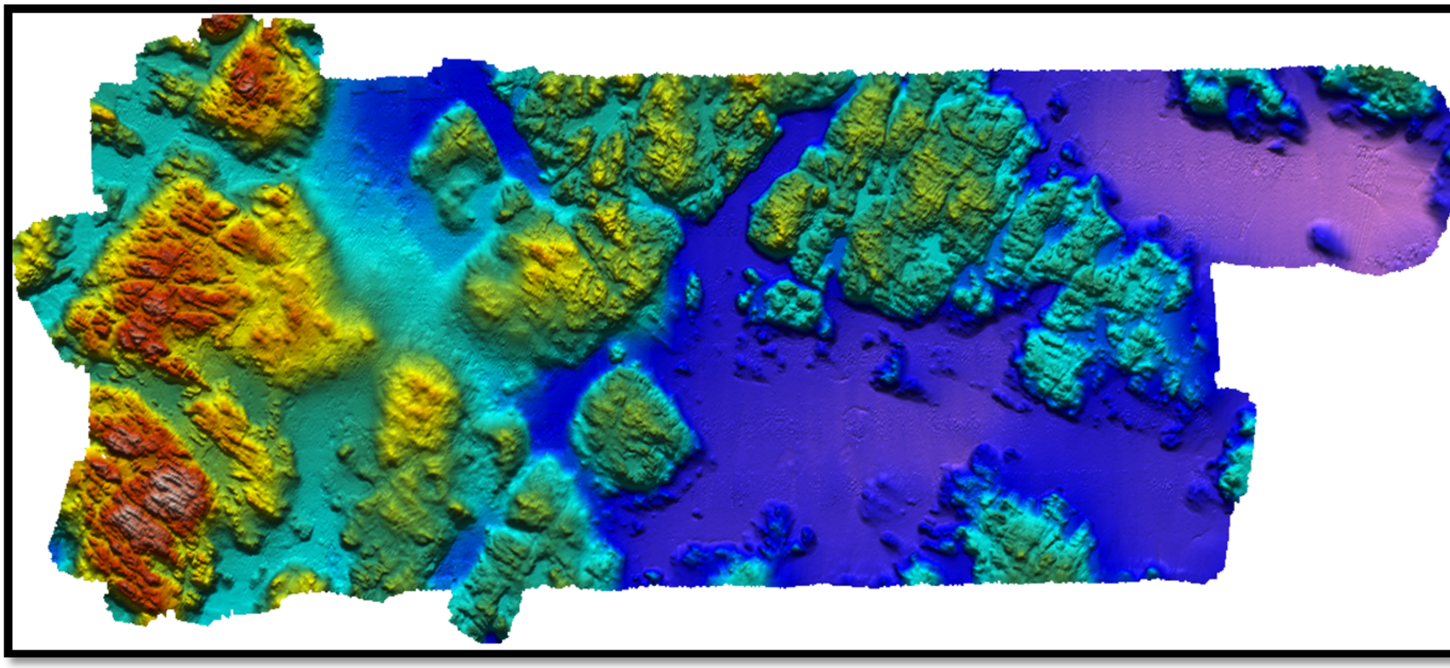
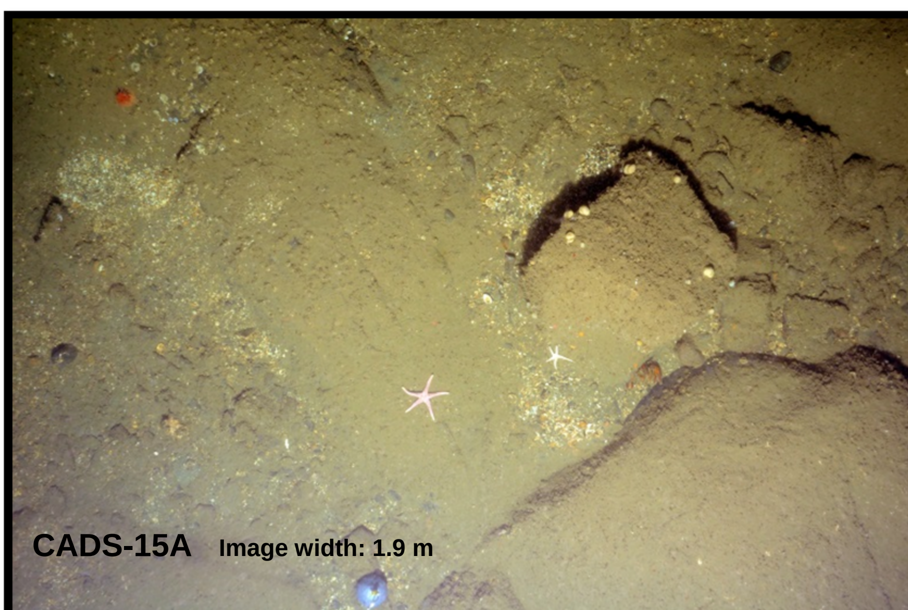
Data Summary Report of the Cape Arundel Disposal Site
August 2013 Monitoring Survey

Disposal Area Monitoring System DAMOS



D A M O S
DISPOSAL AREA MONITORING SYSTEM

Data Summary Report
2013-01
September 2014



US Army Corps of Engineers ®
New England District

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Note on units of this report: As a scientific data summary, information and data are presented in the metric system. However, given the prevalence of English units in the dredging industry of the United States, conversions to English units are provided for general information in Section 1. A table of common conversions can be found in Appendix A.

TABLE OF CONTENTS

Page

APPENDICES

LIST OF TABLES

Page

LIST OF FIGURES

LIST OF ACRONYMS

aRPD	apparent redox potential discontinuity
CAD	computer-aided design
CADS	Cape Arundel Disposal Site
CCOM/JHC	Center for Coastal and Ocean Mapping Joint Hydrographic Center
CO-OPS	Center for Operational Oceanographic Products and Services
CTD	conductivity-temperature-depth
DAMOS	Disposal Area Monitoring System
DGPS	differential global positioning system
GIS	graphic information system
GPS	global positioning system
JPEG	Joint Photographic Experts Group
MBES	Multibeam Echo Sounder
MLLW	mean lower low water
NAE	New England District
NEF	Nikon Electronic Format
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
PPS	pulse-per-second
PV	plan-view
RGB	red green blue (file format)
SBAS	satellite-based differential corrections
SHP	shapefile or geospatial data file
SOP	Standard Operating Procedures
SPI	sediment-profile imaging
TIF	tagged image file
TZM	tide zoning model
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard

1.0 INTRODUCTION

A monitoring survey was conducted at the Cape Arundel Disposal Site (CADS) in August 2013 as part of the U.S. Army Corps of Engineers (USACE) New England District (NAE) Disposal Area Monitoring System (DAMOS) Program. DAMOS is a comprehensive monitoring and management program designed and conducted to address environmental concerns surrounding the placement of dredged material at aquatic disposal sites throughout the New England region. An introduction to the DAMOS Program and CADS, including brief descriptions of previous dredged material disposal and site monitoring activities, is provided below.

1.1 Overview of the DAMOS Program

The DAMOS Program features a tiered management protocol designed to ensure that any potential adverse environmental impacts associated with dredged material disposal are promptly identified and addressed (Germano et al. 1994). For over 35 years, the DAMOS Program has collected and evaluated disposal site data throughout New England. Based on these data, patterns of physical, chemical, and biological responses of seafloor environments to dredged material disposal activity have been documented (Fredette and French 2004).

DAMOS monitoring surveys fall into two general categories: confirmatory studies and focused studies. Confirmatory studies are designed to test hypotheses related to expected physical and ecological response patterns following placement of dredged material on the seafloor at established, active disposal sites. The data collected and evaluated during these studies provide answers to strategic management questions in determining the next step in the disposal site management process. Focused studies are periodically undertaken within the DAMOS Program to evaluate inactive or historical disposal sites and contribute to the development of dredged material placement and capping techniques. The resulting information from DAMOS surveys is used to guide the management of disposal activities at existing sites, plan for use of future sites, and evaluate the long term status of historic sites. The 2013 CADS investigation had combined confirmatory and focused elements for a site that was active relatively recently and was being considered for potential reopening.

Two primary goals of DAMOS confirmatory monitoring surveys are to document the physical location and stability of dredged material placed into the aquatic environment and to evaluate the biological recovery of the benthic community following placement of dredged material. Several survey techniques are employed in order to characterize these responses to dredged material placement. Sequential acoustic monitoring surveys (including bathymetric, acoustic backscatter, and side-scan sonar data collection) are performed to characterize the height and spread of discrete dredged material deposits or mounds created at open water sites as well as the accumulation/consolidation of dredged material into confined aquatic disposal (CAD) cells. Sediment-profile imaging (SPI) and plan-view underwater camera photography, referred to as plan-view (PV) imaging, surveys are performed to provide further physical characterization of the material and to support evaluation of seafloor (benthic) habitat conditions and recovery over time. Each type of data collection activity is conducted periodically at disposal sites, and the conditions found after a defined period of disposal activity are compared with the long-term data set at a specific site to determine the next step in the disposal site management process (Germano et al. 1994). Focused DAMOS monitoring surveys may also feature additional types of data collection activities as deemed appropriate to achieve specific survey objectives, such as sub-bottom profiling, towed video, sediment coring, or grab sampling.

1.2 Introduction to the Cape Arundel Disposal Site

CADS is situated near Cape Arundel in southern Maine (Figure 1-1) and received dredged material periodically between 1985 and 2010. CADS is defined as a 457-m (1500-ft) diameter circle on the seafloor with its center located approximately 5.1 km (3.2 mi) south-southeast of Cape Arundel, Maine (Figure 1-2). As an alternative dredged material disposal site selected by the Corps of Engineers (and not a formally designated site by the USEPA), CADS was closed in 2010 when its temporary status ended. The site was still closed at the time of the 2013 survey, but Congressional legislation reopened the site in early 2014

Water depths at CADS vary from 30 m (98 ft) to 42 m (138 ft) with complex topography (Figure 1-3). CADS is generally deeper in the north and south and shallower in the west and southeast portions. Past surveys have found hard rock outcrops in the shallower areas and relatively soft sediment in the deeper basins in CADS (SAIC 1991). An additional area to the east is under consideration for potential expansion of the disposal site boundary (Figure 1-3). A series of disposal activities and monitoring surveys have taken place at CADS and are briefly described below.

1.3 Historical Dredged Material Disposal Activity

CADS was first surveyed by the DAMOS Program in 1985 prior to the placement of significant quantities of dredged material. Over a 35-year period (1985-2010), approximately 864,000 m^3 (1,130,000 yd^3) of dredged material was placed at CADS (Table 1-1). Dredged material was placed primarily in the central portion of the site, as shown by the 1990 disposal buoy location (Figure 1-3). More than one-half of the dredged material volume (53%) was placed during the 1987-1990 timeframe and less than 10% was placed within the last 15 years.

1.4 Previous CADS Monitoring Surveys

Four monitoring surveys were conducted at CADS prior to the 2013 survey, as follows:

- 1985 Single-beam bathymetry and sediment-profile imaging (SAIC 1987)
- 1987 Single-beam bathymetry and sediment-profile imaging (SAIC 1990)
- 1990 Single-beam bathymetry (SAIC 1991)
- 1997 Multi-beam bathymetry and video (unpublished)

These surveys were primarily focused on estimating dredged material accumulation and determining remaining site capacity for receiving additional dredged material.

1.5 2013 Survey Objectives

An acoustic and sediment-profile/plan-view (SPI/PV) imaging survey was conducted at CADS to characterize the seafloor topography and surficial features. Additional CADS survey objectives were to characterize seafloor conditions in an area to the east of CADS for potential consideration if there was a need for future site expansion (Figure 1-3) and to assess areas near the existing site with SPI/PV for potential use as reference areas.

Table 1-1.

Estimated Volume of Dredged Material Placed at CADS, 1985 - 2010

Time Period	Volume (m^3)	Volume (yd^3)	% Cumulative Volume	Source
1985 - 1987	191,000	250,000	22%	SAIC 1991
1987 - 1990	459,000	600,000	75%	SAIC 1991
1990 - 1997	138,000	180,000	91%	NAE
1997 - 2010	76,000	100,000	100%	NAE
Total Volume	**864,000**	**1,130,000**		

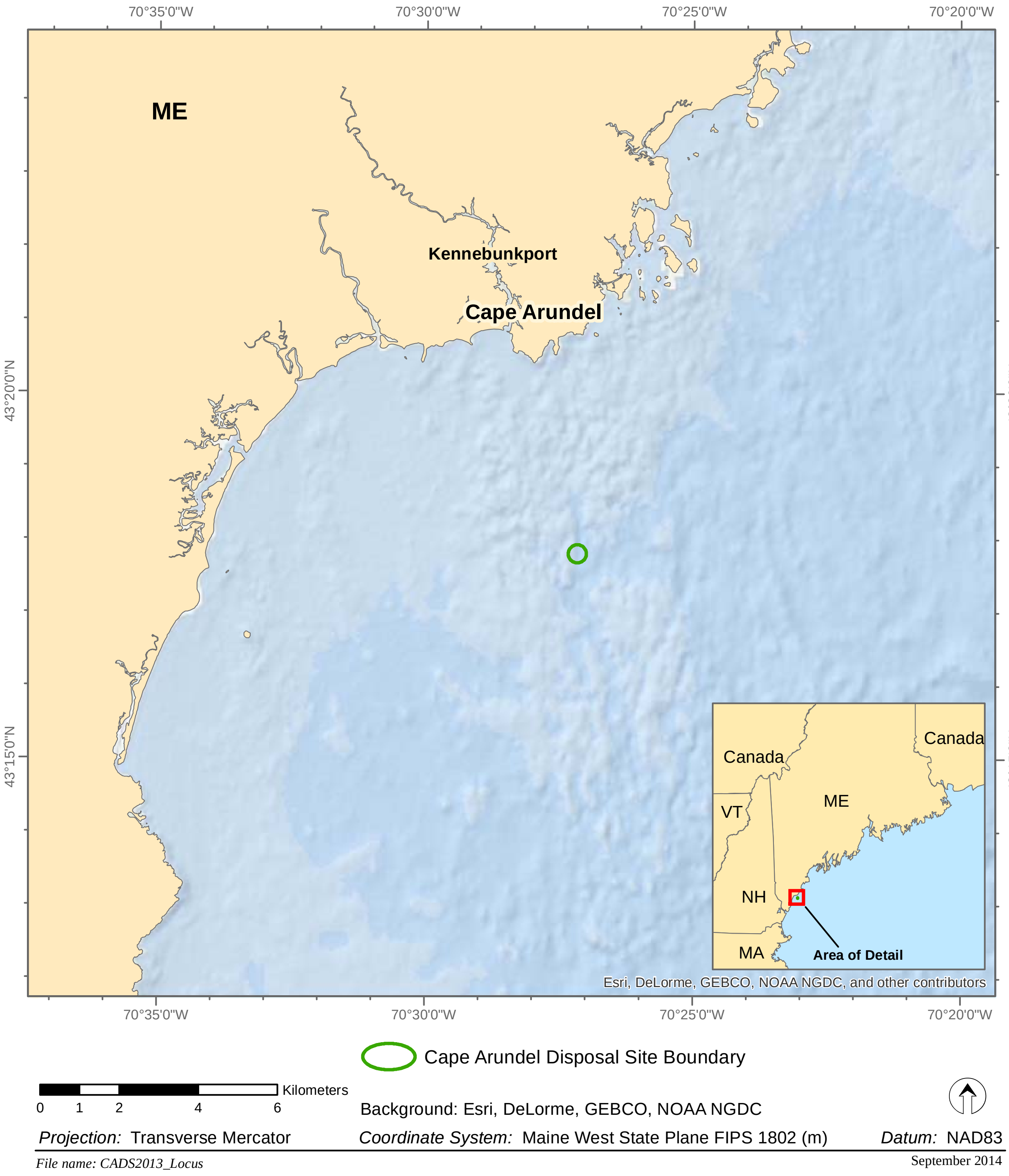


Figure 1-1. Location of Cape Arundel Disposal Site (CADS)

