SUBMERGED CULTURAL RESOURCES ASSESSMENT, LIBERTY DEVELOPMENT PROJECT, BEAUFORT SHELF, ALASKA

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Executive Summary

This report provides the results of an archaeological analysis of seafloor coring and seismic survey data conducted in support of the Liberty Project for BP Exploration (Alaska) Inc. (BPXA) This review addresses a condition in BPXA's ancillary activities notice issued by the Bureau of Ocean Energy Management (BOEM, 2013 Winter Geotechnical and Seabottom Investigation, Liberty Development, Beaufort Sea, Alaska). No cultural resources, of either historic or prehistoric origin, were identified in any of the coring materials or remote-sensing data.

1. Purpose and Scope

BP Exploration (Alaska) Inc. (BPXA) contractors undertook geotechnical and seabottom investigations in support of the Liberty Development in April and July, 2013 (Figure 1). These investigations are used in the evaluation of possible future island locations and proposed pipeline routing.

The Bureau of Ocean Energy Management (BOEM) Notice to Lessees and Operators of Federal Oil and Gas Leases in the Alaska Outer Continental Shelf Region (NTL No. 05-A03) requires archaeological survey and analysis to: "evaluate the existence and location of any submerged archaeological resources, which could be impacted by proposed OCS operations" (MMS 2005). The 2008 Draft EIS notes that "most of the Beaufort Sea Planning Area has never been surveyed for archaeological sites, and no sites on the OCS have been listed on the National Register. Therefore, archaeological resources or potential resources within the Beaufort Sea portion of the planning area must be identified using regional baseline studies, geophysical/geological data, historic accounts of shipwreck disasters, and marine remote-sensing data compiled from required shallow-hazard surveys" (MMS 2008).

In addition, conditions placed on BPXA's 2013 Winter Geotechnical and Seabottom Investigation for the Liberty Development stipulate that "…a brief report of the geotechnical boreholes be prepared by a qualified marine archaeologist" (letter, David Johnston to Mike Brock, March 28, 2013). A follow-up letter dated May 21, 2013, clarified the BOEM's expectations regarding archaeological analysis and reporting requirements for the 2013 activities: "The BOEM requests that core data be examined and documented by a marine archaeologist, and a brief report of the findings be submitted to BOEM and the Alaska State Historical Preservation Office (SHPO)." Additionally, "BOEM also requests that if BPXA conducted seismic studies along the survey route that a discussion of the relevant findings be reported, including features such as drowned landforms of buried channels, drowned islands, terraces, and shorelines."

This report provides the archaeological analysis and interpretation of seafloor coring activities and seismic survey data acquired by BPXA contractors in April and July, 2013.

