporate Initial 1:3 slope at Perimeter

Area Feet^2	Area Meters^2	Volume Meters^3	Total Volume Meters^3
140,199	13,025	6,512	*325,290*
141,758	13,170	6,585	*453,651*
			778,940
279,582	25,974	25,974	*637,630*
282,515	26,247	26,247	*894,224*
			1,531,855
414,478	38,506	57,759	*937,647*
422,270	39,230	58,845	*1,321,861*
			2,259,508
815,162	75,731	230,828	1,791,838
835,532	77,623	236,596	2,568,999
			4,360,837

For the 45 foot calculation, a cut TIN surface was created and these values derived from a direct comparison with the original surface.

	Feet^3	**Meters^3**
Total:	*304,932,022*	**8,634,713**