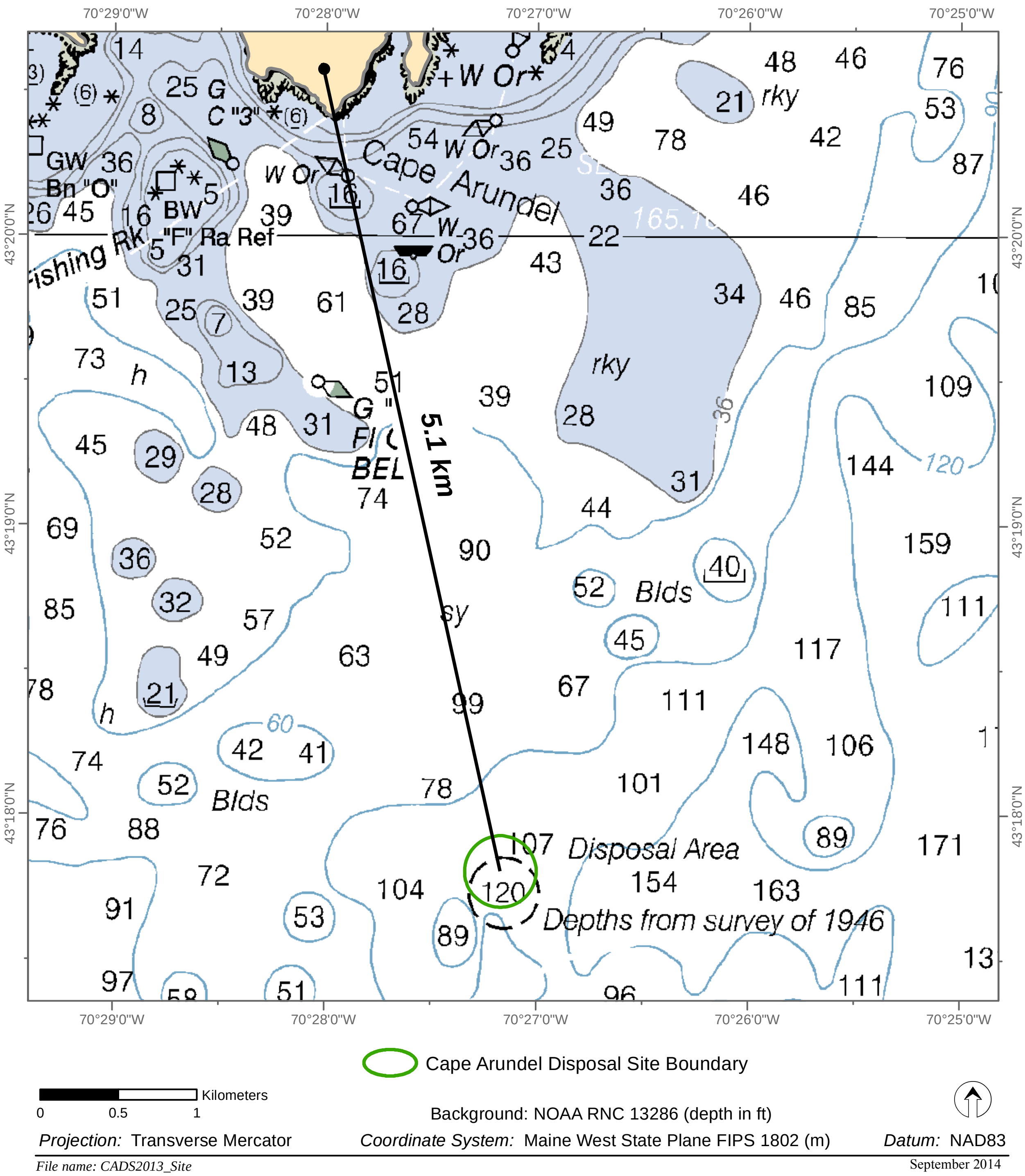


Figure 1-2. CADS with site boundary

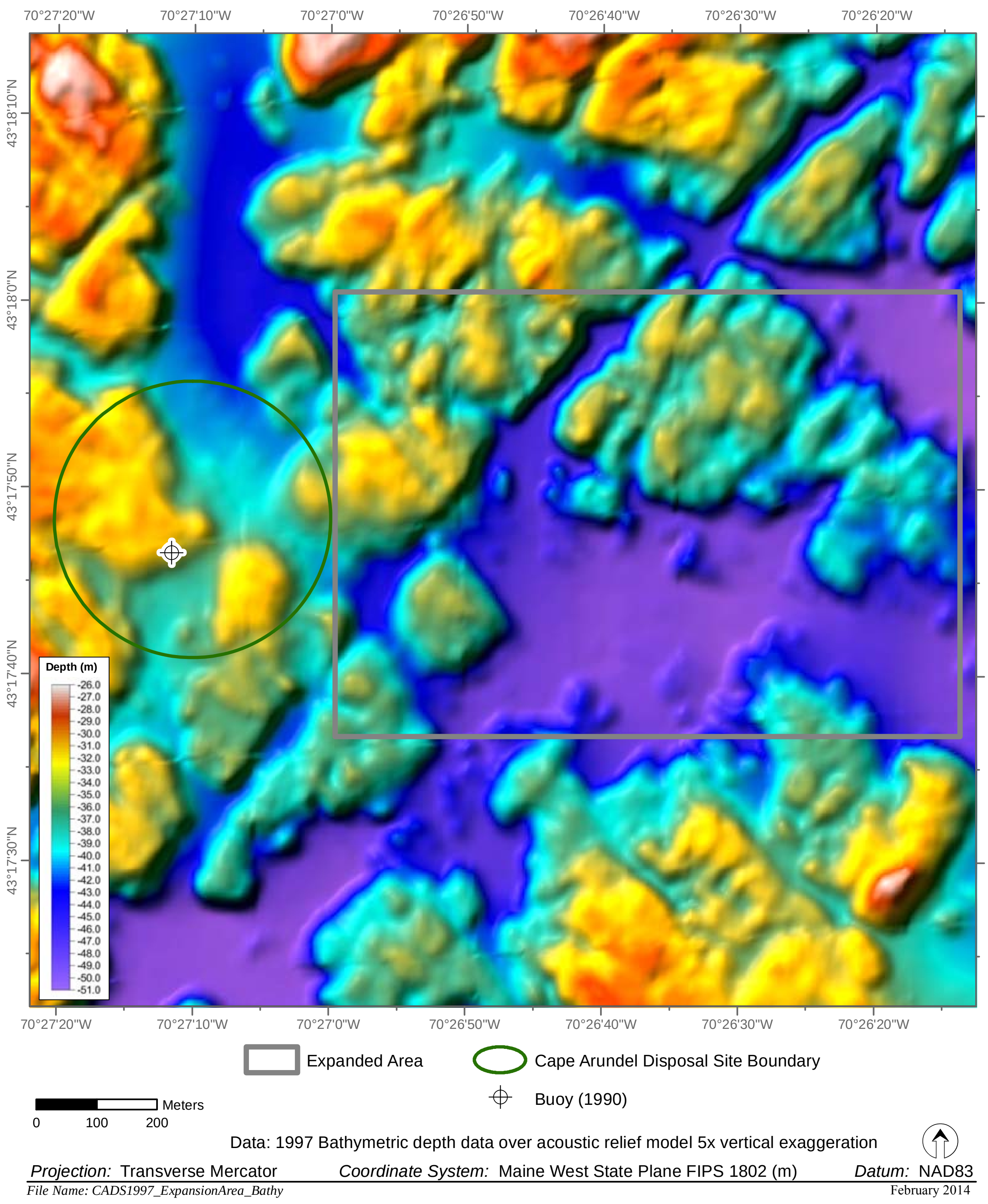


Figure 1-3. Map of CADS and expanded study area to the east

2.0 METHODS

The August 2013 survey at CADS was conducted by a team of investigators from DAMOSVision (CR Environmental and Germano & Associates) aboard the 55-foot R/V *Jamie Hanna*. The acoustic survey was conducted on 17 August 2013 and the SPI/PV survey was conducted on 23 August 2013. An overview of the methods used to collect, process, and analyze the survey data is provided below. Detailed Standard Operating Procedures (SOPs) for data collection and processing are available in Carey et al. (2013).

2.1 Navigation and On-Board Data Acquisition

Navigation for the survey was accomplished using a Hemisphere VS-110 12-channel Differential Global Positioning System (DGPS) and Digital Compass system capable of receiving satellite-based differential corrections (SBAS) and U.S. Coast Guard (USCG) Beacon corrections. Trimble DGPS systems were available as necessary as backups. Both systems are capable of sub-meter horizontal position accuracy. The DGPS system was interfaced to a laptop computer running HYPACK MAX® hydrographic survey software. HYPACK MAX® continually recorded vessel position and DGPS satellite quality and provided a steering display for the vessel captain to accurately maintain the position of the vessel along pre-established survey transects and targets.

Vessel heading measurements were provided by a dual-antenna Hemisphere VS-110 Crescent Digital compass accurate to within 0.05° up to 20 times per second. The pulse-per-second (PPS) signals from the DGPS system were hardware interfaced to HYPACK using a translation circuit and provided microsecond level accuracy of data stream time-tagging from each sensor.

2.2 Acoustic Survey

The acoustic survey included bathymetric, backscatter, and side-scan sonar data collection and processing. The bathymetric data provided measurements of water depth that, when processed, were used to map the seafloor topography. The processed data were also compared with previous surveys to track changes in the size and location of seafloor features. This technique is the primary tool in the DAMOS Program for mapping the distribution of dredged material at disposal sites. Backscatter and side-scan sonar data provided images that supported characterization of surficial topography, sediment texture, and roughness. Each of these acoustic data types is useful for assessing dredged material placement and surficial sediment features.

2.2.1 Acoustic Survey Planning

The acoustic survey featured a relatively high spatial resolution survey of CADS and a lower spatial resolution reconnaissance survey of the expanded area to the east. DAMOSVision hydrographers coordinated with USACE NAE scientists and reviewed alternative survey areas. For CADS, a 600 × 600 m area was selected with a series of survey lines spaced 45 m apart and cross-tie lines spaced 200 m apart (Figure 2-1). For reconnaissance of the expanded area, a series of survey lines spaced 100 m apart were extended from the CADS survey area eastward for a distance of 1000 m creating a 600 × 1000 m reconnaissance survey area. Hydrographers obtained site coordinates, imported them to ArcGIS software, and created maps. The proposed survey area encompassing the entire site was then reviewed and approved by NAE scientists.

2.2.2 Acoustic Data Collection

The 2013 multibeam bathymetric survey of CADS was conducted on 17 August 2013. Data layers generated by the survey included bathymetric, acoustic backscatter, and side-scan sonar and were collected using a Reson 8101 Multibeam Echo Sounder (MBES). This 240-kHz system formed 101 1.5° beams distributed equiangularly across a 150° swath. The MBES transducer was mounted amidships to the port rail of the survey vessel using a high strength adjustable boom, and offsets between the primary DGPS antenna and the sonar were precisely measured and entered into HYPACK. The transducer depth below the water surface (draft) was checked and recorded at the beginning and end of data acquisition, and confirmed using the bar-check method.

The MBES topside processor was equipped with components necessary to export depth solutions, backscatter, and side-scan sonar signals to the HYPACK MAX® acquisition computer via Ethernet communications. HYPACK MAX® also received and recorded navigation data from the DGPS, motion data from a serially interfaced TSS DMS 3-05 motion reference unit (MRU), and heading data from the Hemisphere compass system. Several patch tests were conducted during the surveys to allow computation of angular offsets between the MBES system components. The system was calibrated for local water mass speed of sound by performing conductivity-temperature-depth (CTD) casts at frequent intervals throughout the survey day with a Seabird SBE-19 Seacat CTD profiler. Additional confirmations of proper calibration, including static draft, were obtained using the "bar check" method, in which a metal plate was lowered beneath the MBES transducer to a known depth (e.g., 5.0 m) below the water surface. "Bar-check" calibrations were accurate to within 0.05 m in tests conducted at the beginning and end of the survey day.

2.2.3 Bathymetric Data Processing

Bathymetric data were processed using HYPACK HYSWEEP® software. Processing components are described below and included

- Adjustment of data for tide fluctuations
- Correction of ray bending associated with refraction in the water column
- Removal of spurious points associated with water column interference or system errors
- Development of a grid surface representing depth solutions
- Statistical estimation of sounding solution uncertainty
- Generation of data visualization products

Tidal adjustments were accomplished using a Tide Zoning Model (TZM) calculated by the National Oceanic and Atmospheric Administration's (NOAA's) Center for Operational Oceanographic Products and Services (CO-OPS) specifically for this survey area. The model applied corrections of -6 minutes and height × 1.01 to the six-minute Mean Lower Low Water (MLLW) data series acquired at NOAA's Fort Point Tide Station (#8423898).

Correction of sounding depth and position (range and azimuth) associated with refraction due to water column stratification was conducted using a series of three sound-velocity profiles acquired by the survey team. Data artifacts associated with refraction remain in the bathymetric surface model at a relatively fine scale (generally less than five to 10 cm) relative to the survey depth.

Data acquired in the disposal site portion of the survey area were filtered to accept only beams falling within an angular limit of 45° to minimize refraction artifacts. Data acquired in the eastern reconnaissance portion of the survey area were retained to an angular limit of 60° to maximize bottom coverage. Spurious sounding solutions were flagged or rejected based on the careful examination of data on a sweep-specific basis.

The 240 kHz Reson 8101 MBES system has a published nadir beam width of 1.5° (across track) and 1.5° along track. Assuming an average depth of 40 m and a maximum beam angle of 45°, the average diameter of the beam footprint was calculated at approximately 1.5 × 2.1 m (3.1 m^2). Data were reduced to a cell (grid) size of 2.0 × 2.0 m, acknowledging the system's fine range resolution while accommodating beam position uncertainty. This data reduction was accomplished by calculating and exporting the average elevation for each cell in accordance with USACE recommendations (USACE 2002).

Within-cell standard deviations (1-sigma) ranged from 0 to 2.81 m (average 0.11). Ninety-five percent of the cell-specific standard deviation values were less than 0.28 m. The average root mean squared uncertainty at the 95th percentile confidence interval (1.96 - sigma) was 0.22 m. Ninety-five percent of these uncertainty values were less than 0.55 m. Uncertainty estimates greater than approximately 0.20 m were constrained to steep ledge slopes and outer beams of reconnaissance transects. It is noteworthy that the most stringent National Ocean Service (NOS) standard for this project depth (Special Order 1A) would call for a 95th percentile confidence interval (95% CI) of 0.45 m at the maximum site depth (49.7 m) and 0.39 m at the average site depth (39.7 m).

Nadir data from the mainstay and cross-tie transects were compared to further refine the uncertainty assessment. Differences between co-located points occupied on perpendicular transects were tabulated and statistically analyzed to assess and report data quality relative to promulgated USACE performance standards (note that USACE standards were developed for a maximum depth of 80 ft). The average difference between 63 co-located points at cross-tie intersections was -0.025 m, indicating that the TZM effectively minimized tide bias. The standard deviation of these comparisons was 0.13 m, indicating high repeatability. The 95th percentile accuracy estimate for cross-tide comparisons was calculated per USACE (2002) as 0.26 m, further demonstrating data compliance with the promulgated USACE performance standard of 0.61 m in depths greater than 40 ft (12.2 m).

Reduced data were exported in ASCII text format with fields for Easting, Northing, and MLLW Elevation (meters). All data were projected to the Maine State Plane (West), NAD83 (metric). A variety of data visualizations were generated using a combination of IVS3D Fledermaus (V.7), ESRI ArcMap (V.10.1), and Golden Software Surfer (V.10). Visualizations and data products included:

- ASCII databases of all processed soundings including MLLW depths and elevations
- Contours of seabed elevation (50-cm, 1.0-m and 2.0-m intervals) in a geospatial data file (SHP) format suitable for plotting using geographic information system (GIS) and computer-aided design (CAD) software
- 3-dimensional surface maps of the seabed created using 5× vertical exaggeration and artificial illumination to highlight fine-scale features not visible on contour layers delivered in grid and tagged image file (TIF) formats, and
- An acoustic relief map of the survey area created using 2× vertical exaggeration, delivered in georeferenced TIF format.

2.2.4 Backscatter Data Processing

Backscatter data provided an estimation of surficial sediment texture based on sediment surface roughness and were extracted from cleaned files. Mosaics of beam time-series (BTS) backscatter data were created using HYPACK®'s implementation of GeoCoder software developed by scientists at the University of New Hampshire's NOAA Center for Coastal and Ocean Mapping (UNH/NOAA CCOM). A seamless mosaic of unfiltered BTS data was developed and exported in grayscale TIF format. BTS data were also exported in ASCII format with fields for Easting, Northing, and backscatter (dB). A Gaussian filter was applied to backscatter data to minimize nadir artifacts and the filtered data were used to develop a grid of backscatter values using a 3-m node interval. The grid of filtered data was delivered in ESRI binary GRD format to facilitate comparison with other data layers.

2.2.5 Side-Scan Sonar Data Processing

The side-scan sonar data were processed using HYPACK®'s implementation of GeoCoder software. A seamless mosaic of unfiltered side-scan sonar data was developed and exported in grayscale TIF format using a resolution of 0.5-m per pixel.

2.2.6 Acoustic Data Analysis

The processed bathymetric grids were converted to rasters, and bathymetric contour lines and acoustic relief models were generated and displayed using GIS. The backscatter mosaics and filtered backscatter grid were combined with acoustic relief models in GIS to facilitate visualization of relationships between acoustic datasets (images and color-coded grids are rendered with sufficient transparency to allow three-dimensional acoustic relief model to be visible underneath).

2.3 Sediment-Profile and Plan-View Imaging Survey

Sediment-profile imaging (SPI) and plan-view (PV) imaging are monitoring techniques used to provide data on the physical characteristics of the seafloor and the status of the benthic biological community.

2.3.1 SPI and PV Survey Planning

For the CADS survey, a total of 30 SPI/PV stations were planned with 8 stations within CADS, 16 stations in the extended area to the east, and 3 stations in each of two reference areas. Survey planning included review of acoustic survey results from 1997 and preliminary August 2013 acoustic results. Based on acoustic data review, recent dredged material appeared to have been placed near the center of the disposal site which is flanked by rocky outcrop areas and areas of soft sediment at deeper depths. A random location generator was used to select 5 stations in the deeper sediments (>40 m; Stations 7-11) and 3 stations on the rocky flanks (<40 m; Stations 12-14) within the site (Figure 2-2).

Two potential reference areas (EREF and NREF) were selected based on a review of 1997 acoustic results, with 3 stations randomly selected within each reference area (Stations 1-3 and 4-5; Figure 2-2). Within the expanded area to the east, 7 stations were placed in the northern half (Stations 15-21) and 9 stations were placed in the southern half (Stations 22-30; Figure 2-2). SPI/PV station locations are provided in Table 2-1 and actual SPI/PV station replicate locations are provided in Appendix B.

2.3.2 Sediment-Profile Imaging

Sediment-profile imaging (SPI) is a monitoring technique used to provide data on the physical characteristics of the seafloor as well as the status of the benthic biological community. The technique involves deploying an underwater camera system to photograph a cross section of the sediment-water interface. In the 2013 survey at CADS, high-resolution SPI images were acquired using a Nikon® D7000 digital single-lens reflex camera mounted inside an Ocean Imaging® Model 3731 pressure housing system. The pressure housing sat atop a wedge-shaped prism with a front faceplate and a back mirror. The mirror was mounted at a 45° angle to reflect the profile of the sediment-water interface. As the prism penetrated the seafloor, a trigger activated a time-delay circuit that fired an internal strobe to obtain a cross-sectional image of the upper 15–20 cm of the sediment column (Figure 2-3).

The camera remained on the seafloor for approximately 20 seconds to ensure that a successful image had been obtained. Details of the camera settings for each digital image are available in the associated parameters file embedded in each electronic image file. For this survey, the ISO-equivalent was set at 640, shutter speed was 1/250, f-stop was f9, and storage was in compressed raw Nikon Electronic Format (NEF) files (approximately 20 MB each). Electronic files were converted to high-resolution JPEG (8-bit) format files (3264 × 4928 pixels) using Nikon Capture® NX2 software (Version 2.2.7).

Test exposures of the Kodak® Color Separation Guide (Publication No. Q-13) were made on deck at the beginning and end of the 2013 survey to verify that all internal electronic systems were working to design specifications and to provide a color standard against which final images could be checked for proper color balance. After deployment of the camera at each station, the frame counter was checked to ensure that the requisite number of replicates had been obtained. In addition, a prism penetration depth indicator on the camera frame was checked to verify that the optical prism had actually penetrated the bottom to a sufficient depth. If images were missed or the penetration depth was insufficient, the camera frame stop collars were adjusted and/or weights were added or removed, and additional replicate images were taken. Changes in prism weight amounts, the presence or absence of mud doors, and frame stop collar positions were recorded for each replicate image.

Each image was assigned a unique time stamp in the digital file attributes by the camera's data logger and cross-checked with the time stamp in the navigational system's computer data file. In addition, the field crew kept redundant written sample logs. Images were downloaded periodically to verify successful sample acquisition and/or to assess what type of sediment/depositional layer was present at a particular station. Digital image files were renamed with the appropriate station names immediately after downloading as a further quality assurance step.

2.3.3 Plan-View Imaging

An Ocean Imaging® Model DSC16000 plan-view underwater camera (PV) system with two Ocean Imaging® Model 400-37 Deep Sea Scaling lasers mounted to the DSC16000 was attached to the sediment-profile camera frame and used to collect plan-view photographs of the seafloor surface; both SPI and PV images were collected during each "drop" of the system. The PV system consisted of a Nikon D-7000 encased in an aluminum housing, a 24 VDC autonomous power pack, a 500 W strobe, and a bounce trigger. A weight was attached to the bounce trigger with a stainless steel cable so that the weight hung below the camera frame; the scaling lasers projected two red dots that are separated by a constant distance (26 cm) regardless of the field-of-view of the PV system, which can be varied by increasing or decreasing the length of the trigger wire. As the camera apparatus was lowered to the seafloor, the weight attached to the bounce trigger contacted the seafloor prior to the camera frame hitting the bottom and triggered the PV camera (Figure 2-3). Details of the camera settings for each digital image are available in the associated parameters file embedded in each electronic image file; for this survey, the ISO-equivalent was set at 400. The additional camera settings used were as follows: shutter speed 1/20, f10, white balance set to flash, color mode set to Adobe RGB, sharpening set to none, noise reduction off, and storage in compressed raw NEF files (approximately 20 MB each). Electronic files were converted to high-resolution JPEG (8-bit) format files (3264 × 4928 pixels) using Nikon Capture® NX2 software.

Prior to field operations, the internal clock in the digital PV system was synchronized with the GPS navigation system and the SPI camera. Each PV image acquired was assigned a time stamp in the digital file and redundant notations in the field and navigation logs. Throughout the survey, PV images were downloaded at the same time as the SPI images after collection and evaluated for successful image acquisition and image clarity.

The ability of the PV system to collect usable images was dependent on the clarity of the water column. Water conditions at CADS allowed us to use a 1.6-m trigger wire, resulting in an area of bottom visualization approximately 2 m × 1.3 m in size.

2.3.4 SPI and PV Data Collection

The SPI/PV survey was conducted at CADS on 23 August 2013 aboard the R/V *Jamie Hanna*. At each station, the vessel was positioned at the target coordinates and the camera was deployed within a defined station tolerance of 10 m. Four replicate SPI and PV images were collected at each of the stations (Appendix B). The three replicates with the best quality images from each station were chosen for analysis (Appendix C).

The DGPS described above was interfaced to HYPACK® software via laptop serial ports to provide a method to locate and record target sampling locations. Throughout the survey, the HYPACK® data acquisition system received DGPS data. The incoming data stream was digitally integrated and stored on the PC's hard drive. Actual SPI/PV sampling locations were recorded as target files using this system.

2.3.5 SPI and PV Data Analysis

Computer-aided analysis of the resulting images provided a set of standard measurements to allow comparisons between different locations and different surveys. The DAMOS Program has successfully used this technique for over 30 years to map the distribution of disposed dredged material and to monitor benthic recolonization at disposal sites.

Following completion of data collection, the digital images were analyzed using Adobe Photoshop® CS 5 Version 12.1. Images were first adjusted in Adobe Photoshop® to expand the available pixels to their maximum light and dark threshold range. Linear and areal measurements were recorded as number of pixels and converted to scientific units using the Kodak® Color Separation Guide for measurement calibration. Detailed results of all SPI and PV image analyses are presented in Appendix C.

2.3.5.1 SPI Data Analysis

Analysis of each SPI image was performed to provide measurement of the following standard set of parameters:

Sediment Type–The sediment grain size major mode and range were estimated visually from the images using a grain size comparator at a similar scale. Results were reported using the phi scale. Conversion to other grain size scales is provided in Appendix D. The presence and thickness of disposed dredged material were also assessed by inspection of the images.