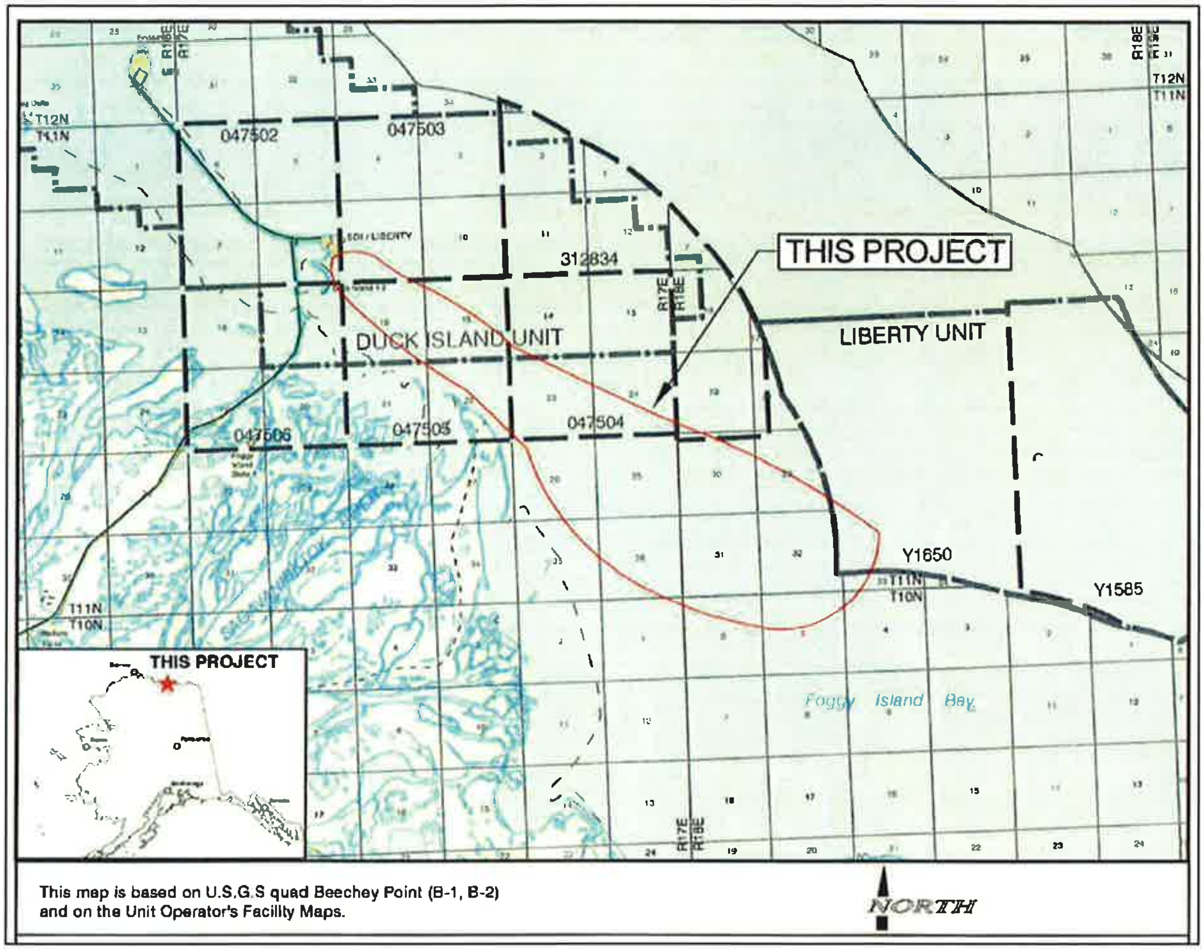

Figure 1. Project area (map provided by BPXA, February 2013).

2. Project Background

2.1 Physical Environment

The Beaufort Sea is a marginal sea of the Arctic Ocean, bounded on the west by Point Barrow, Alaska, and on the east by Banks Island in the Canadian Arctic archipelago. There are no major offshore islands in the Beaufort Sea, although there are many small coastal shoals and barrier islands, particularly near river mouths. The most significant rivers in terms of freshwater discharge are the Mackenzie and the Colville.

The Arctic Coastal Plain (part of the North Slope physiographic unit) is characterized by a gently sloping tundra-covered plain extending from the northern foothills of the Brooks Range to the Beaufort Sea. The low rolling hills and flatlands are dissected by numerous braided rivers which issue from the Brooks Range and flow northward to the Beaufort coast. The coast consists largely of low-lying wetland tundra, dotted extensively with thaw lakes and ponds. Shorelines are irregular because the generally retreating coast has intersected valleys and thaw lakes.

Coastline topography is low to moderate, with most coastal bluffs less than 5 meters (m) high. Extensive shallow deltas form at the mouths of major rivers (Wahrhaftig 1965; Hartwell 1973).

The main rivers along the Alaskan Beaufort coast are the Colville, Sagavanirktok, Canning, and Kuparuk. None of these rivers have year-round flow; all freeze and cease flowing by January, and resume flow in late March or early June. The entire slope is underlain by continuous permafrost, and consists of alluvial and glacial sediments overlying bedrock. The ground surface seasonally thaws to a depth of ca. 30 centimeters (cm); sediments below this are permanently ice bonded to a depth of hundreds of meters. Subsea permafrost is extensive in nearshore areas as well, with variable offshore distribution.

The climate of the Alaskan Beaufort Sea coast is classified as polar tundra (Köppen classification - ET), with extremely cold winters, cool summers, and low annual precipitation. Subfreezing temperatures prevail for most of the year, with mean temperatures rising above freezing only between June and August. High winds are frequent, and coastal fog is common in summer. Maximum precipitation occurs in August, and maximum snow cover in April (although snow may occur in any season). By mid- to late June the seasonal snowpack has generally disappeared. However, climatological observations show a trend towards earlier snowmelt and higher spring temperatures in the Alaskan Arctic over the last 40-60 years (Foster 1989; Stone et al. 2002).

Sea ice dominates the entire Beaufort Sea area, and nearshore waters are typically ice-covered for about 9 months of the year. Ice begins forming in late September to early October, and reaches maximum thickness and extent in April or May. The mean sense of ice motion in the Beaufort Sea is anti-cyclonic (clockwise) around the Beaufort Gyre, generally moving southward and westward, approximately parallel to the Alaska coast. Leads, ridges, and other deformation patterns of pack ice generally reflect interaction of the moving ice with fixed landmasses and grounded ice features (Mahoney et al. 2012). River runoff generally peaks in late May or early June, and the large influx of freshwater initiates breakup of sea ice at river mouths and in nearshore lagoons (Pollard and Segar 1994). As breakup proceeds, nearshore leads form, varying in extent and situation from several kilometers (km) to several hundred km (Eicken et al. 2006; Mahoney et al. 2012).

Arctic sea ice cover has undergone significant changes in the past two decades, with five record minima attained between 2001 and 2007, a small expansion in 2008-2011, and the lowest extent ever recorded in September 2012 (Eicken et al. 2006; Comiso et al. 2008; Mahoney et al. 2012). The trend is towards shorter ice-cover seasons, and thinner ice-cover in general. These data have raised speculation that the Arctic may see entirely ice-free summers as early as 2030 (Wang and Overland 2009; Stroeve et al. 2007, 2012).

The Beaufort Sea continental shelf consists of two "steps": the inner shelf extends approximately to the 50 m isobath, and a steep slope drops to the outer shelf (between the 150 and 500 m isobaths) (MMS 2008). Further offshore is the abyssal Canada Basin, with a maximum depth of approximately 3800 m. The inner shelf in the central and western Beaufort is relatively narrow, extending approximately 80-90 km offshore, but even narrower in the eastern Beaufort, approximately 40-60 km offshore. Prominent features of the inner shelf are broad shallows off major rivers, sand and gravel islands trending parallel to the coast, and sand and gravel shoals in nearshore water (approximately10 m to 20 m deep) (Barnes et al. 1984). Circulation in deeper waters of the Beaufort Sea is dominated by the anti-cyclonic motion of the Beaufort Gyre, driven by a persistent region of high atmospheric pressure (the Beaufort High). Old and thick ice from regions north of the Canadian Arctic Archipelago is thus driven into the Beaufort Sea and along the Alaskan coast, although Gyre strength varies from year to year (Mahoney et al. 2012). Nearshore circulation is driven primarily by wind stress, with currents responding rapidly to changes in the local wind field. Tidal variations in the Beaufort Sea are quite small, with a diurnal range of 10-30 cm. However, summer and fall storm surge events can induce much more significant changes in local sea level (Pollard and Segar 1994). High winds can cause super-elevation of the ocean surface, resulting in inundation of low-lying coastal areas and overtopping of offshore barrier islands.