Penetration Depth–The depth to which the camera penetrated into the seafloor was measured to provide an indication of the sediment density or bearing capacity. The penetration depth can range from a minimum of 0 cm (i.e., no penetration on hard substrata) to a maximum of 20 cm (full penetration on very soft substrata).

Surface Boundary Roughness–Surface boundary roughness is a measure of the vertical relief of features at the sediment-water interface in the sediment-profile image. Surface boundary roughness was determined by measuring the vertical distance between the highest and lowest points of the sediment-water interface. The surface boundary roughness (sediment surface relief) measured over the width of sediment-profile images typically ranges from 0 to 4 cm, and may be related to physical structures (e.g., ripples, rip-up structures, mud clasts) or biogenic features (e.g., burrow openings, fecal mounds, foraging depressions). Biogenic roughness typically changes seasonally and is related to the interaction of bottom turbulence and bioturbational activities.

Apparent Redox Potential Discontinuity (aRPD) Depth–The aRPD depth provides a measure of the integrated time history of the balance between near-surface oxygen conditions and biological reworking of sediments. Sediment particles exposed to oxygenated waters oxidize and lighten in color to brown or light gray. As the particles are buried or moved down by biological activity, they are exposed to reduced oxygen concentrations in subsurface pore waters and their oxic coating slowly reduces, changing color to dark gray or black. When biological activity is high, the aRPD depth increases; when it is low or absent, the aRPD depth decreases. The aRPD depth was measured by assessing color and reflectance boundaries within the images.

Infaunal Successional Stage–Infaunal successional stage is a measure of the biological community inhabiting the seafloor. Current theory holds that organism-sediment interactions in fine-grained sediments follow a predictable sequence of development after a major disturbance (such as dredged material disposal), and this sequence has been divided subjectively into three stages (Rhoads and Germano 1982, 1986). Successional stage was assigned by assessing which types of species or organism-related activities were apparent in the images.

Additional components of the SPI analysis included calculation of means and ranges for the parameters listed above and mapping of means of replicate values from each station. Station means were calculated from three replicates from each station and used in statistical analysis.

2.3.5.2 PV Data Analysis

The PV images provided a much larger field-of-view than the SPI images and provided valuable information about the landscape ecology and sediment topography in the area where the pinpoint "optical core" of the sediment profile was taken. Unusual surface sediment layers, textures, or structures detected in any of the sediment-profile images can be interpreted in light of the larger context of surface sediment features; i.e., is a surface layer or topographic feature a regularly occurring feature and typical of the bottom in this general vicinity or just an isolated anomaly? The scale information provided by the underwater lasers allows for accurate density counts (number per square meter) of attached epifaunal colonies, sediment burrow openings, or larger macrofauna or fish which may have been missed in the sediment-profile cross section. Information on sediment transport dynamics and bedform wavelength were also available from PV image analysis. Analysts calculated the image size and field-of-view and noted sediment type; recorded the presence of bedforms, burrows, tubes, tracks, trails, epifauna, mud clasts, and debris; and included descriptive comments (Appendix C).

2.3.6 Statistical Methods

Statistical analysis was used to aid in the assessment of the benthic recolonization status of the recently formed dredged material deposit relative to reference conditions. The two SPI parameters which are most indicative of recolonization status, and which also lend themselves to quantitative analysis, are the depth of the aRPD (an indirect measure of the degree of biological reworking of surface sediments) and the infaunal successional stage. For the statistical analysis, the mean value for aRPD (based on n = 3 replicate images) was utilized, while the maximum value among the three replicates was used as the successional stage rank for each station. The successional stage ranks had possible values between 0 (no fauna present) and 3 (Stage 3); half ranks were also possible for the "in-between" stages (e.g., Stage 1 going to 2 had a value of 1.5).

Traditionally, study objectives have been addressed using point null hypotheses of the form "There is no difference in benthic conditions between the reference area and the dredged material deposit." An approach using bioequivalence or interval testing is considered to be more informative than the point null hypothesis test of "no difference." In reality, there is always some small difference, and the statistical significance of this difference may or may not be ecologically meaningful. Without an associated power analysis, this type of point null hypothesis testing provides an incomplete picture of the results.

In this application of bioequivalence (interval) testing, the null hypothesis presumes the difference is great, i.e., an inequivalence hypothesis (e.g., McBride 1999). This is recognized as a 'proof of safety' approach because rejection of the inequivalence null hypothesis requires sufficient proof that the difference is actually small. The null and alternative hypotheses to be tested were:

$$H0: \; d \leq -\delta \;\text{ or }\; d \geq \delta \text{ (presumes the difference is great)}$$

$$H_A: \; -\delta < d < \delta \text{ (requires proof that the difference is small)}$$

where d is the difference between the reference site and dredged material deposit means.

If the null hypothesis is rejected, it is concluded that the two means are equivalent to one another within ±δ units. The size of δ should be determined from historical data and/or best professional judgment to identify a maximum difference that is within background variability/noise and is therefore not ecologically meaningful. Based on historical DAMOS data, δ values of 1 cm for aRPD and 0.5 for successional stage rank (on the 0–3 scale) have been established.

The test of the interval hypothesis can be broken down into two one-sided tests (TOST) (McBride 1999 after Schuirmann 1987) which are based on the normal distribution, or, more typically, on Student's *t*-distribution when sample sizes are small and variances must be estimated from the data. The statistics used to test the interval hypotheses shown here are based on such statistical foundations as the Central Limit Theorem (CLT) and basic statistical properties of random variables. A simplification of the CLT says that the mean of any random variable is normally distributed. Linear combinations of normal random variables are also normal, so a linear function of means is also normally distributed. When a linear function of means is divided by its standard error the ratio follows a *t*-distribution with degrees of freedom associated with the variance estimate. Hence, the *t*-distribution can be used to construct a confidence interval around any linear function of means.

In the sampling design utilized in the 2013 SPI survey at CADS, there were three distinct areas (two reference areas and the recent disposal area CADS), and the difference equation of interest was the linear contrast between the grand mean of the two reference means minus the mean on CADS dredged material deposit, or

$$[^1/_2\ (\text{Mean}_{\text{EREF}} + \text{Mean}_{\text{NREF}}) - (\text{Mean}_{\text{CADS}})]$$

where $\text{Mean}_{\text{CADS}}$ was the arithmetic mean for the stations within the specified area (each reference area or CADS dredged material deposit).

The two reference areas collectively represented ambient conditions, but if there were mean differences among these two areas then pooling them into a single reference group would increase the variance beyond true background variability. The effect of keeping the two reference areas separate has little effect on the grand reference mean (if n is equal among these areas), but it maintains the variance as a true background variance for each individual population with its respective mean.

The difference equation, $\hat{d}$, for the comparison of interest was:

$$[^1/_2\ (\text{Mean}_{\text{EREF}} + \text{Mean}_{\text{NREF}}) - (\text{Mean}_{\text{CADS}})] \qquad \text{[Eq. 1]}$$

and the standard error of each difference equation was calculated assuming that the variance of a sum is the sum of the variances for independent variables, or:

$$SE(\hat{d}) = \sqrt{\sum_j \left(S_j^2 c_j^2 / n_j\right)} \qquad \text{[Eq.2]}$$

where:

c_j = coefficients for the *j* means in the difference equation, $\hat{d}$ [Eq. 1] (i.e., for equation 1 shown above, the coefficients were 1/2 for each of the two reference areas, and -1 for the dredged material deposit).

S_j^2 = variance for the j^{th} area. If equal variances are assumed, a single pooled residual variance estimate can be substituted for each group, equal to the mean square error from an ANOVA based on all four groups.

n_j = number of replicate observations for the j^{th} area.

The inequivalence null hypothesis was rejected (and equivalence was concluded) if the confidence interval on the difference of means, $\hat{d}$, was fully contained within the interval [–δ, +δ]. Thus the decision rule was to reject H_0 if:

$$D_L = \hat{d} - t_{\alpha,\upsilon} se(\hat{d}) > -\delta \quad \text{and} \quad D_U = \hat{d} + t_{\alpha,\upsilon} se(\hat{d}) < \delta \qquad \text{[Eq. 3]}$$

where:

$\hat{d}$	=	observed difference in means between the reference areas and dredged material deposit
$t_{\alpha,\upsilon}$	=	upper (100-α)th percentile of a Student's *t*-distribution with υ degrees of freedom
$se(\hat{d})$	=	standard error of the difference (Eq. 2)
υ	=	degrees of freedom for the standard error. If a pooled residual variance estimate was used, it was the residual degrees of freedom from an ANOVA on all groups (total number of stations minus the number of groups); if separate variance estimates were used, degrees of freedom were calculated based on the Brown and Forsythe estimation (Zar 1996).

Validity of the normality and equal variance assumptions were tested using Shapiro-Wilk's test for normality on the area residuals (α = 0.05) and Levene's test for equality of variances among the four areas (α = 0.05). If normality was not rejected but equality of variances was, then a parametric t-interval was used for the difference equation and the variance for the difference equation was based on separate variances for each group. If systematic deviations from normality were identified, then a non-parametric bootstrapped interval was used.

Table 2-1.

CADS 2013 Survey Target SPI/PV Station Locations

Target Station Locations			Target Station Locations		
Station	**Latitude (N)**	**Longitude (W)**	**Station**	**Latitude (N)**	**Longitude (W)**
7	43° 17.918'	70° 27.182'	19	43° 17.884'	70° 26.749'
8	43° 17.904'	70° 27.144'	20	43° 17.880'	70° 26.521'
9	43° 17.901'	70° 27.109'	21	43° 17.841'	70° 26.754'
10	43° 17.870'	70° 27.120'	22	43° 17.753'	70° 26.921'
11	43° 17.850'	70° 27.086'	23	43° 17.754'	70° 26.744'
12	43° 17.829'	70° 27.026'	24	43° 17.758'	70° 26.627'
13	43° 17.748'	70° 27.165'	25	43° 17.760'	70° 26.493'
14	43° 17.826'	70° 27.259'	26	43° 17.731'	70° 26.597'
15	43° 17.952'	70° 26.851'	27	43° 17.695'	70° 26.673'
16	43° 17.954'	70° 26.674'	28	43° 17.669'	70° 26.750'
17	43° 17.956'	70° 26.530'	29	43° 17.625'	70° 26.842'
18	43° 17.885'	70° 26.833'	30	43° 17.669'	70° 26.631'

Target Reference Station Locations		
Station	**Latitude (N)**	**Longitude (W)**
NREF-1	43° 18.307'	70° 27.197'
NREF-2	43° 18.311'	70° 27.140'
NREF-3	43° 18.257'	70° 27.165'
EREF-4	43° 18.329'	70° 26.117'
EREF-5	43° 18.297'	70° 26.119'
EREF-6	43° 18.312'	70° 26.155'

Note: Coordinate system NAD83

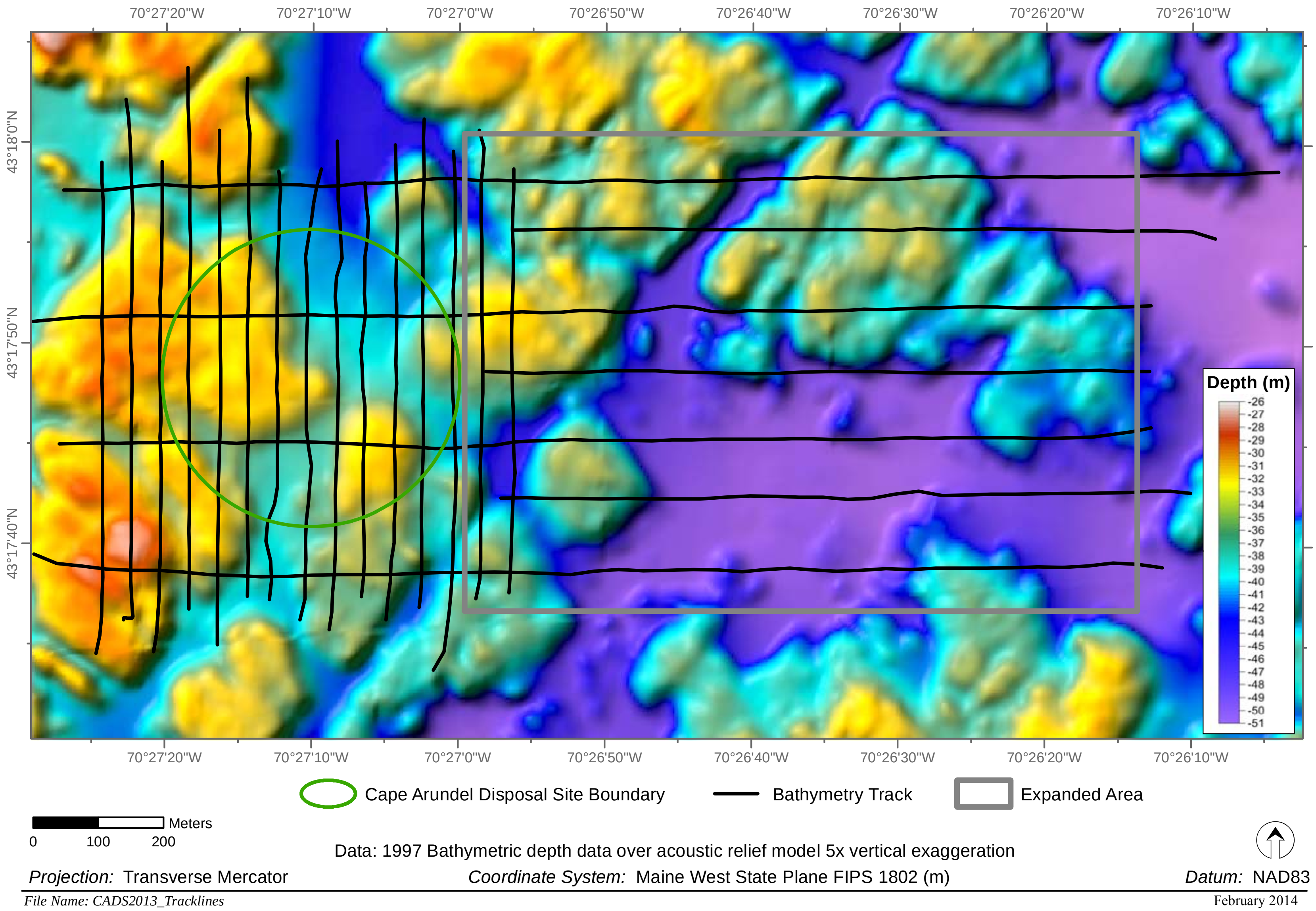


Figure 2-1. Acoustic survey tracklines at CADS and expanded area

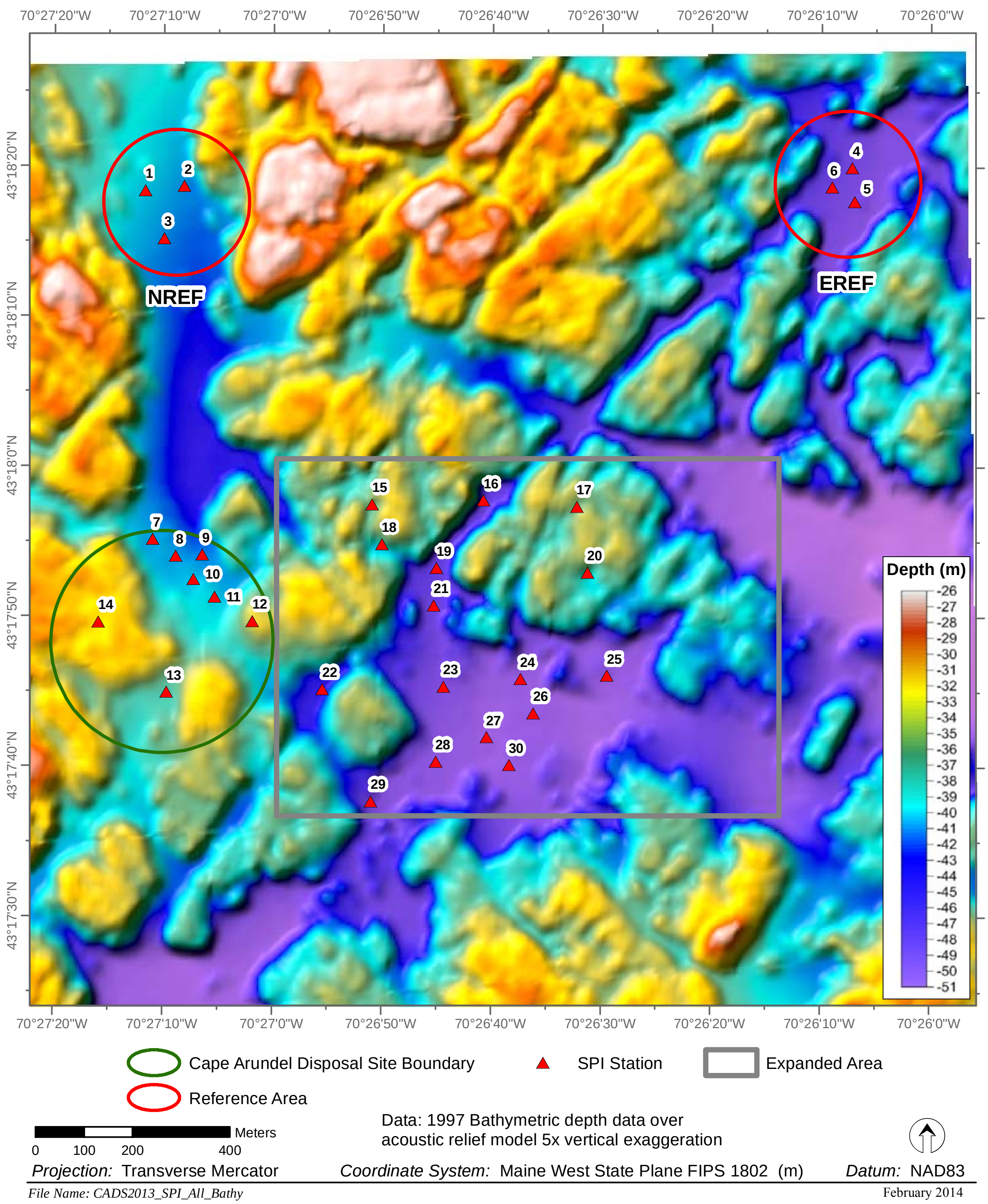


Figure 2-2. CADS, expanded area, and reference areas with target SPI/PV stations indicated

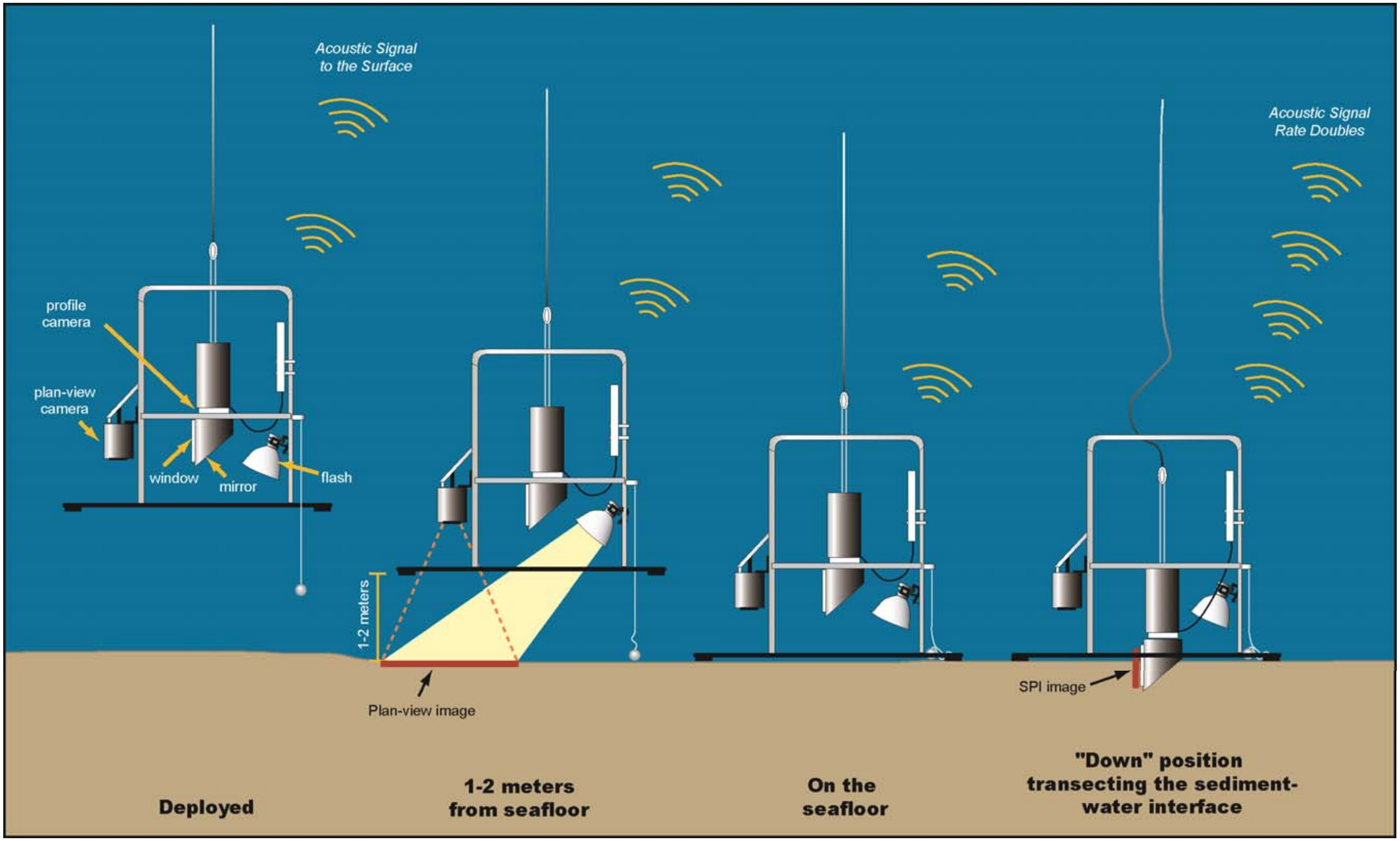


Figure 2-3. Schematic diagram of the SPI/PV camera deployment

3.0 RESULTS

3.1 Acoustic Survey

An acoustic survey was conducted in August 2013 to assess dredged material distribution and surficial sediment characteristics at CADS and an expanded area. Survey results included bathymetric contours, acoustic relief models, backscatter mosaics, side-scan sonar mosaics, and a comparison of 2013 bathymetry to the bathymetry of previous surveys. Each type of acoustic data revealed different information that led to insights regarding the topography and surficial sediment at the site.

3.1.1 Existing Bathymetry

The bathymetry of CADS as surveyed in 2013 revealed variable topography with promontories (30 to 33 m deep) in the northwest and southeast, deeper waters to the north-northeast (39 to 42 m) and south (37 to 39 m) (Figure 3-1). Relatively steep slopes (e.g., 5 m rise over 50 m run) were observed throughout the site. A well-defined dredged material disposal mound was not readily observable in the bathymetric contour map.

An additional area immediately to the east of CADS (referred to as the expanded area) was surveyed in 2013 and revealed similar variable topography in deeper waters (Figure 3-2). In the expanded area, shallower areas were observed to the north (32 to 36 m deep) and a deeper, relatively flat basin (45 to 47 m) was observed to the south. Relatively steeper slopes were observed between the shallower rocky areas and the basins (e.g., 10 m rise over 50 m run).

Multibeam bathymetric data rendered as an acoustic relief model (grayscale with hillshading) provided a more detailed representation of the surface of CADS (Figure 3-3) and the expanded area (Figure 3-4). In general, results for topographic patterns and acoustic backscatter appeared similar in the disposal site and expanded area. The conditions of the rocky outcrops were similar within CADS and in the expanded area. Soft sediment was observed in the deeper and flatter basins of CADS and of the expanded area.

Clear acoustic evidence of dredged material placement activity was detectable at many locations throughout the site and the expanded area, including in deeper soft sediments and in rocky areas. Within the site, many impact craters, small-scale mounds, and other features were revealed that are indicative of dredged material placement (Figure 3-4). Evidence of dredged material placement was also observed immediately outside the site boundary (e.g., to the north) and throughout the expanded area. Specifically, several relatively large features were revealed in the southern flat region within the expanded area.

3.1.2 Acoustic Backscatter and Side-Scan Sonar

Acoustic backscatter data provided an estimate of surficial sediment texture (hard, soft, rough, and smooth). A mosaic of unfiltered backscatter data for CADS and the expanded area (Figure 3-5) generally revealed the shallower areas as harder surfaces having a stronger acoustic return (lighter gray in Figure 3-5) and deeper areas as soft sediment having a weaker acoustic return (darker gray). A similar general pattern of harder surfaces (e.g., rock) in the rocky outcrop areas and softer sediment surfaces in the basins were also observed in the expanded area.

Dredged material placement activities were clearly detectable in the patterns of backscatter within portions of the disposal site and expanded area. Within CADS, the backscatter image revealed circular patterns of increased backscatter appearing as small white dots on the relatively flat seafloor of the disposal site (particularly in the north and southwest basins). In the expanded area, larger circular areas of increased backscatter were revealed in the southern basin. In each of these basins, areas of increased backscatter (lighter gray indicative of harder material or rougher surface texture) stand out against the background of soft sediment (dark gray). Filtered backscatter and side-scan sonar mosaics showed similar patterns of hard surfaces and soft sediment throughout CADS and the expanded area (Appendix E).

3.1.3 Comparison with Previous Bathymetry

Multi-beam bathymetric data for the 1997 survey was used to generate a contour map (Figure 1-3) to which the 2013 bathymetric data (Figure 3-2) was compared by subtracting bottom depths in the 1997 survey from those of the 2013 survey. The resulting depth difference map (Figure 3-6) revealed that dredged material appeared to have accumulated primarily in the deeper, soft-bottom area surrounding the rocky outcrops at the center of the site. Dredged material also appeared to have accumulated on rocky shallower areas (e.g., in the southeast and southwest quadrants of the site). However, some caution should be used to interpret these apparent accumulations as the steepest slopes (e.g., southeast of the site boundary) typically have unavoidable errors due to slight position offsets between surveys. The slope exaggerates the apparent difference, while flat areas are less prone to this type of error. The placement activity had not created a typical mound detectable on the flat seafloor, but there was clear evidence of 0.5 to 1.5 m of accumulated dredged material spread over flat features near the center of the disposal site. Large increased amounts of accumulation were not to be expected because by 1997 (when the previous survey was performed) an estimated 90% (788,000 m^3) of the total amount of dredged material placed at CADS was already in place (Table 1-1).

These observations were consistent with previous CADS monitoring surveys that found similar flat features near the center of the site (SAIC 1990, SAIC 1991). A 1987 survey, conducted after 22% of the total amount of dredged material had been placed, found dredged material accumulation up to one meter thick primarily near the historical buoy location and to the east and north (SAIC 1990). A 1990 survey, conducted after a cumulative total of 75% of material had been placed, found dredged material accumulation of up to 3 meters thick since the 1987 survey, primarily near the center and to the north and east (SAIC 1991). In the 1987 and 1990 surveys, estimation of dredged material accumulation on the seafloor was found to be difficult due to the site's complex topography (e.g., relatively steep and variable slopes) and the relatively larger uncertainty associated with the bathymetric measurement technique during that time period.

The depth difference contour of the expanded area did not reveal large changes in the seafloor since 1997. Several apparent areas of 0.5 m of dredged material accumulation (Figure 3-7, in green) were revealed in the southern basin, but other areas showed similar amounts of loss. Relatively small-scale changes in the seafloor in the expanded area suggested that dredged material was distributed randomly, rather than repeatedly placed at specific locations. The apparent depth difference associated with the relatively steep (1:10) slopes at the edge of rock outcrops (dark blue in Figure 3-7) is attributable to measurement error as described above.

3.2 Sediment-Profile and Plan-View Imaging

The primary purpose of the SPI/PV survey at CADS was to characterize the physical features of the surface sediment throughout the study area and to assess the status of benthic recolonization within the disposal site. A total of 30 SPI/PV stations were occupied with 8 stations within CADS, 16 stations in the expanded area, and 3 stations in each of two reference areas (Figure 3-8). A station summary of some measured parameters can be found in Tables 3-1 and 3-2 with a complete set of results in Appendix C.

3.2.1 Reference Areas

The two areas proposed as reference areas, east reference (EREF) and north reference (NREF), were chosen based on 1997 acoustic data to closely resemble the sediment conditions within the disposal site and to be placed at least 500 m away from the primary area of disposal activity (Figure 3-8). Three stations were occupied in each reference area. Acoustic data were not collected at the reference areas in 2013.

Physical Sediment Characteristics

All 6 stations (summing EREF and NREF stations) were located in relatively deep (>40 m) and flat areas. In EREF, all three stations had a grain size major mode of silt/clay (Figure 3-9). NREF had two stations with a layer of very fine to fine sand over silt/clay and one station with silt/clay.

Camera penetration depths were between 10 and 20 cm indicating relatively soft sediment (Figure 3-10). In EREF, two stations had a penetration depth of over 15 cm and one was 14.7 cm (Appendix C). In NREF all three stations had penetration between 10 and 14.9 cm. All six stations had mean boundary roughness between 0. 9 and 2.0, except one station in NREF (3.25) (Figure 3-11; Appendix C).

Biological Conditions

In EREF, two stations had aRPD over 3 cm and one less than 3 cm (2.6 cm, Figure 3-12 and Appendix C). All three stations in NREF had aRPD less than 3 cm. All reference area stations had successional stage of 3 or 1 on 3 (Figure 3-13). Many of the reference area stations had polychaete tubes and abundance evidence of bioturbation (burrows, feeding voids, fecal pellets; Appendix C). The combination of aRPD, successional stage and visual evidence indicates that the potential reference area stations were in a healthy biological condition.

3.2.2 Disposal Site and Expanded Survey Area

SPI/PV stations in CADS and the expanded area varied by depth and sediment types (Figures 3-14 and 3-15) and were grouped into three categories:

- Rocky areas, including Stations 12, 14, 15, 17;
- Deeper soft sediment, including Stations 8, 23, 24; and
- Deeper hard surface, including Stations 9, 26, and 27.

CADS and the expanded area were divided into these three categories for description and statistical analysis. For the statistical analysis, deeper soft sediment stations in CADS and the expanded area were compared to the reference area stations (shallower and deeper hard stations were excluded as the statistical comparison was not valid given the physical difference in the sites). Dredged material was observed in each of the three types of stations, but was particularly clear in the deeper hard surface stations where soft sediment was expected. Deeper hard surface stations were located a distance from rocky areas and had hard surfaces visible in acoustic data.

Physical Sediment Characteristics

The grain size major mode within CADS was very fine to fine sand (4 to 2 phi) in the deeper stations, except for the indeterminate measurement at Station 9, indicating a hard surface (Figure 3-16). CADS rocky outcrop stations (12 and 14) were indeterminate and very coarse sand/gravel. In the expanded area, grain size major mode varied through a wide range from very coarse sand/gravel to silt/clay with several stations with a layer of very fine to fine sand over silt/clay (Figure 3-16).

Camera penetration varied within CADS from 2.9 to 11.9 cm with zero to 5 cm of penetration at 5 of 8 stations (Figure 3-17). In the expanded area, a wide range was observed with 5 stations at less than 5 cm, 4 stations from 5 to 10, and 7 stations with penetration over 15 cm. Mean boundary roughness at stations within CADS and the expanded area ranged from indeterminate to 3.6 cm (Figure 3-18).

Biological Conditions

Four stations in CADS had aRPD greater than 3 cm, one station had aRPD less than 3 cm, and three stations were indeterminate (Figure 3-19). In the expanded area, five stations had aRPD greater than 3 cm, seven stations had less than 3 cm, and four stations were indeterminate. SPI values were indeterminate at most of the stations located on rock (e.g., Stations 9, 14, 15, and 17), but useful information was derived from the PV images at these stations. All stations in CADS and the expanded area had successional stage classifications of 1 on 3 or 2 on 3 with the exception of Station 14 with one replicate of 1 going to 2 (Figure 3-20). Soft sediment stations within CADS and the expanded area had abundant evidence of bioturbation including visible polychaetes, feeding voids and burrows (Appendix C). Stations on harder bottom were more variable but had abundant evidence of biological activity (encrusting animals, tracks and trails, tubes and burrows in crevices).

Plan-View Imaging Analysis

Within CADS, plan-view images confirmed observations from the acoustic and SPI surveys (Figure 3-21). The acoustic survey identified stations in deeper areas with soft sediment, such as

Stations 7 and 8 (Figure 3-15). The SPI survey found that these stations were soft and had very fine to fine surficial sand (Figures 3-16 and 3-7) and plan-view images confirm smooth sandy and flat surfaces at Stations 7 and 8. Rocky outcrop Station 12 and deeper Station 9 were identified in the acoustic survey as hard (Figure 3-15). The SPI survey at these stations revealed hard, impenetrable material and the plan-view images of Stations 12 and 9 confirmed the presence of rock, cobble, and gravel.

Plan-view images also confirmed acoustic and SPI survey observations in the expanded area (Figure 3-22). In the southern basin, the acoustic and SPI surveys revealed soft sediment at stations such as 23 and 24 and the plan-view images confirmed the presence of a smooth flat sediment surface. The acoustic and SPI/PV survey revealed hard surface areas in the southern basin, at stations such as 26 and 27, and the plan-view survey confirmed that these stations contain rock and cobble surfaces. Similarly, in the northern basin, plan-view images confirmed and enhanced our understanding of the seafloor (Figure 3-23).

3.2.3 Statistical Comparisons

The statistical analysis focused on comparison of the deeper and softer sediment group of CADS stations (Stations 7, 8, 10) to the soft-bottom reference areas (NREF and EREF; Stations 1-6). These stations were included to provide a comparison between similar soft sediment conditions at the reference areas. Stations situated in rocky substrata are difficult to sample with SPI techniques and were excluded from the equivalency analysis.

Mean aRPD depths: A statistical analysis summary of the mean aRPD depths by sampling area are shown in Table 3-1 and Figure 3-23. All data were examined with boxplots that display the station means, ranges, and quartiles of groups. Stations were categorized as soft or rocky with counts indicated in black. The boxplots showed that the soft sediments of the expanded area had a wider range of aRPD conditions compared to the soft sediments of the disposal site and reference areas. CADS soft and rocky station aRPDs were observed to be similar to those of the EREF area.

Rocky area stations were then set aside and the residuals from the remaining three groups (CADS soft, NREF, EREF) were combined to assess normality and compare variances. Results for the normality test indicated that the area residuals (i.e., each observation minus the area mean) were normally distributed (Shapiro-Wilk's test p-value = 0.08). Levene's test for equality of variances was not rejected (p=0.3) so a pooled variance estimate and associated degrees of freedom was used for the bioequivalence test. Results are shown in Table 3-2.

The mean of reference area station means (2.8 cm) was less than the mean of disposal area stations (3.4 cm). This difference of 0.6 cm is not statistically equivalent because the upper and lower 95% confidence bounds are not fully contained within the equivalence interval [-1, +1]. In practical terms, these results mean that the apparent RPD values measured at the soft sediment stations of the disposal site were deeper than those measured at the proposed reference areas (Boxplot Figure 3-24).

The mean aRPD depth in the expanded area was 0.2 cm deeper than the pooled mean of the reference areas (Table 3-1). Although the mean was deeper, the expanded area showed a wide range of aRPD depths; this range extended to include all of the other responses of soft bottom stations (Figure 3-24). NREF tended to have distinctly lower values of aRPD depths than other soft bottom stations and the mean was lower than all other soft bottom means (Figure 3-24 and Table 3-1).

Successional Stage Ranks: All of the stations selected for assessment had Successional Stage 3 conditions so statistical comparisons were not needed (Table 3-1).

Table 3-1.

Summary of Station Means by Sampling Area

		Mean aRPD (cm)		Successional Stage Rank	
Area	**N[1]**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Reference Areas					
EREF	3	3.14	0.52	3	0
NREF	3	2.40	0.53	3	0
Mean		2.77		3	
Disposal Site					
CADS (soft)	3	3.36	0.25	3	0
CADS (rocky)	2	3.29	0.88	3	0
Expanded (soft)	11	2.98	0.94	3	0
Expanded (rocky)	1	1.87	n/a	3	0

[1] The number of stations with determinate aRPD values

Table 3-2.

Summary Statistics and Results of Inequivalence Hypothesis for aRPD Values

Comparison	Observed Difference ($\hat{d}$)	SE($\hat{d}$)	df for SE($\hat{d}$)	95% Lower Confidence Bound	95% Upper Confidence Bound	
Reference (mean of NREF and EREF) vs. CADS (soft)	-0.60	0.318	6	-1.21	0.02	d

d = fail to reject the inequivalence hypothesis: the two group means are significantly different.
s = reject the inequivalence hypothesis: the two group means are significantly similar.