Sea ice limits the open water season along the Beaufort Sea coast to approximately three summer months, effectively limiting coastal processes to this period. Despite the short annual period of open water, coastal erosion rates in this region are among the highest in the world, caused by the combined thermal-mechanical processes of thermokarst (thawing permafrost and melting ground ice) and wave action, especially during storm surges (Reimnitz and Barnes 1974; Forbes and Taylor 1994). Erosion mechanics are strongly influenced by the ice content of the sediments, as higher ice content is associated with increased thermal erosion rates. Thawing of ground ice leads to subsidence and seasonal slump. Large scale retrogressive thaw slump can expand rapidly inland, eroding large volumes of sediment from shoreline areas (Lantuit and Pollard 2008). Along bluff faces, niche erosion spreads both vertically and laterally along the boundaries of ice-wedge polygons. Bluffs are eventually undermined by wave action, leading to block collapse (Ravens et al. 2012). A further significant cause of shoreline erosion is sediment entrainment and transport by frazil ice (Aré et al. 2008). Analysis by Reimnitz et al. (1988b) suggests coastal retreat along the Beaufort shore ranging from about 7 to 27 km since 5000 B.P., with accretion only at major river mouths (such as the Colville). Rates of retreat typically range from 2 to 6 m/year, but can reach as high as 18 m/year (Reimnitz et al. 1988b; Harper 1990). More recent shoreline-change analyses indicate increasing rates of erosion since the early 2000s, associated with warming temperatures and expanded spatial and temporal extent of open water conditions (Wendler et al. 2010; Ravens et al. 2012). In general, seafloor surficial sediments tend to become finer grained away from the current shoreline. Sand predominates in nearshore areas, while silt and clay-sized sediment materials are predominant further offshore (Golder 2013a).

There is currently no comprehensive sea-level history for the Beaufort Sea. Data derived from radiocarbon dating of organic materials obtained from sediment cores may be used to construct a relative sea level (RSL) curve, although variation may exist due to localized eustatic and isostatic conditions. The most pertinent studies are described below and presented in comparative form in Figure 2. Fairbanks' (1989) global RSL curve, based on Caribbean coral reef cores, is also graphed for comparative purposes.

In one of the first comprehensive works to evaluate regional sea-level history, Dixon et al. (1978) suggested a sea level of -125 m at the height of the Late Wisconsin glaciation (ca. 25,000 – 20,000 B.P.), with subsequent stillstands at -82 m (ca. 15,000 – 14,800 B.P.), -66 m (ca. 13,750 B.P.), -55 m (ca. 12,700 B.P.), -38 m (ca. 9400 B.P.), and -28 m (ca. 8700 B.P.). Levels were derived from interpretation of submerged marine sill and terrace bathymetry, and chronology was "extrapolated from other sources" (Dixon et al. 1978:II-25). Later works attempted to refine the potential sea level chronology. Jordan and Mason (1999) dated a series of peat samples from near Barrow, suggesting sea levels of -12 m at 7000 to 6000 B.P., and -1.5 m at around 5000 to 4500 B.P. Based on an extensive review of dated core materials (mostly peat samples), Darigo et al. (2007) concluded that at the beginning of the Holocene, sea level in the Beaufort was at or below -50 m. By 9000 B.P., sea level had risen to about -44 m, was at -12 m by about 6000 B.P., and reached near modern levels (within -2 m) by about 5000 years B.P. (Darigo et al. 2007).

Hill et al. (1993) have developed an RSL curve for the eastern Beaufort shelf, derived from 36 dated marine and terrestrial samples. Although none of the samples could directly record a specific sea level position, the suite of ages was used to create a constrained range. The Hill et al. RSL curve is markedly different from the other three Beaufort curves, possibly representing specific isostatic and sediment loading conditions of the Mackenzie River delta. Hill et al.'s eastern Beaufort curve also contrasts sharply with McManus and Creager (1983), who analyzed core samples from the Chukchi and northern Bering Sea shelves. McManus and Creager suggest a sea level of -68 m at ca. 19,000 B.P., near -55 m at 16,000 B.P., and -30 m by 12,000 B.P. (cf. Hill and Driscoll 2008 for the Chukchi Sea).

No clear accord exists between previous sea level studies, although there is general agreement that Holocene rates broadly parallel the global curve developed by Fairbanks (1989). Localized processes likely introduce considerable variability into sea level reconstructions.

The Liberty development is located in Foggy Island Bay, Stefansson Sound, offshore of the Sagavanirktok River delta. Foggy Island Bay is situated between the Sagavanirktok and Shaviovik Rivers, and is sheltered by the McClure Islands (approximately 10-20 km offshore). Proposed drilling sites are located approximately 9 km offshore in in 2 to 7 m of water, with proposed pipeline variants extending to the Endicott SDI facility. Previous studies (BPXA 2007) have shown that the shoreline is actively retreating, through both wave-induced and thermal erosion processes. In contrast to open seas north of the barrier islands, first-year ice is the only significant ice feature in Stefansson Sound and Foggy Island Bay. The ice within the bay usually achieves a maximum thickness of around 2.1 m, and remains virtually motionless throughout the winter. Strudel scour and ice wallow can occur during the springtime thaw and breakup (BPXA 2007; Aré et al. 2008; see also Section 2.3 above). High-resolution sonar and bathymetric data acquisition and compilation efforts are ongoing; these data will be analyzed and incorporated in later versions of this report as they become available.

Water depths within the bay are generally less than 10 m. Relief is minor, comprised mainly of scattered strudel scours and ice gouges. Surficial indications of ice gouging are light, due to the protective offshore barrier island complex and the shallow water environment (Marmaduke and Watson 1999). Surficial seafloor sediments generally consist of unconsolidated Holocene deposits up to 3 m thick. The total thickness of Holocene sediments varies greatly, and in some areas can be up to 50 m deep. Previous studies (i.e., Trefry et al. 2003; BPXA 2007) concluded that current general sedimentation rates within the lagoon are extremely low (<0.1 cm/yr), although greater sediment deposition at the mouth of the Sagavanirktok and Kadleroshilik rivers is to be expected. Holocene deposits are underlain by Pleistocene silts and clays, which also outcrop in some areas of the seafloor. Lag deposits of Pleistocene cobbles and boulders (the

"Boulder Patch", supporting a unique benthic biota) also occur, primarily in the western portion of the bay (Marmaduke and Watson 1999; Dunton and Schonberg 2000; BPXA 2007; Darigo et al. 2007).

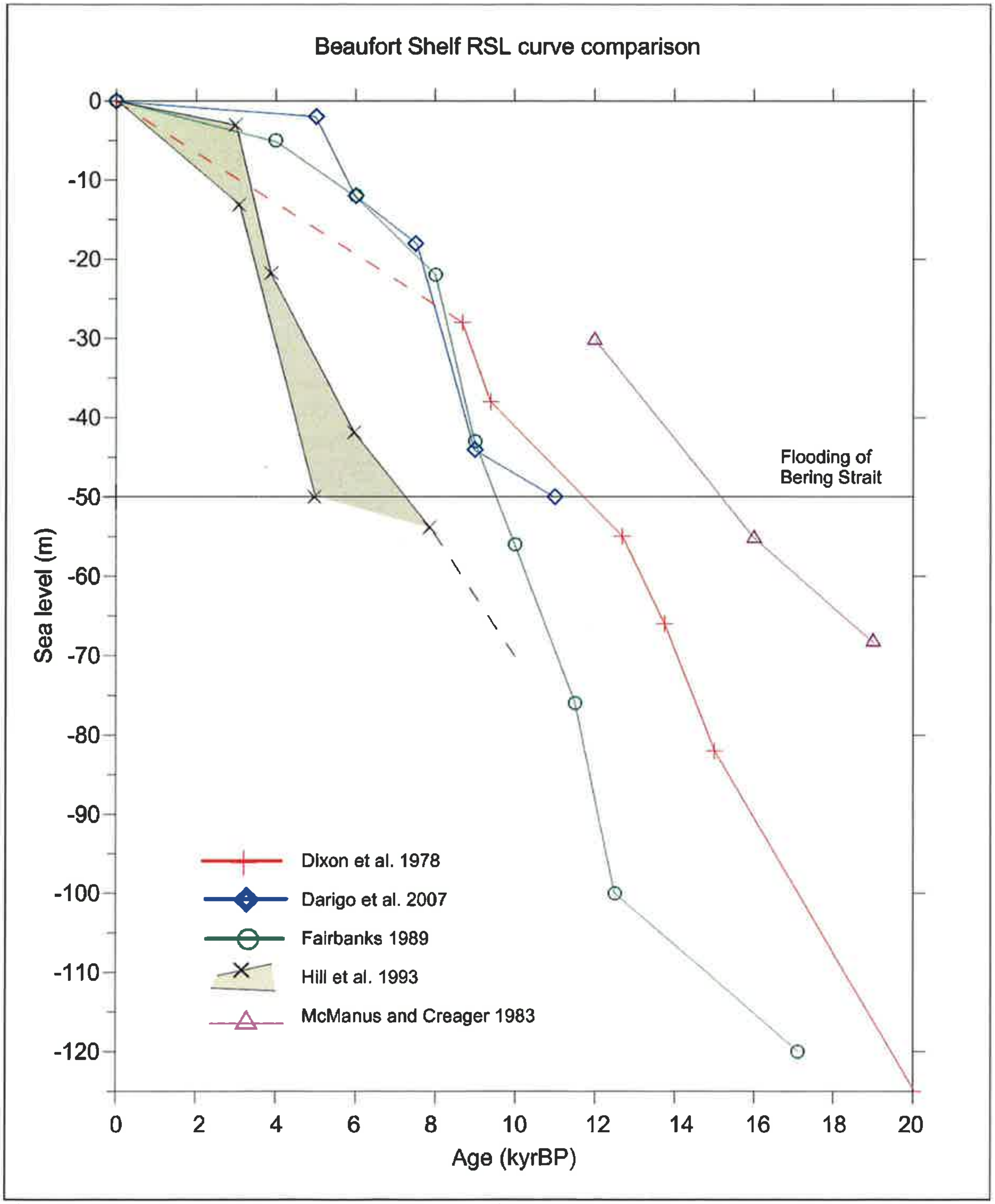

Figure 2. Comparison of relative sea level (RSL) curves developed for the Beaufort and Chukchi Seas, with the Fairbanks (1989) global RSL curve.