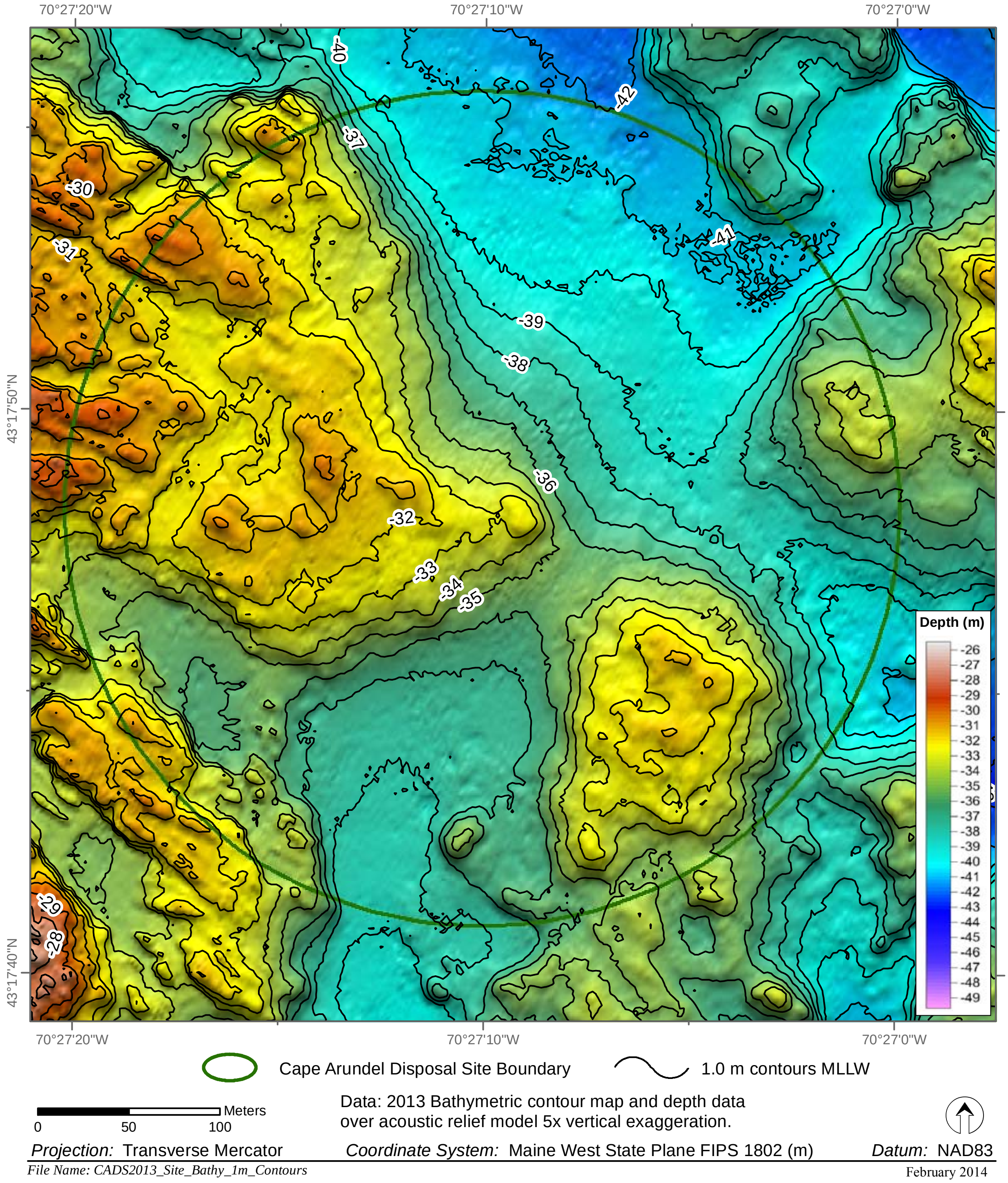


Figure 3-1. Bathymetric contour map of CADS – August 2013

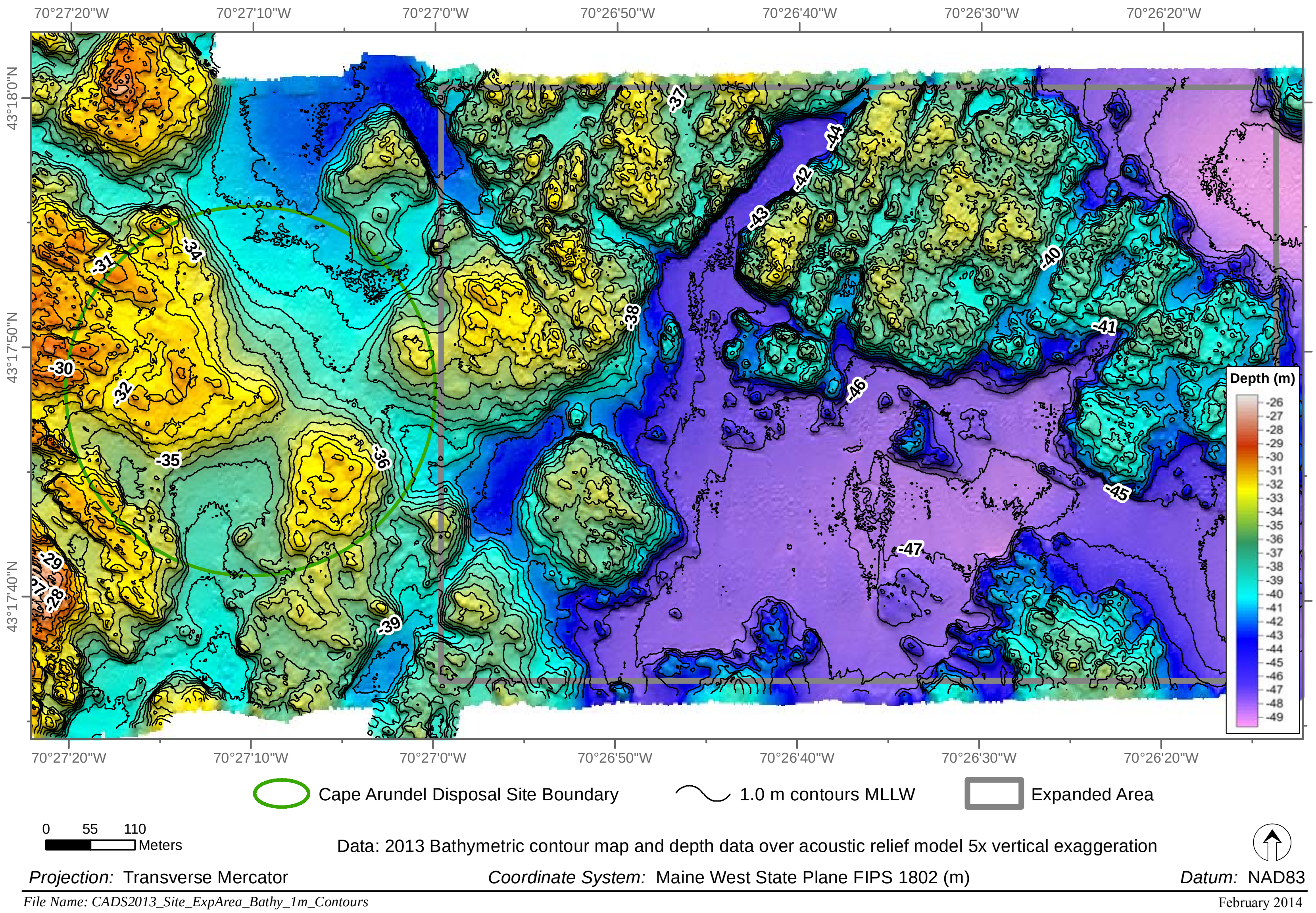


Figure 3-2. Bathymetric contour map of CADS and expanded area – August 2013

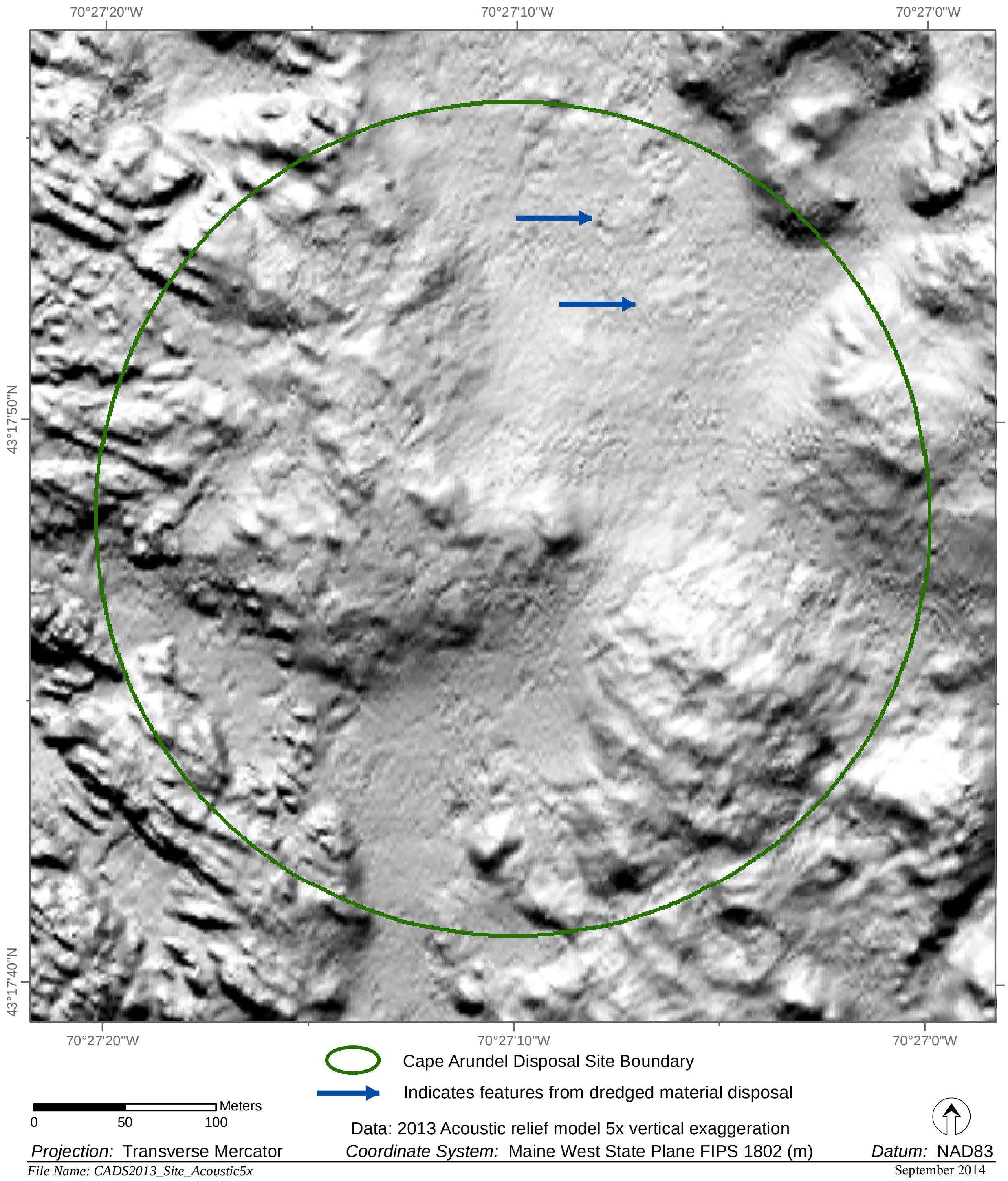


Figure 3-3. Acoustic relief model of CADS – August 2013

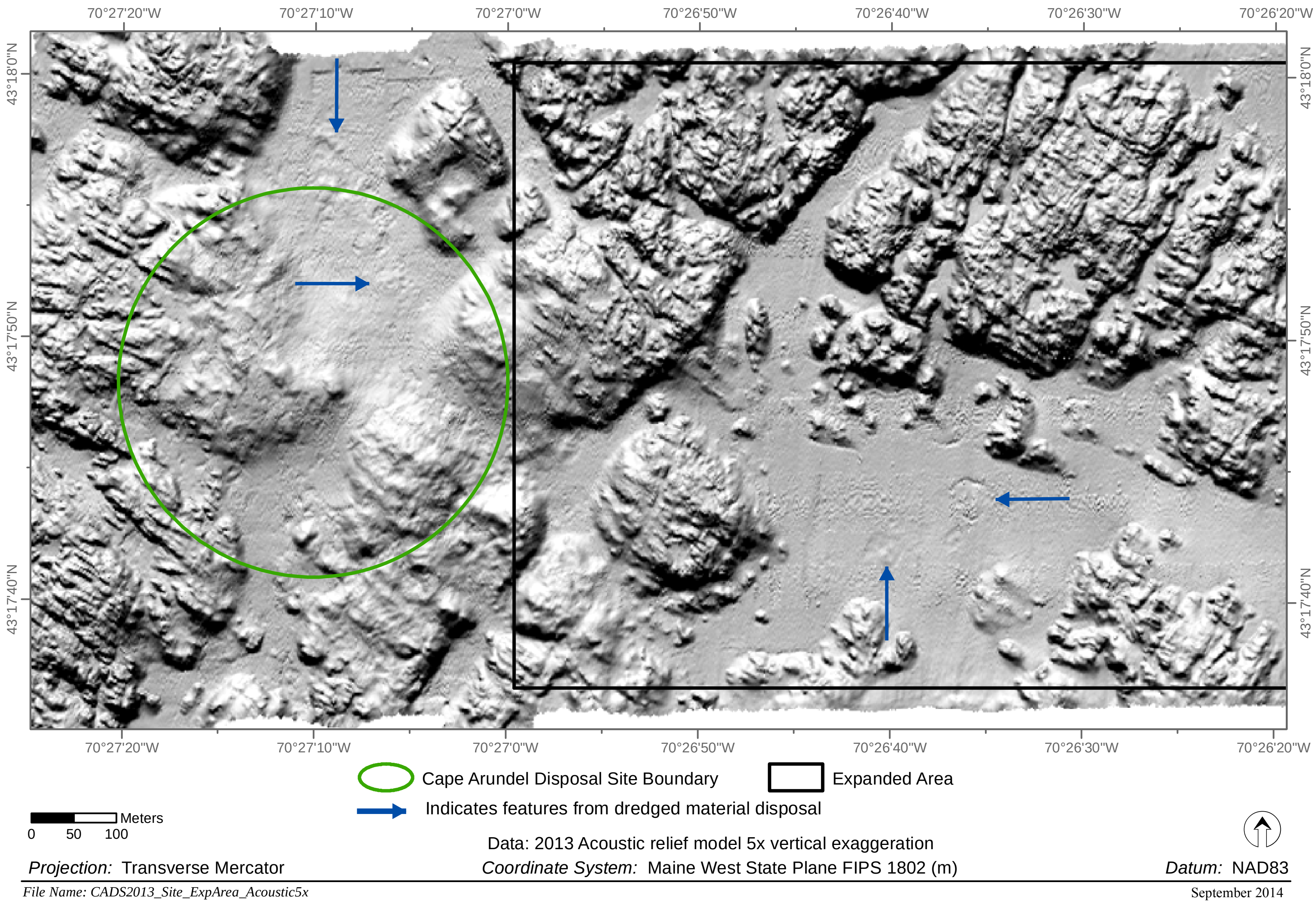


Figure 3-4. Acoustic relief model of CADS and expanded area – August 2013

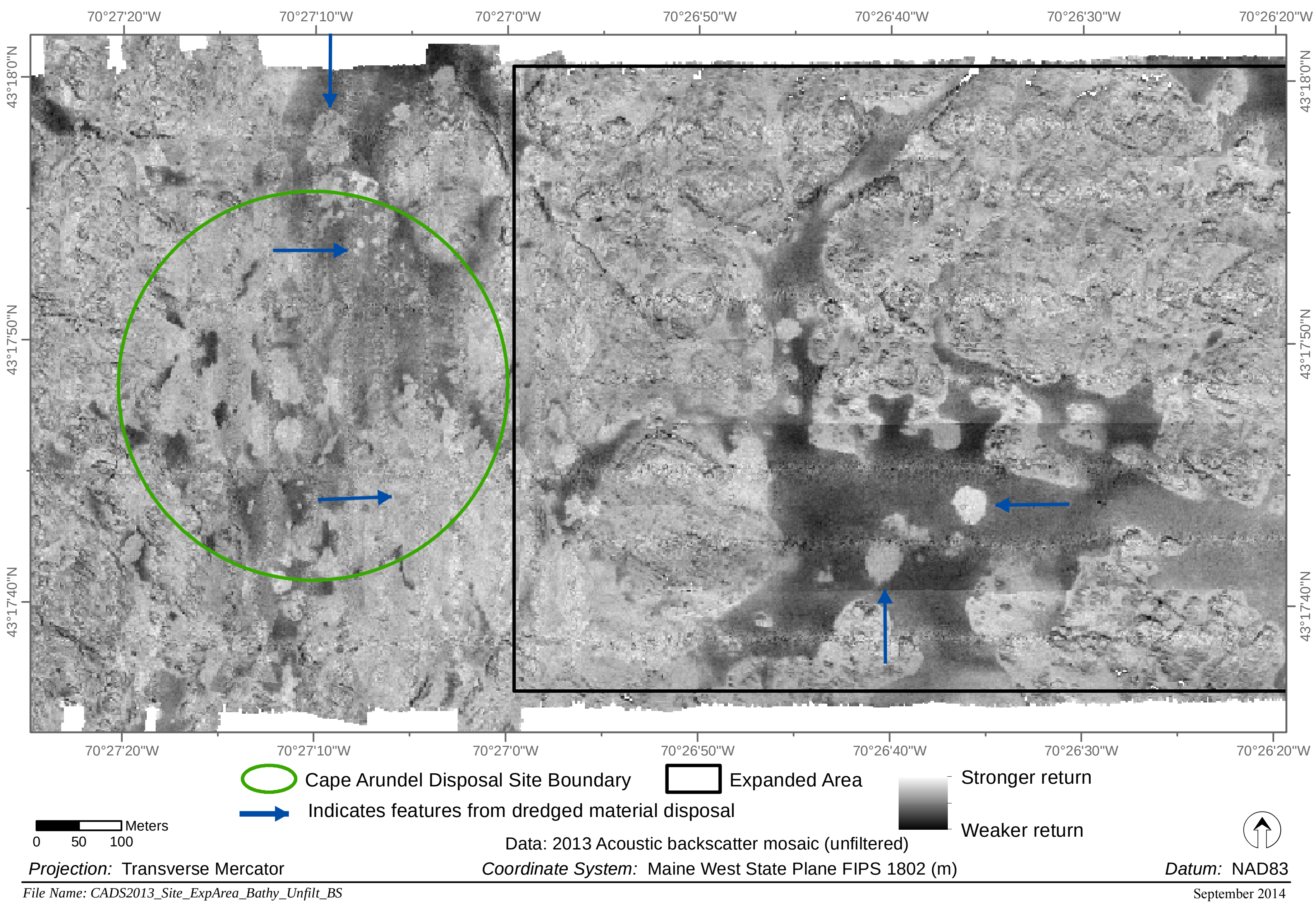
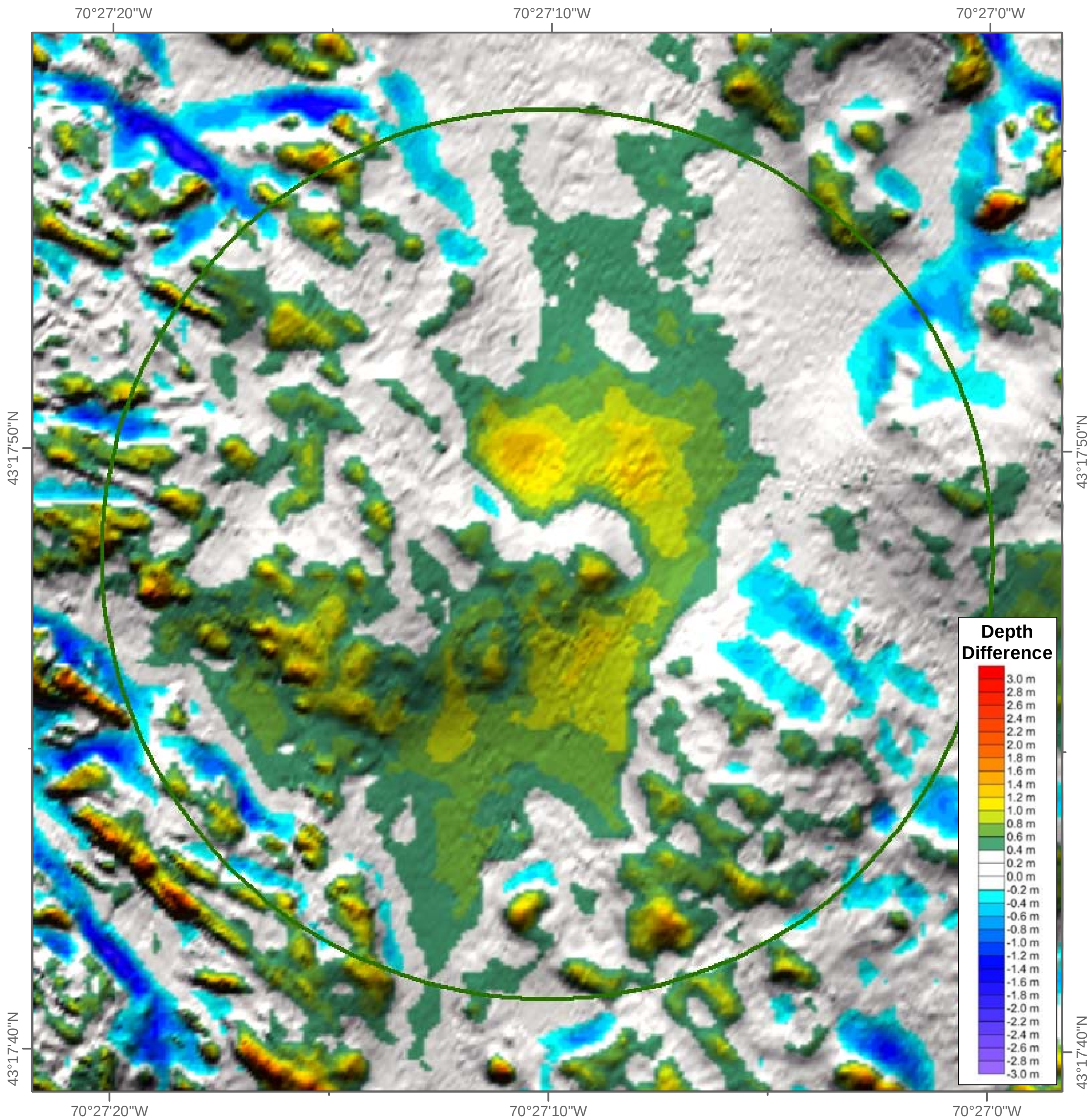


Figure 3-5. Mosaic of unfiltered backscatter data of CADS and expanded area – August 2013



Notes:
1. Data - Depth difference (1997-2013) over 2013 acoustic relief model 5x vertical exaggeration.
2. Positive values (green/red shading) indicate a decrease in depth. Negative values (blue shading) indicate an increase in depth.
3. Differences 0.4 to -0.2 m fall within the estimated combined uncertainty between the 2013 and 1997 surveys and are not depicted.