2.2 Potential for submerged cultural resources

The existence of a land bridge between Asia and North America (and adjacent areas of exposed continental shelf) during periods of lowered sea level is considered by the archaeological community as paramount in understanding theories of human colonization of the Americas (for example see Jablonski 2002; Bonnichsen et al. 2005; Morrow and Gnecco 2006). Although the possibility of an early maritime entrance is not ruled out (cf. Fladmark 1979; Dixon 2011), prevailing theories favor an overland route for the first humans in North America.

Human occupation in the New World dates from at least 15,000 cal BP (the Clovis complex in mid-latitude North America), although the oldest known archaeological sites in Alaska (the Swan Point and Broken Mammoth sites in the Shaw Creek Flats of the Tanana Valley) date to around 14,800 cal BP (Holmes 1996, 2011). Potential therefore exists for prehistoric archaeological sites along the submerged portions of the continental shelf of the Arctic Ocean and Beaufort Sea.

Theories of overland entry focus on the importance of terrestrial mammals, especially extinct Ice Age 'megafauna' (mammoth, steppe bison, etc.). Migrating herds of Ice Age fauna undoubtedly crossed the Bering Land Bridge, potentially drawing human predators (the first colonists of the Americas) in their wake. In this view, the specialist mammoth hunters initially entered Alaska between the glaciated Brooks and Alaska Ranges, and then ventured south through an ice-free corridor between the Cordilleran and Laurentide ice sheets. Dikov (1983) has also suggested the possibility that mammoth hunters from north Yakutia crossed from Siberia to Alaska by a northern route, across what is now the Chukchi Sea. In any case, descendants of the initial colonists spread across both North and South America within 1000 years (Fiedel 2005). To achieve such rapid spread, groups would need to be highly mobile with few or no long-term habitation sites, and likely leaving traces only of hunting stations and overnight camps.

Traces of these camps in the archaeological record would consist of lithic artifacts (the remains of weapons, tools, and their manufacture), campsites (hearths, faunal remains, and tent rings), kill and butchery sites, and perhaps burials. The oldest archaeological sites in Alaska (the Denali complex sites of the Nenana and Tanana Valleys) are relatively ephemeral. Lithic artifacts are present, as is charcoal, and faunal material is sparse, except in rare deeply stratified sites such as Broken Mammoth and Swan Point (Holmes 1996, 2001, 2011).

No Holocene glaciations occurred on the north slope of the Brooks Range, and no barriers to either faunal or human occupation are known (Figure 3). Hopkins (1983:346) suggests that human populations in Beringia prior to climatic amelioration circa 14,000 years ago would have been entirely dependent on land mammals for food as well as for other essential requirements. Because it likely had the mildest climate as well as the highest organic productivity, the now-submerged continental shelf might have been the most attractive to early human populations. The offshore areas of the project are therefore located within a region which has potential for the presence of remains of prehistoric human transit and occupation that may be significant to understanding human migration to the North American continent.

Recognizing the presence of prehistoric remains in the current underwater environment is difficult. Although sedimentation rates vary, virtually any deposition of sediment is likely to obscure visible traces of prehistoric human activity. Intact archaeological deposits would almost certainly be buried and thus apparent only after intrusive testing (coring or dredging). Though the likelihood may be small, the possibility of encountering prehistoric remains in the submarine environment certainly exists. For example, extensive paleoshoreline modeling in the Queen Charlotte Islands combined with remote sensing techniques (i.e., swath bathymetry) has led to the identification of high potential landforms such as paleobeaches, terraces, and fluvial confluences for archaeological sampling. Targeted "grab-bag" dredging on these high potential features has resulted in the retrieval of archaeological material from a depth of ca. 55 m in Werner Bay, western Hecate Strait (Fedje and Christensen 1999:647). This site was last sub-aerial at ca. 10,200 B.P. Similar underwater investigations in shallower waters on the drowned continental shelf of Florida have resulted in the identification of a number of paleoindian sites, as well as the recovery of lithic debitage and diagnostic artifacts (Faught 2004). Underwater excavations in Europe have also resulted in retrieval of material, for example at the Mesolithic site of Tybrind Vig, Denmark (Anderson 1987), along the continental shelves of France, Greece, and along the eastern Mediterranean (see Masters and Flemming 1983 for several case studies).