0 50 100 Meters

Projection: Transverse Mercator *Coordinate System:* Maine West State Plane FIPS 1802 (m) *Datum:* NAD83

File Name: CADS2013_1997_DD_Site February 2014

Figure 3-6. Depth difference map of CADS: 1997 vs. 2013

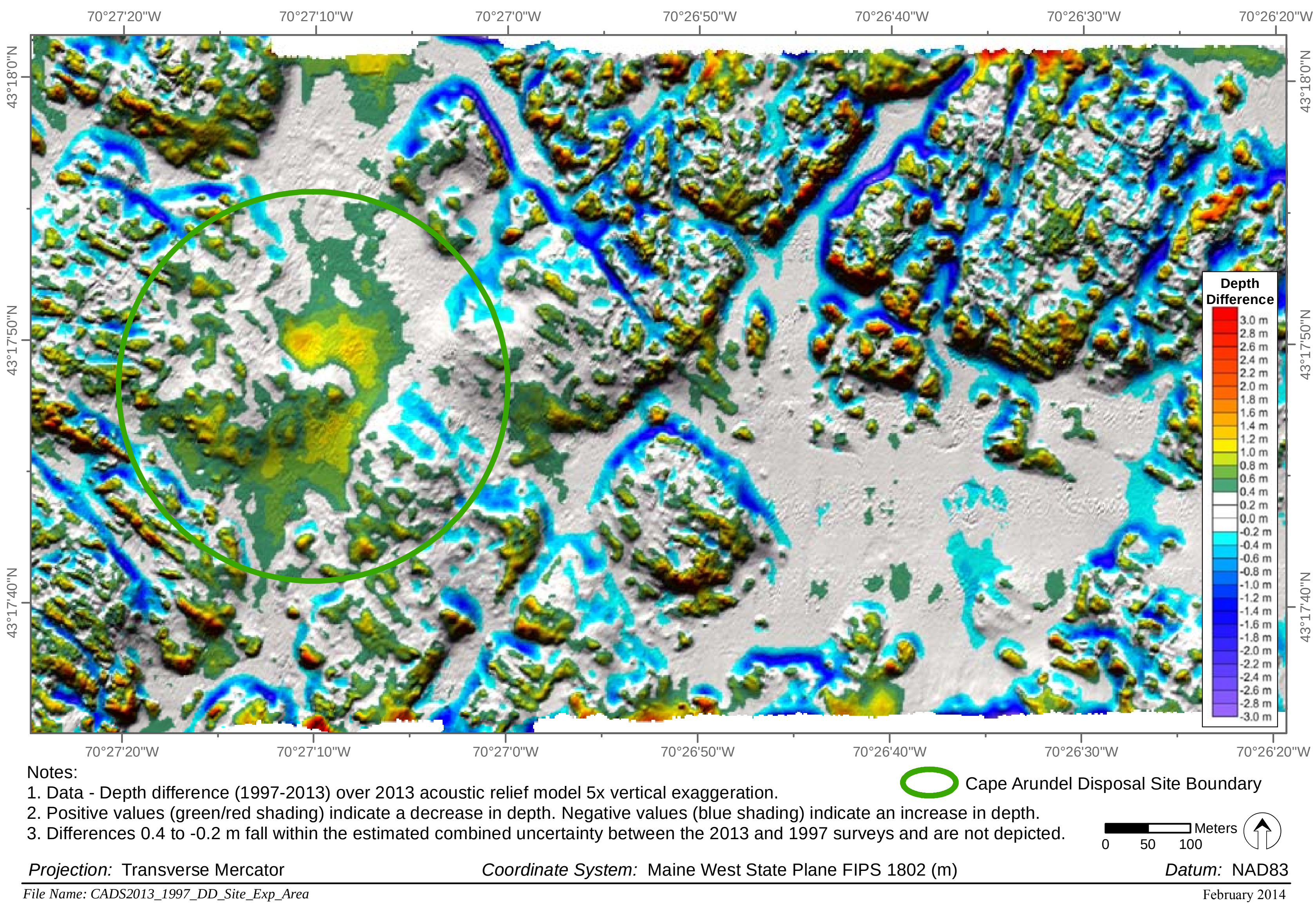


Figure 3-7. Depth difference contour map of CADS and expanded area: 1997 vs. 2013

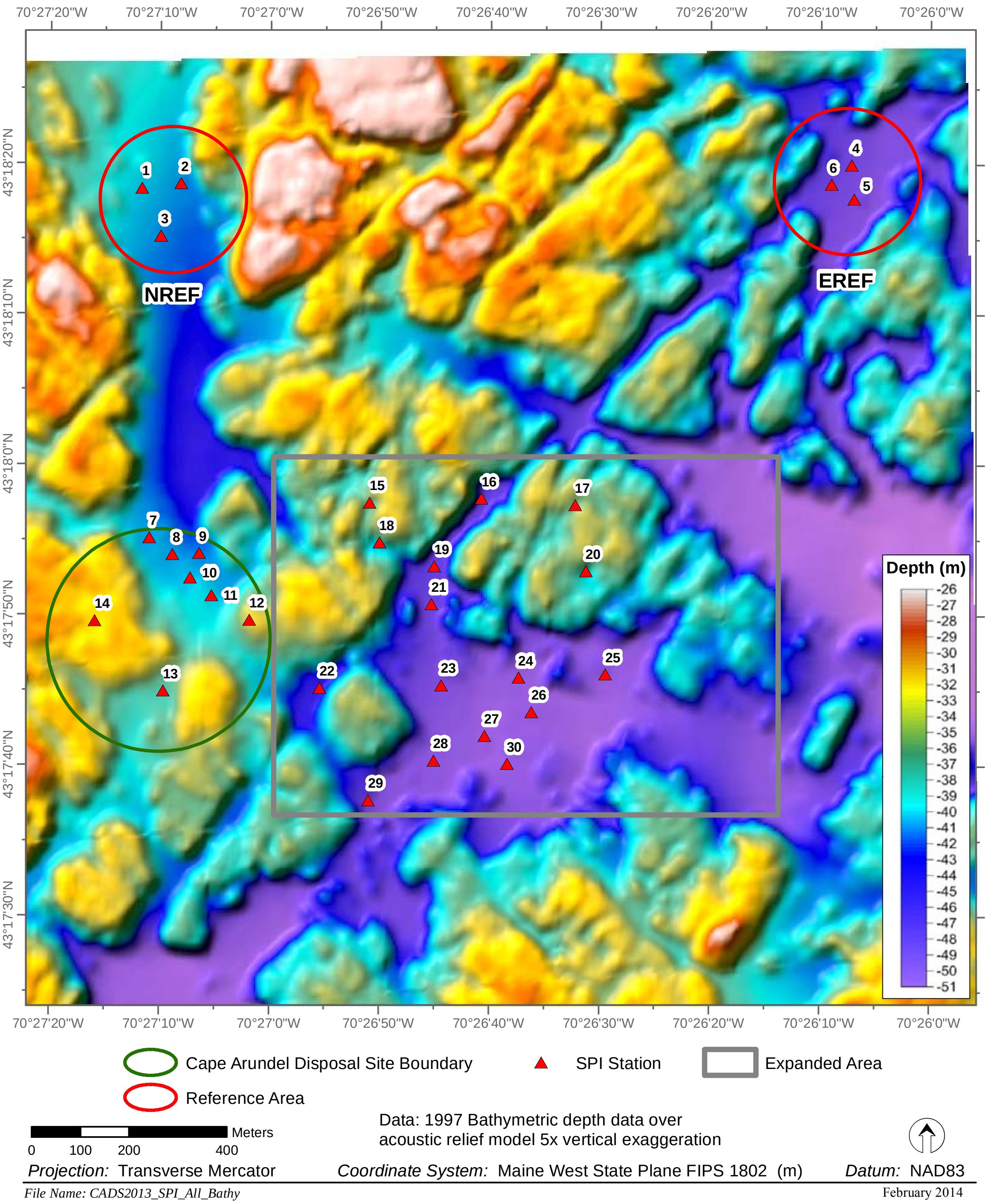


Figure 3-8. CADS, expanded area, and reference areas with target SPI/PV stations indicated

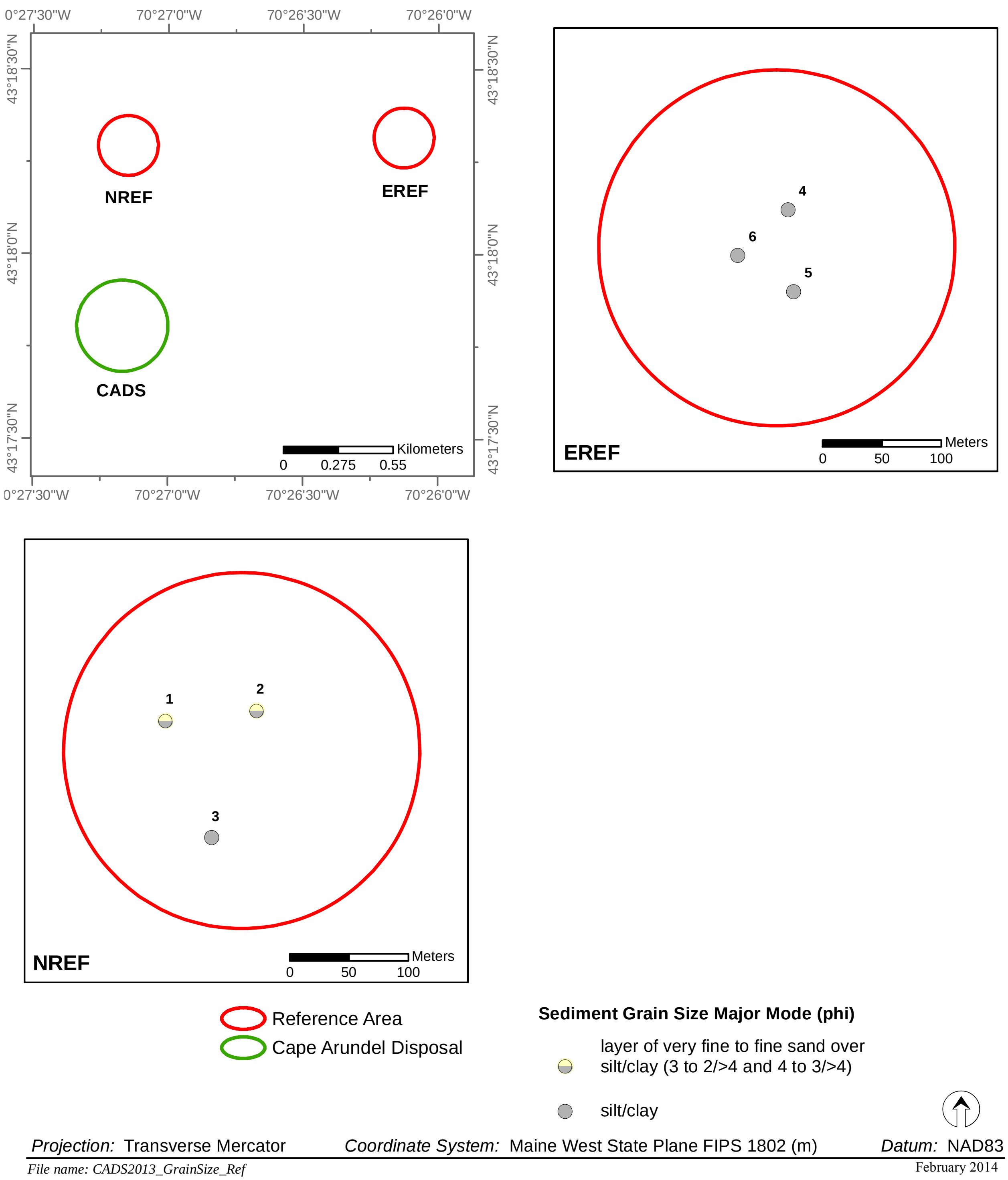


Figure 3-9. Sediment grain size major mode (phi units) at stations within the CADS reference areas

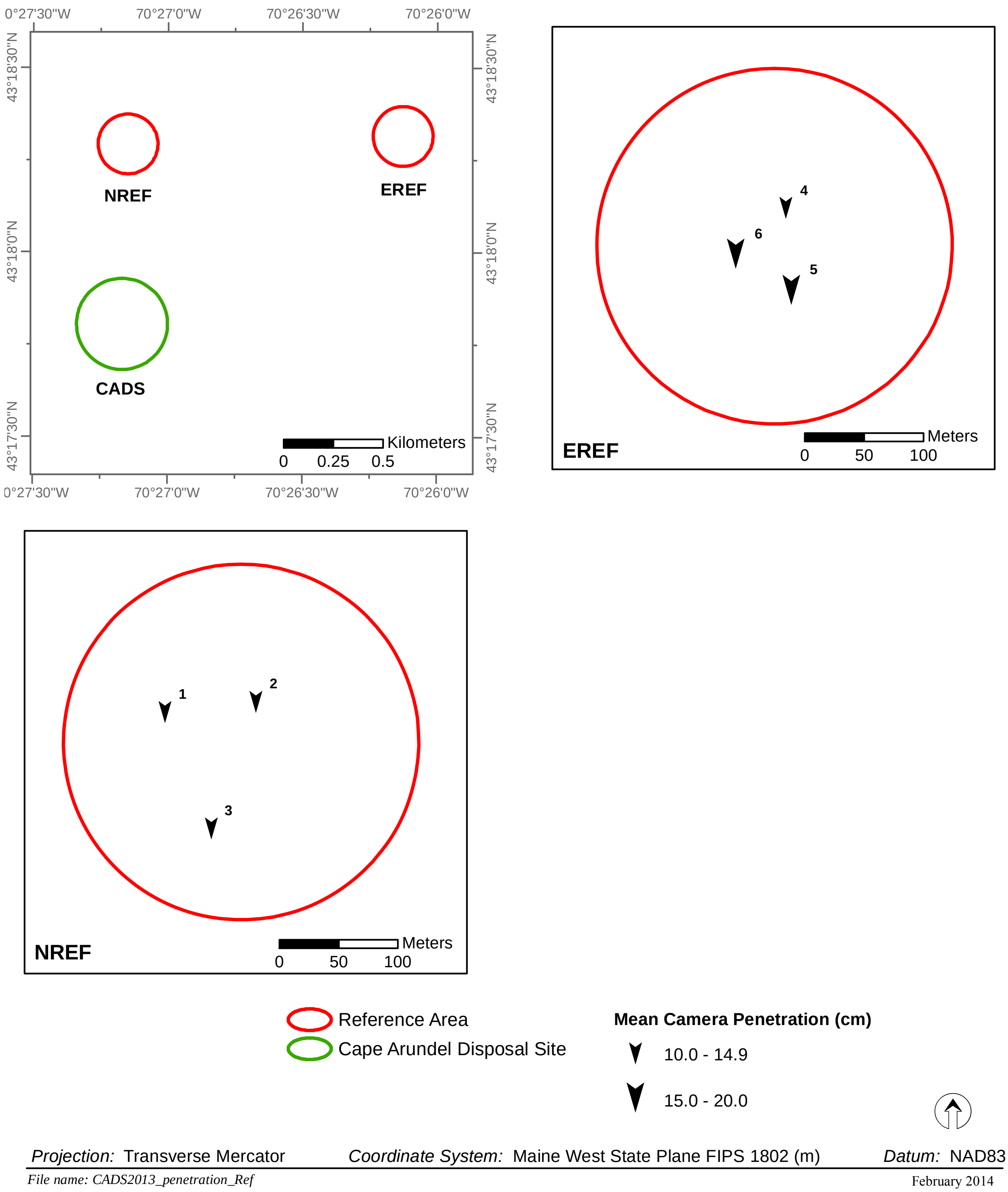


Figure 3-10. Mean station camera prism penetration depths (cm) at stations within the CADS reference areas

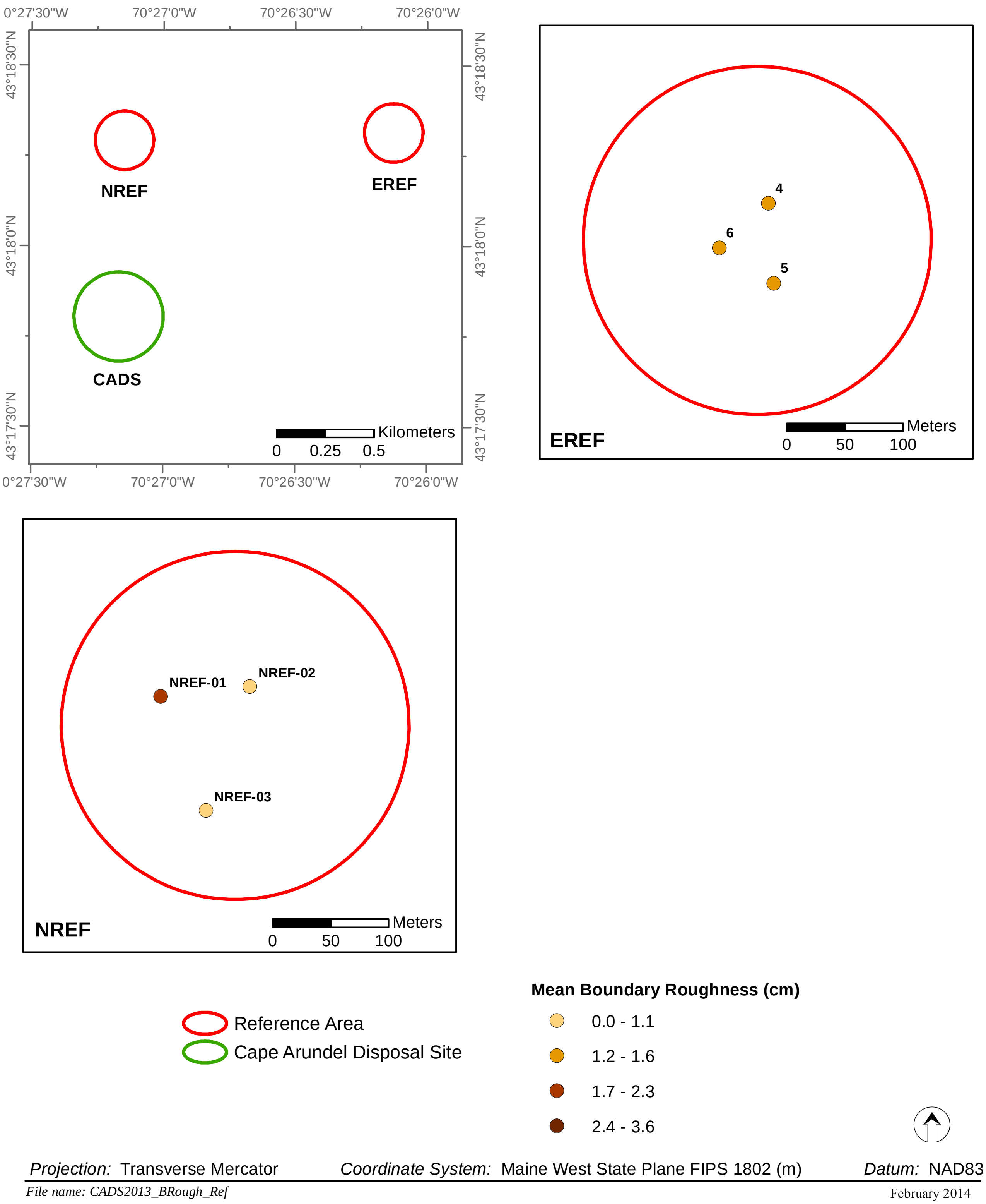


Figure 3-11. Mean station small-scale boundary roughness values (cm) at stations within the CADS reference areas