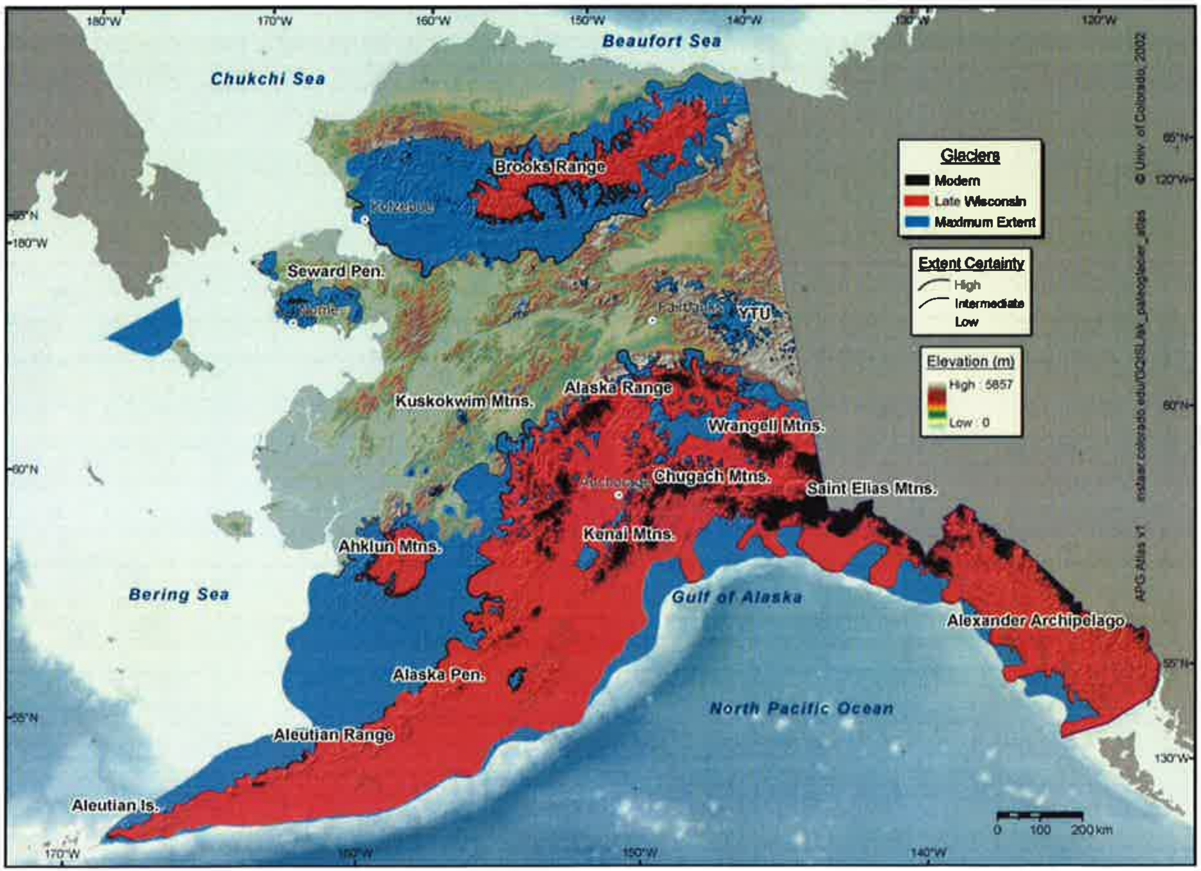

Figure 3. Map of glacial extents in Alaska, showing unglaciated Beaufort Sea coast (image from Manley and Kaufman 2002).

2.3 Implications of sea ice processes for submerged cultural resources

The potential preservation of submerged cultural resources in the Beaufort Sea is complicated by the dynamics of the seasonal growth, movement, and retreat of sea ice. Sea ice can be broadly classified in three forms: landfast (or shorefast) ice, stamukhi (or shear) ice, and pack (or polar) ice (Wadhams 2000; Leppäranta 2005). Landfast ice is attached to the shore, is generally immobile, and extends offshore to about the 20 m isobath. Landfast ice is often also frozen in contact with the seafloor, leading to the term 'bottomfast' ice (cf. Wadhams 2000). 'Stamukhi' ice is formed in the zone of dynamic interaction between landfast ice and pack ice. Intense shear and pressure ridging occurs in this zone, particularly in water depths between 15 and 45 m. Grounded stamuhki ridges form a stabilizing buffer zone at the seaward edge of the landfast ice zone, where incursions of polar pack ice impact the relatively immobile shorefast ice. Pack ice includes both first-year and multi-year ice and is mobile and dynamic, moving under the influence of water currents and (especially) winds.

Pack ice is subject to immense wind fields generated over a large area. Wadhams (2000:65) estimates that concentrated pack ice responds to wind fields integrated over a distance of up to 400 km upwind. The convergence of fields of moving pack ice (or pack ice impacting with shorefast ice) results in linear deformation features called pressure ridges. The intense pressure eventually builds up ice masses both above the water's surface (ice sails) and below (ice keels). Ice keels are far more extensive than sails (the average sail-height to keel-depth ratio is 1:4.5, although it may be as high as 1:9) (Kovacs and Mellor 1974:136). Ridge keels are also generally 2 to 3 times wider than sails (Wadhams 2000). Ice gouging occurs where ice keels are driven into the seabed, and are moved by the accumulated energies of the encompassing pack ice structure. The resulting furrows or tracks in the seafloor are described as ice gouges (Barnes et al. 1984), or ice scour (Wadhams 2000).

Ice grounding and gouging are common in all arctic coastal waters, from the sea's edge to considerable depths (Kovacs and Mellor 1974). Seasonal patterns of ice formation and movement determine the locations and intensity of ice gouging. Although the most intense areas of ice gouging occur in the stamukhi zone, gouges have been observed in water depths from 0 to 125 m (Barnes et al. 1984). Limited or no gouging occurs in the landfast zone during periods of maximum ice extent, however gouging and associated processes can occur in this zone during spring break-up. Barnes et al. (1984) also noted gouge widths up to ca. 70 m, and to depths of 5.5 m below the seafloor. Deep gouges tend to produce high flanking ridges on either side, creating combined vertical relief of up to 8 m. The highest gouge densities are in water between 20 and 40 m deep, as are maximum gouge depths. Gouges in water deeper than ca. 55 m are assumed by some researchers to be relict from periods of lower sea-level, as modern ice features generally do not have keels extending beyond ca. 60 m deep (Kovacs and Mellor 1974). Others, however, suggest that keels of great depth may occasionally form in shear zones along the shelf, and that deepwater gouges may thus be modern in origin (Reimnitz and Barnes 1974; Barnes et al. 1984; Reimnitz et al. 1988a). Wadhams (2000:72) also ascribes deepwater gouges to rare pressure ridges of extreme depth, embedded in the polar pack, which scour the seabed without halting the pack as a whole.