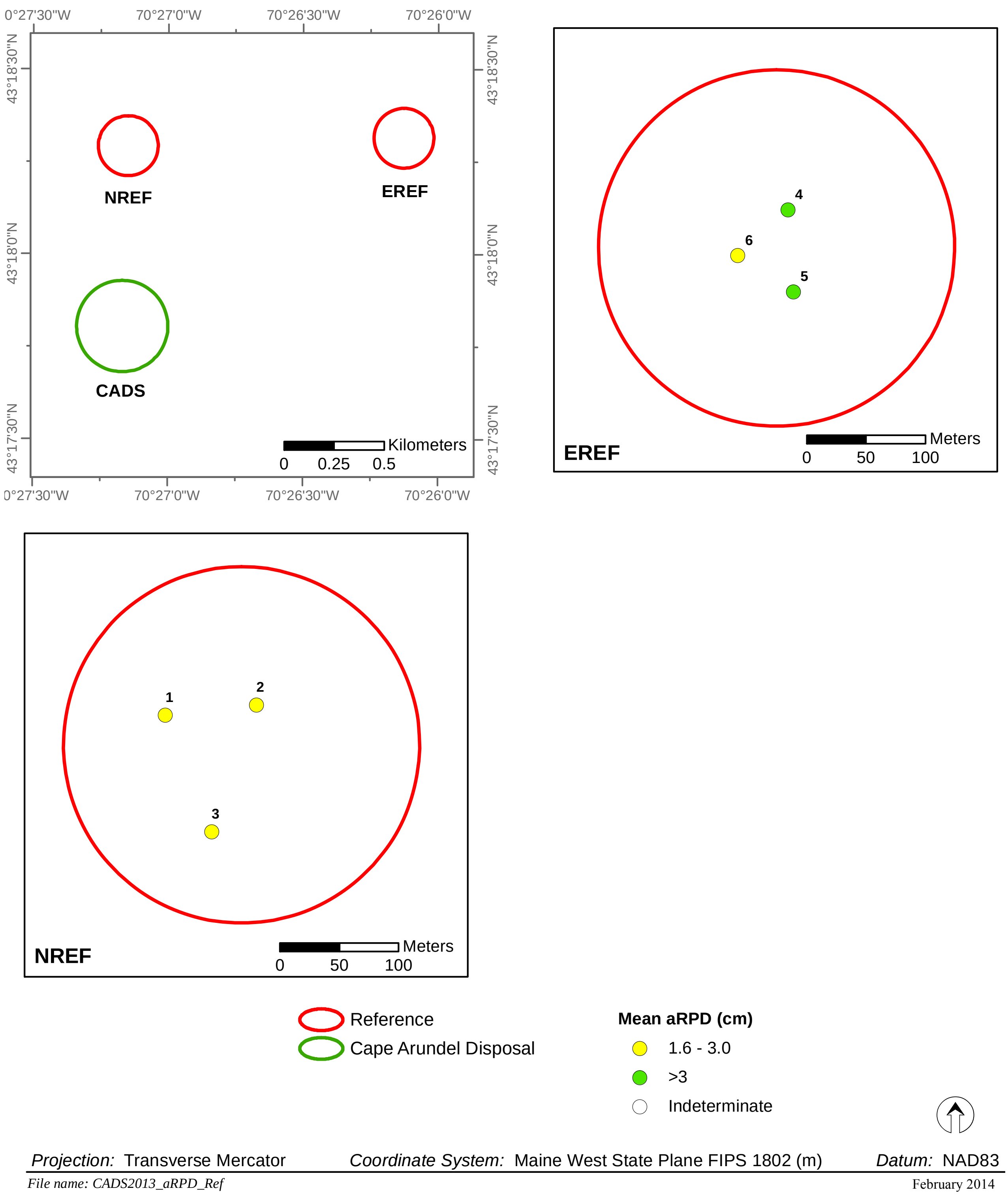


Figure 3-12. Mean station aRPD depth (cm) at stations within the CADS reference areas

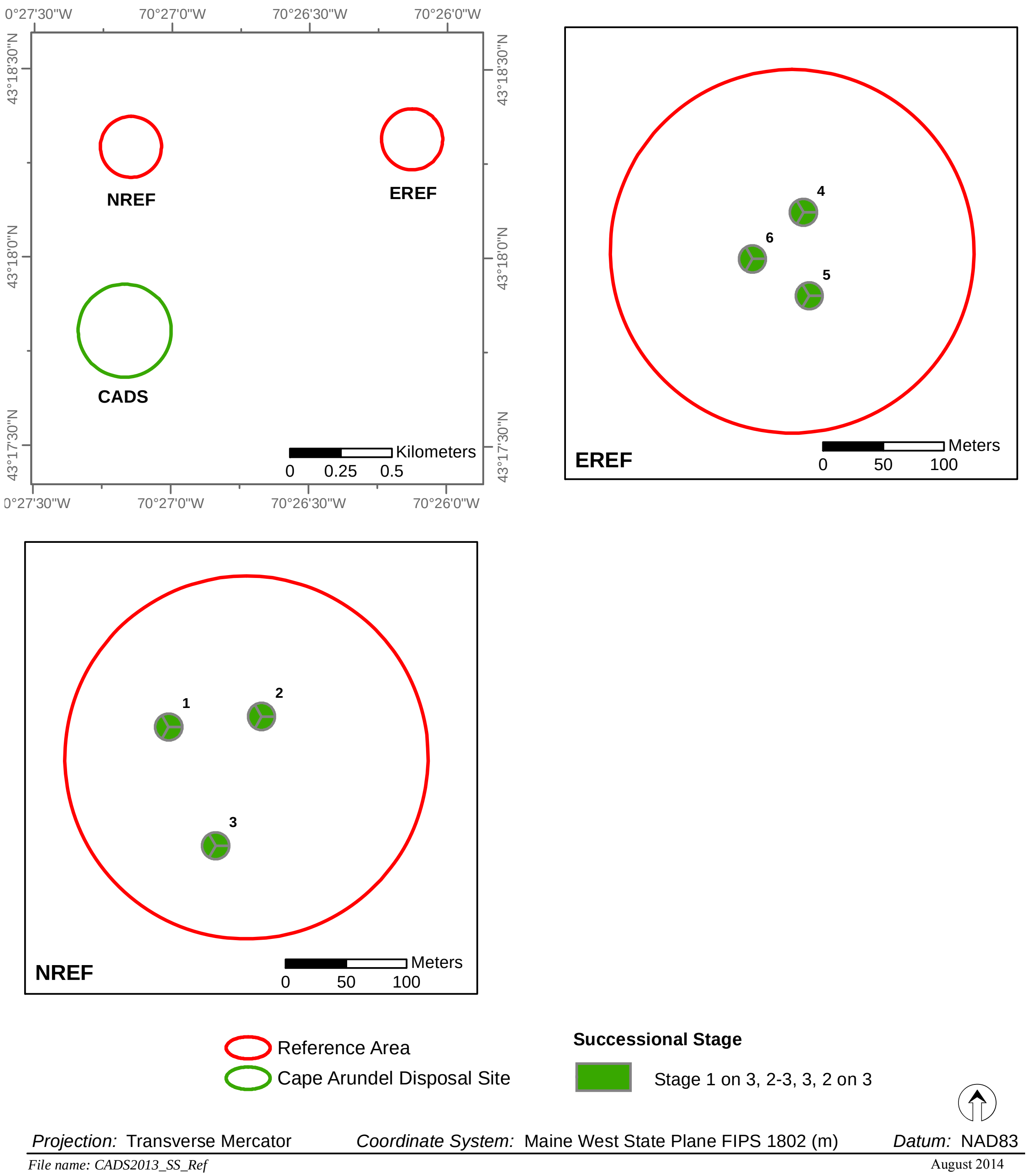


Figure 3-13. Infaunal successional stages found at stations within the CADS reference areas

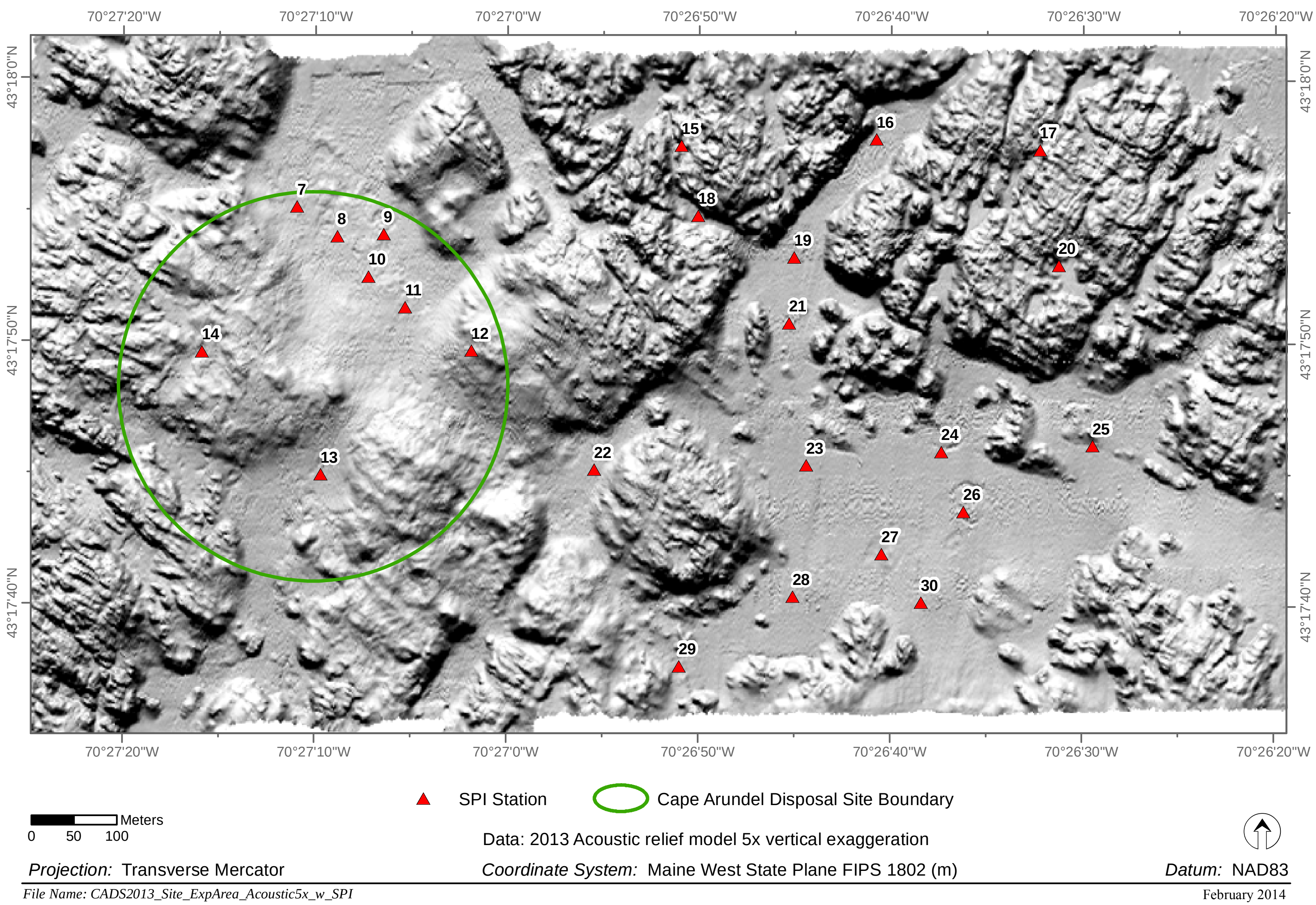


Figure 3-14. Acoustic relief model of CADS and expanded area with SPI/PV stations

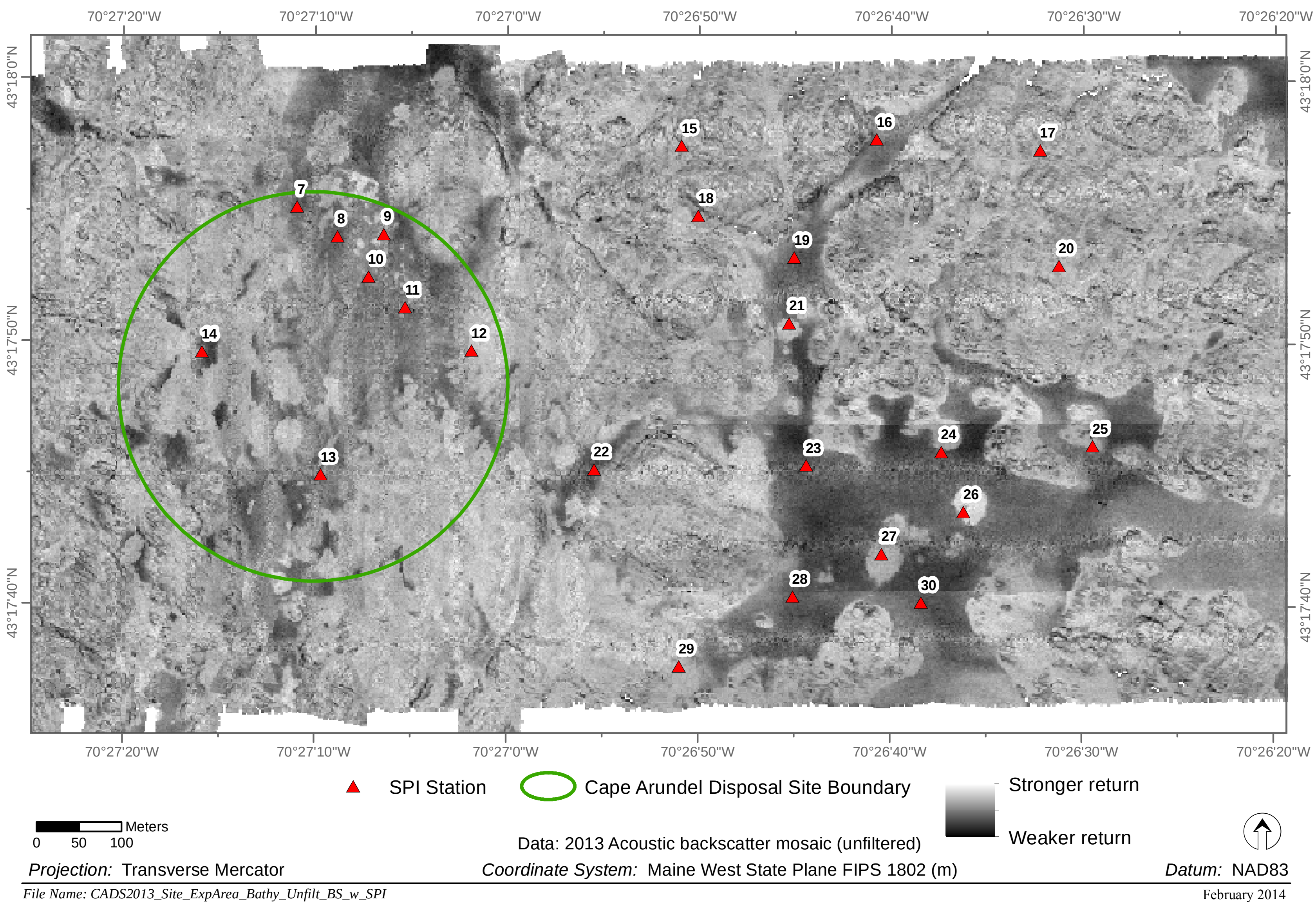


Figure 3-15. Mosaic of unfiltered backscatter data of CADS and expanded area with SPI/PV stations

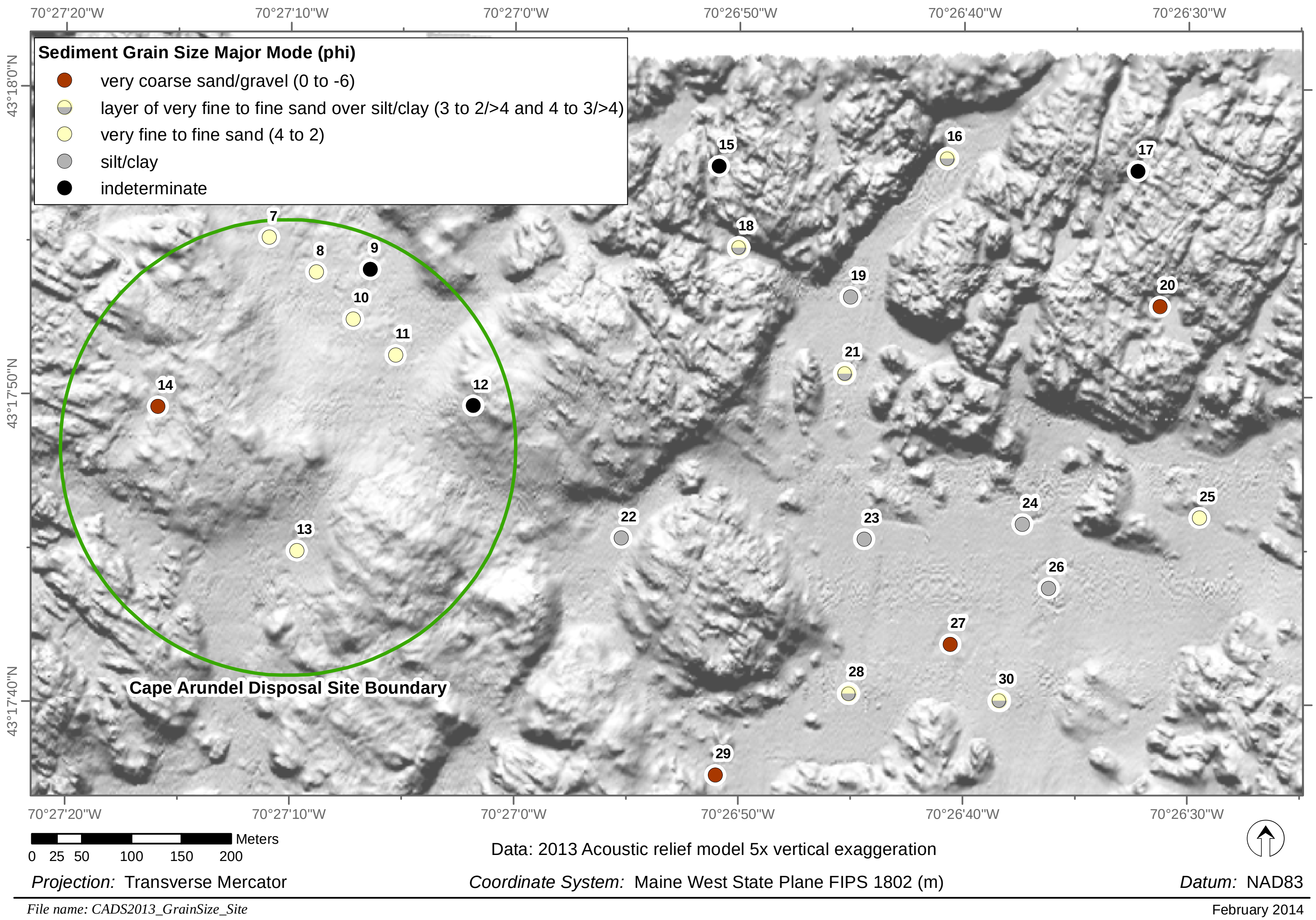


Figure 3-16. Sediment grain size major mode (phi) at CADS and expanded area

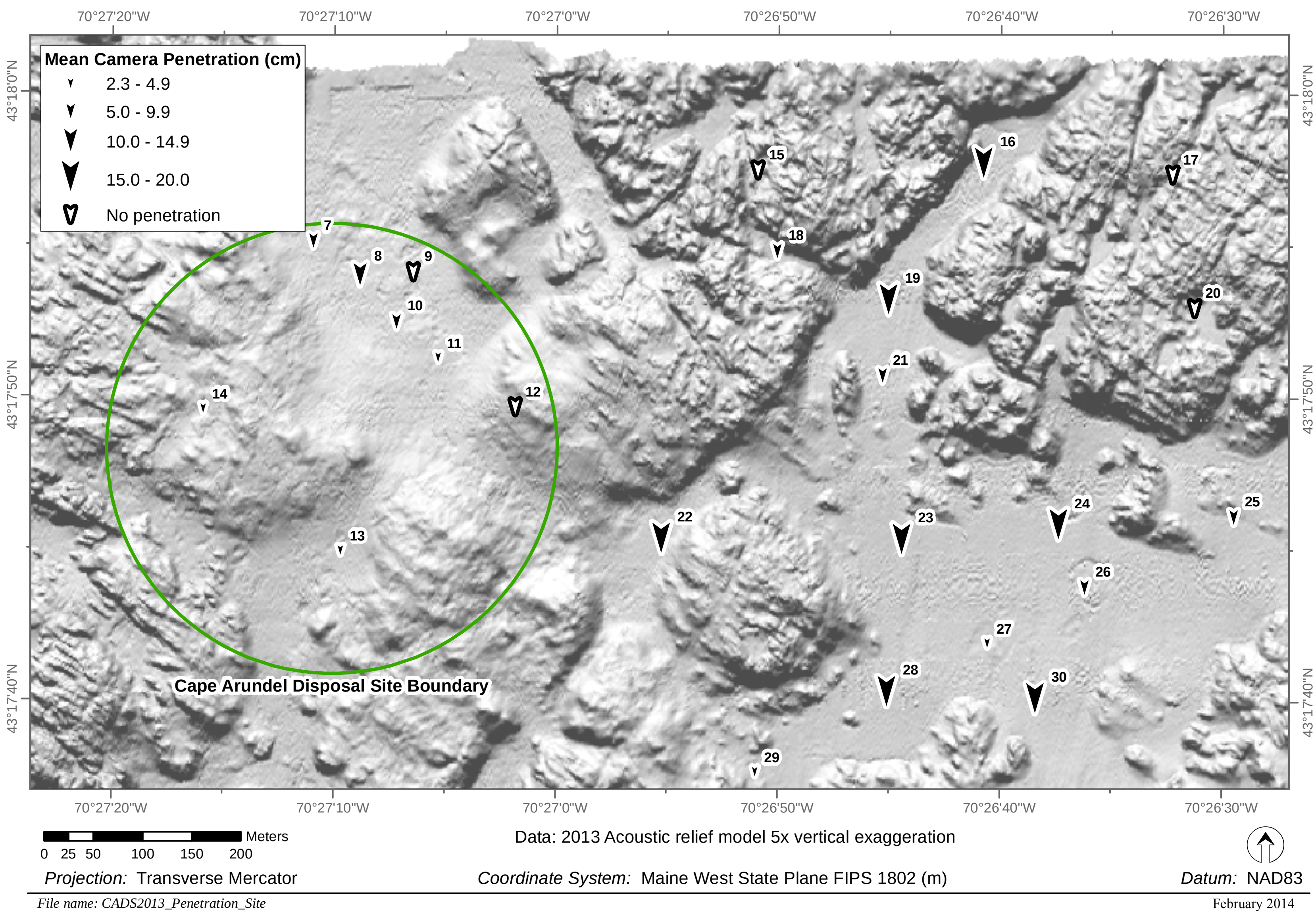


Figure 3-17. Mean station camera prism penetration depth (cm) at CADS and expanded area