Another sea ice process with considerable potential for impact to submerged cultural resources is the phenomenon known as 'strudel scour'. During the spring melt season, North Slope rivers initially thaw from the headwaters, and subsequently flood towards the sea. The rapid buildup in stream flow before river mouths are free of ice compels discharge water to flow seaward over the nearshore bottomfast sea ice (known as 'sea ice overflood', cf. Walker 1974; Barnes and Reimnitz 1976; Hearon et al. 2009). Overflood extent can reach distances of as much as 15-20 km or more from the river mouths, and encompass hundreds of square km (Barry et al. 1979; Hearon et al. 2009). As overflood waters travel over the ice sheet, they create channels, widen cracks, and eventually drain through openings in the ice to the seawater below. When large amounts of overflood waters are draining through the ice, these holes can serve as focal points for vertically oriented axial jets with vortical motion (subsurface whirlpools). Because the seafloor in flooded areas is generally quite shallow, the vertical jets of overflood water often encounter the bottom and may excavate craters more than 4 m deep and 20 m in diameter, termed 'strudel scours' (Reimnitz et al. 1974; Reimnitz and Kempema 1982).

Other similar sea ice-driven processes (ice wallowing, bulldozing, pile-up, rafting, and sediment entrainment) all contribute to shoreline retreat and seafloor sediment reworking and transport, with potential implications for preservation of coastal and submerged cultural resources (Aré et al. 2008). The combination of the various processes lead Darigo et al. (2007) to conclude that bottom sediments offshore of about the 20-m isobath would be ice-gouged and reworked, "...likely precluding preservation of paleolandforms below this depth." The seafloor landward of the 20-m isobath may be more protected from ice gouging, although not from strudel scour, and significant regional variability is likely.

3. Previous Studies

Two previous studies address various aspects of the potential for submerged cultural resources in the Beaufort Sea in general (Dixon et al. 1978; Darigo et al. 2007), and one investigation specifically targeted Foggy Island Bay and the Liberty project area (Marmaduke and Watson 1999). In addition, Reanier (2008) reviewed previous cultural resources and geophysical investigations of the Liberty project area.

The earliest of the general studies (Dixon et al. 1978) pointed out that as archaeological research conducted on the North Slope included some the oldest evidence for human occupation of the Arctic, and that geophysical research indicated that the adjacent outer continental shelf was exposed and habitable during periods of lower sea level, that it should be considered as part of a possible Pleistocene migration route from Asia to North America. However, Dixon et al. concluded that "severe problems" exist in attempting to delineate areas likely to contain archaeological sites (i.e., extremely flat topography, modification of bottom sediments during the Holocene, and geological processes such as ice gouging).

Based on an extensive review of previous cores and shallow seismic data, Darigo et al. (2007) concluded that there are several geomorphologies where late Pleistocene – early Holocene terrestrial landforms on the Beaufort Sea shelf are more likely to be preserved. These include wide inshore areas of the landfast ice zone, areas inshore of barrier islands, and areas between major river systems.

Holocene sediments in the Liberty project area ranging from 0 to 2.6 m thick were mapped by Watson (1998), thicker towards the east, thinning to the west until Pleistocene boulder patch materials are exposed on the seafloor. Holocene deposits consist of unconsolidated sediments, likely including both marine and fluvial-deltaic sediments deposited in a flooded lagoon environment between the Sagavanirktok delta and the McClure Islands (Watson 1998). Some older deposits, located below Holocene sediments through most of the area, are occasionally exposed. Containing “coarse material, peat layers, and small distributary channels”, these exposures were interpreted by Marmaduke and Watson (1999) as Pleistocene in age. Geophysical data indicate landforms possibly representing a peat bog or lagoonal depression 3 to 4 m deep, with adjacent terrace-like features and a relict island, that developed during a Holocene sea level stand about 6 m below present. These deposits, classified on the core logs as organic silt, fibrous peat, or thin interbedded organics, generally occur between 5 and 11 m below the sea floor and range from several cm to ~2 m thick.

Marmaduke and Watson (1999) identified a number of buried and near-surface distributary channels and channel fragments, identified as remnants of the Sagavanirktok delta front complex from a lower sea level stand. However, the MMS (cited in Darigo et al. 2007) suggested that smaller channel fragments could be buried strudel-scour depressions. Subbottom profiles also show a depression-like feature, lying adjacent to a possible buried island or other geomorphic high point. The authors interpret this as a “narrow terrace or floodplain”, which was an active drainage before ca. 10,000 BP (Marmaduke and Watson 1999).

Marmaduke and Watson (1999) concluded that: “The eastern margin channel is the only readily identifiable terrestrial feature in the near surface sediments in the Liberty Project survey area. None of the sediments associated with the channel indicate preservation of landforms likely to contain archaeological remains of terrestrial origin.”

4. 2013 Geotechnical Cores

Geotechnical cores were collected from April 3rd to April 9th, 2013, by Golder Associates, Inc. (Golder) (Figure 4).

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Conclusions of the 2013 Golder investigations are generally in accord with those of earlier studies (i.e., Marmaduke and Watson 1999). Sand and silty sand sediments are derived from Sagavanirktok River deposits, some of which may be old overbank deposits. Sand layers in the Delta zone overlie a dense, poorly graded sand and gravel layer. The depth to the top of the sand and gravel layer varies considerably, suggesting that old river channels may have existed in this area (likely corresponding with Marmaduke and Watson's (1999) distributary channels). These deposits are noticeably lacking in the Transitional zone, dominated by mixed energy coastal processes (erosion, transportation, and deposition).

Subsurface organic materials were encountered in a number of individual bores. Speciation and radiocarbon dating analyses were undertaken on three samples recovered from two boreholes (one from L13-13 [redacted] and two from L13-22 [redacted] Dating and speciation results are presented in Table 1. [redacted]

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Samples from borehole L13-22 (*Succinid* sp. gastropod (snail), and *Drepanocladus* or *Entodon* sp. moss) both represent terrestrial species (Figures 6 and 7). All the above genera are represented on the Arctic plain today (Steere 1978; Baxter 1987). The samples from L13-22 correlate well with a lower sea level and exposed sub-aerial surface, indicating that the deposit is likely dated in place to the early or middle Holocene. The early/mid-Holocene dates support the current relative sea level curve models, i.e., sea level at this time was lower than 10 m below the current level.

The Pleistocene date on a wood sample (*Betula* sp. (birch), presumably driftwood) from borehole L13-13 likely indicates a secondary depositional context, reworked from older deposits (Figure 8). This date is comparable to others obtained on samples taken from the Chukchi seafloor at much greater depths (Rogers 2012). The age of the wood fragments is considerably older than the Final Wisconsin glaciations (LGM ca. 18,000 yrs B.P.), and hence far earlier than any human presence in Alaska.

Table 1. Marine Core Samples Analysis Summary.

Sample and Lab No.	**Provenience (bore and depths[1])**	**Coordinates (NAD83)**	**Material**	**Age Determination (BP)**	**Calibrated Date (BP), 2σ[2]**	**Speciation[3]**
BPL-001 UGAMS 14749	L13-13/E3 -9.8 ft./-3.1 m MLLW 38.5 ft./11.7 m bm	70.27225 N 147.70045 W	wood fragments	47,350 ± 560	beyond calibration curve	*Betula* sp.
BPL-004 UGAMS 14750	L13-22/E12 -2.9 ft./-0.9 m MLLW 30-30.8 ft./9.1-9.4 m bm	70.31836 N 147.86107 W	gastropod shell	7420 ± 30	8180-8330 cal BP	*Succinid* sp.
BPL-005 UGAMS 14751	L13-22/E12 -2.9 ft./-0.9 m MLLW 30-30.8 ft./9.1-9.4 m bm	70.31836 N 147.86107 W	moss	6230 ± 30	7020-7250 cal BP	*Drepanocladus* or *Entodon* sp.

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[1] Ft/m below mean lower low water (MLLW), and Ft/m below mudline (bm).

[2] Radiocarbon age determinations were calibrated with Calib 6.1 software (Reimer et al. 2009).

[3] Speciation analysis was undertaken by Owen Davis, University of Arizona Palynology Laboratory.

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Figure 6. *Succinid* sp. gastropod shell, from borehole L13-22, magnification approximately 80x.

Figure 7. *Drepanocladus* or *Entodon* sp. moss, from borehole L13-22, magnification approximately 80x.

Figure 8. *Betula* sp. wood fragments, from borehole L13-13.

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6. Conclusions

No cultural resources, of either historic or prehistoric origin, were identified in any of the materials recovered for analysis or in remote-sensing data acquired by BPXA's 2013 Winter Geotechnical and Seabottom Investigation. Dated samples provide support for the suggestion that buried paleolandforms exist in offshore areas of northern Alaska's continental shelf. These samples also provide evidence relating to paleoclimates and environmental conditions before, during, and after the last glaciation.

7. Limitations

Because archaeological materials, features, and other potentially significant cultural remains are commonly buried, they may not be identifiable from the surface or revealed in limited subsurface sampling. Should indications of potentially significant cultural resources be encountered during ground-disturbing activities, all work in that area should cease until the discovery can be fully evaluated by a qualified archaeologist, and the Alaska State Historic Preservation Office (SHPO) notified. In the event that human remains or other indications of burials are found on Federal or Tribal lands, the provisions of the Native American Graves Protection and Repatriation Act (NAGPRA) must be followed. Immediate steps must be taken to secure and protect the human remains and cultural items, including stabilization or covering, as appropriate. BPXA should immediately notify Alaska SHPO, Alaska State Troopers, and the local Native American organizations likely to be culturally affiliated with the discovered human remains.

This project was carried out, and this report prepared, in accordance with generally accepted professional practices for the nature and conditions of the work completed in the same or similar localities, at the time the work was performed. This report is not meant to represent a legal opinion. We do not warrant that we have identified all potentially significant cultural resources present in this project area, as these may be hidden in such a way that only extensive excavations, use of remote sensing equipment (e.g., ground penetrating radar, and magnetometer), or other methods not included in our scope of work could reveal them. No other warranty, expressed or implied, is made.

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