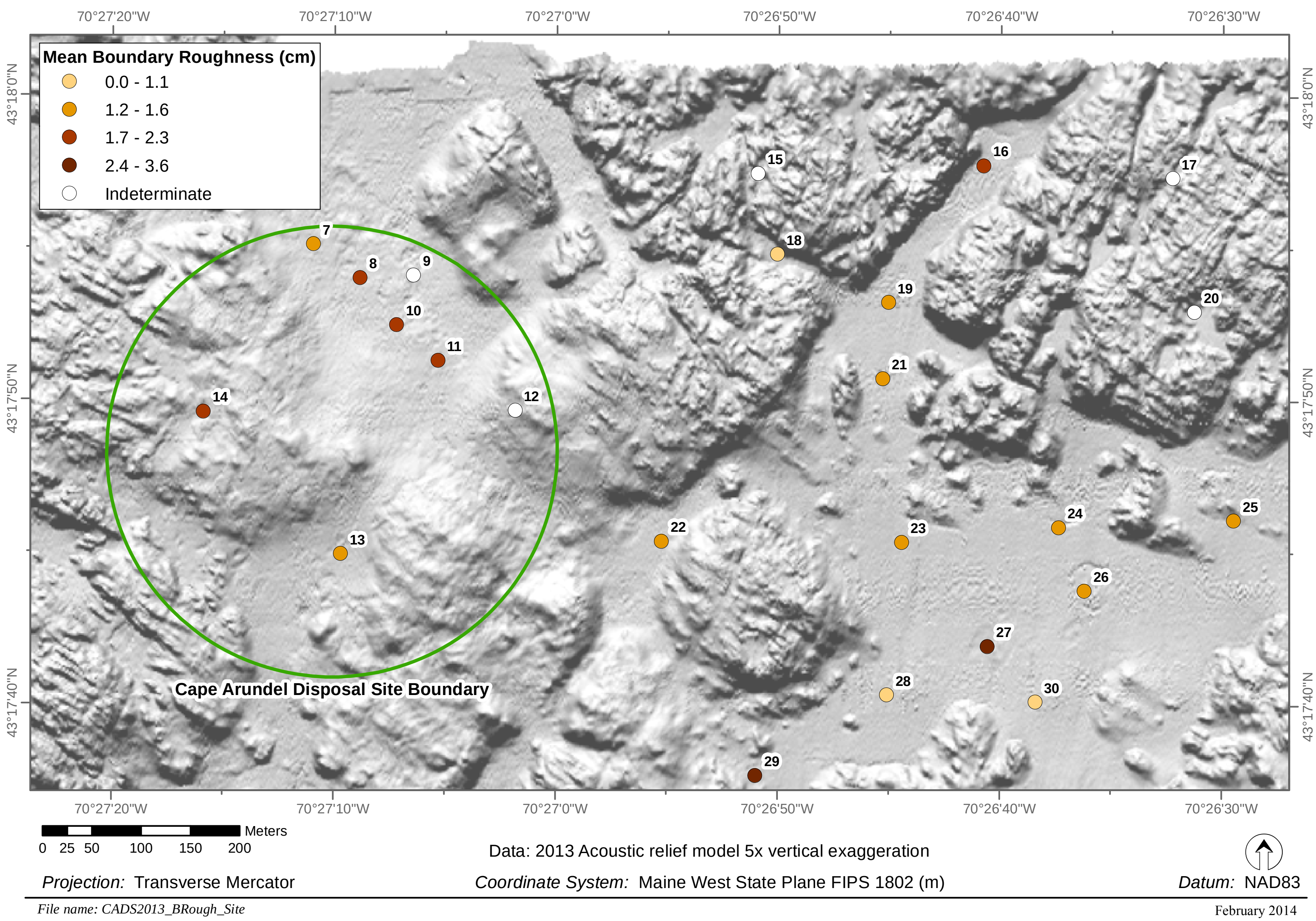


Figure 3-18. Mean station small-scale boundary roughness values (cm) at CADS and expanded area

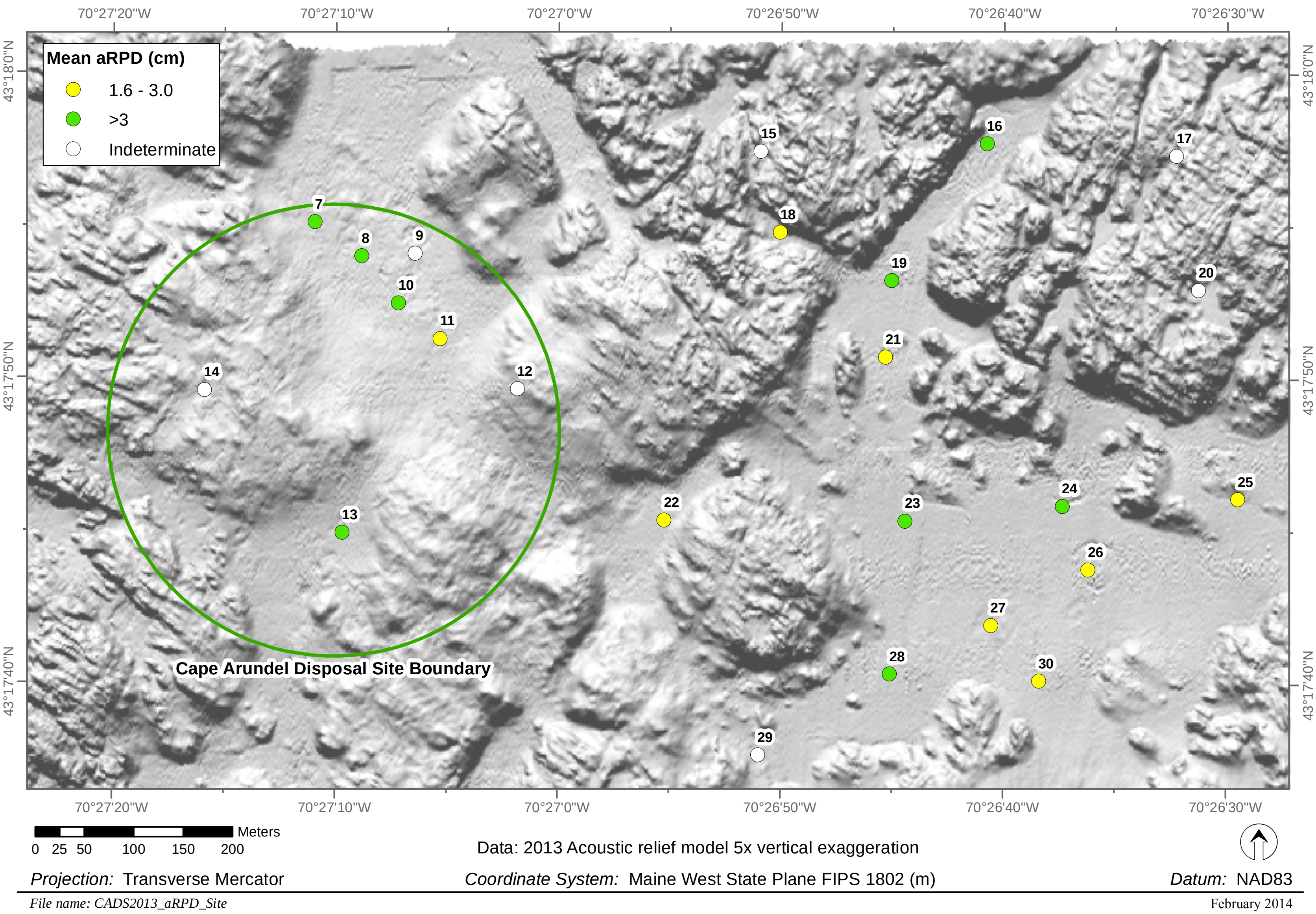


Figure 3-19. Mean station aRPD depth (cm) at CADS and expanded area

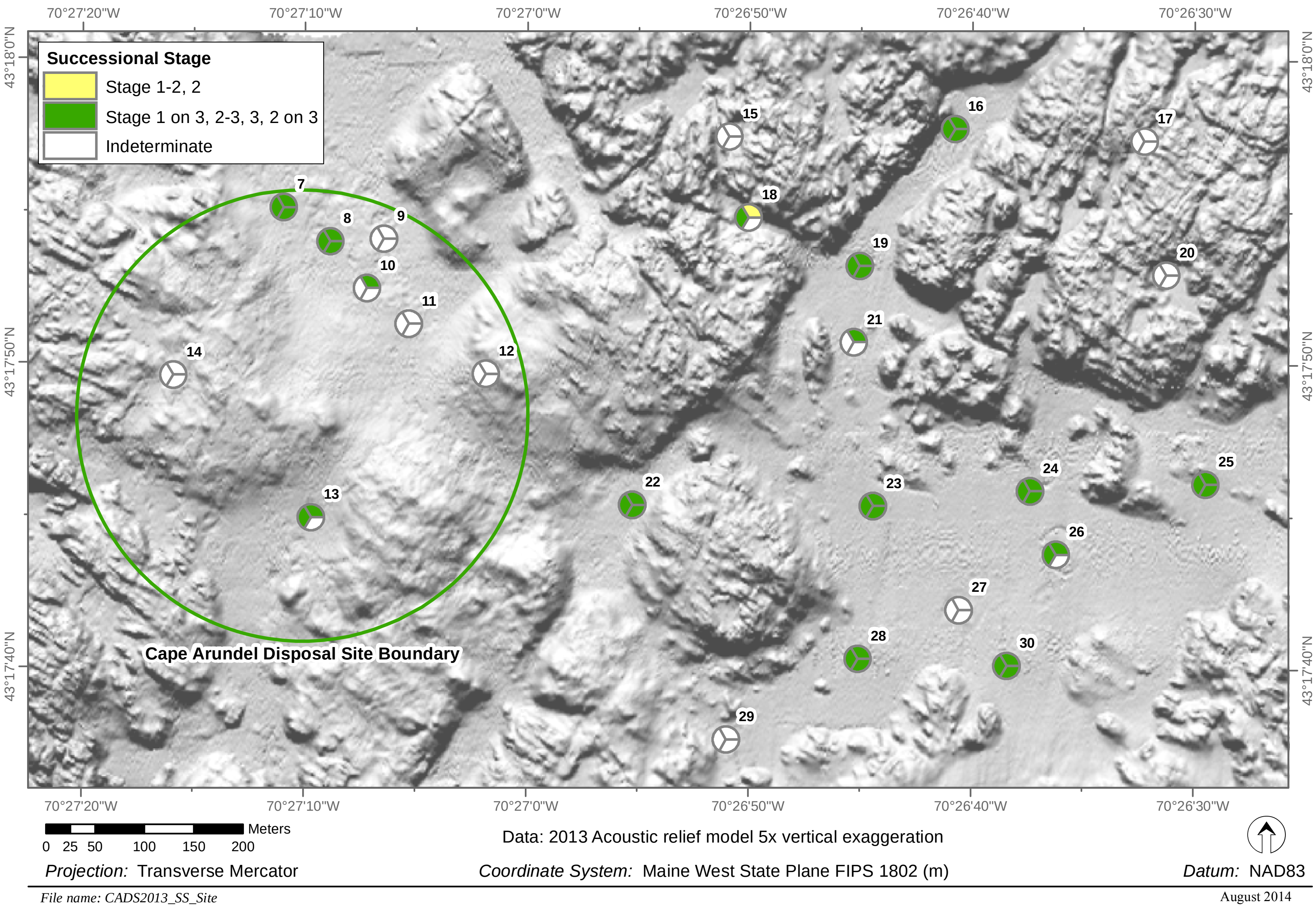


Figure 3-20. Infaunal successional stages found at CADS and expanded area

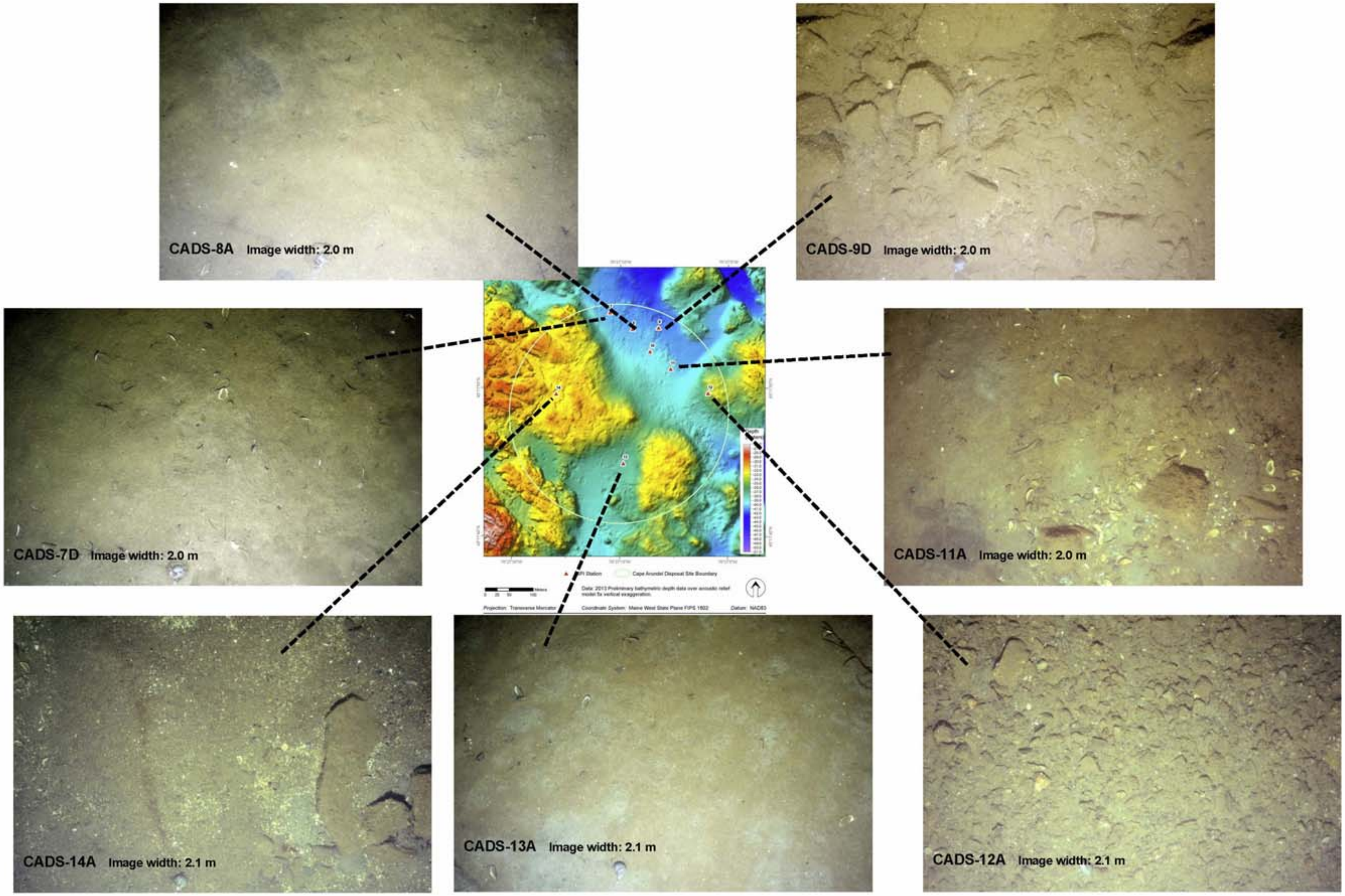


Figure 3-21. Plan-view images at CADS selected stations

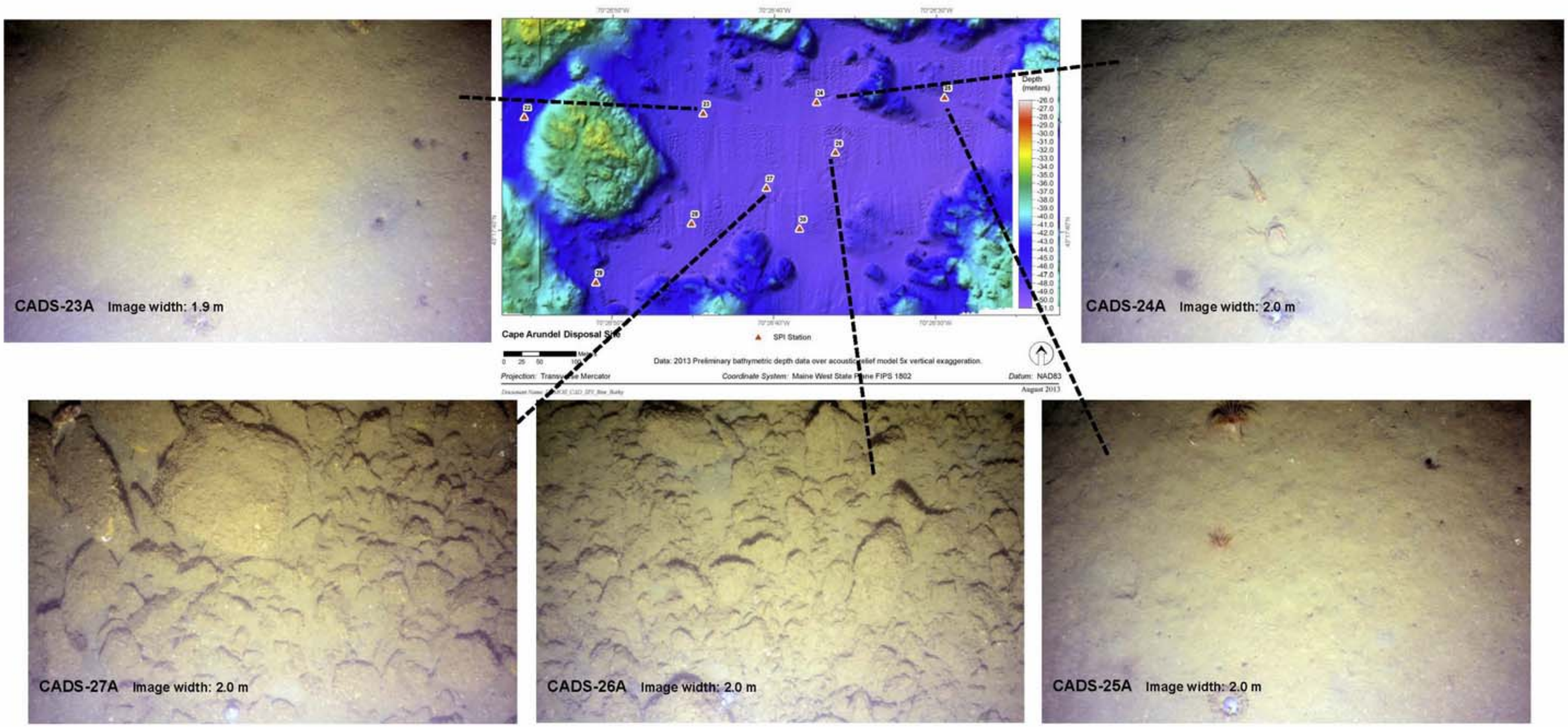


Figure 3-22. Plan-view images at selected southern expanded area stations

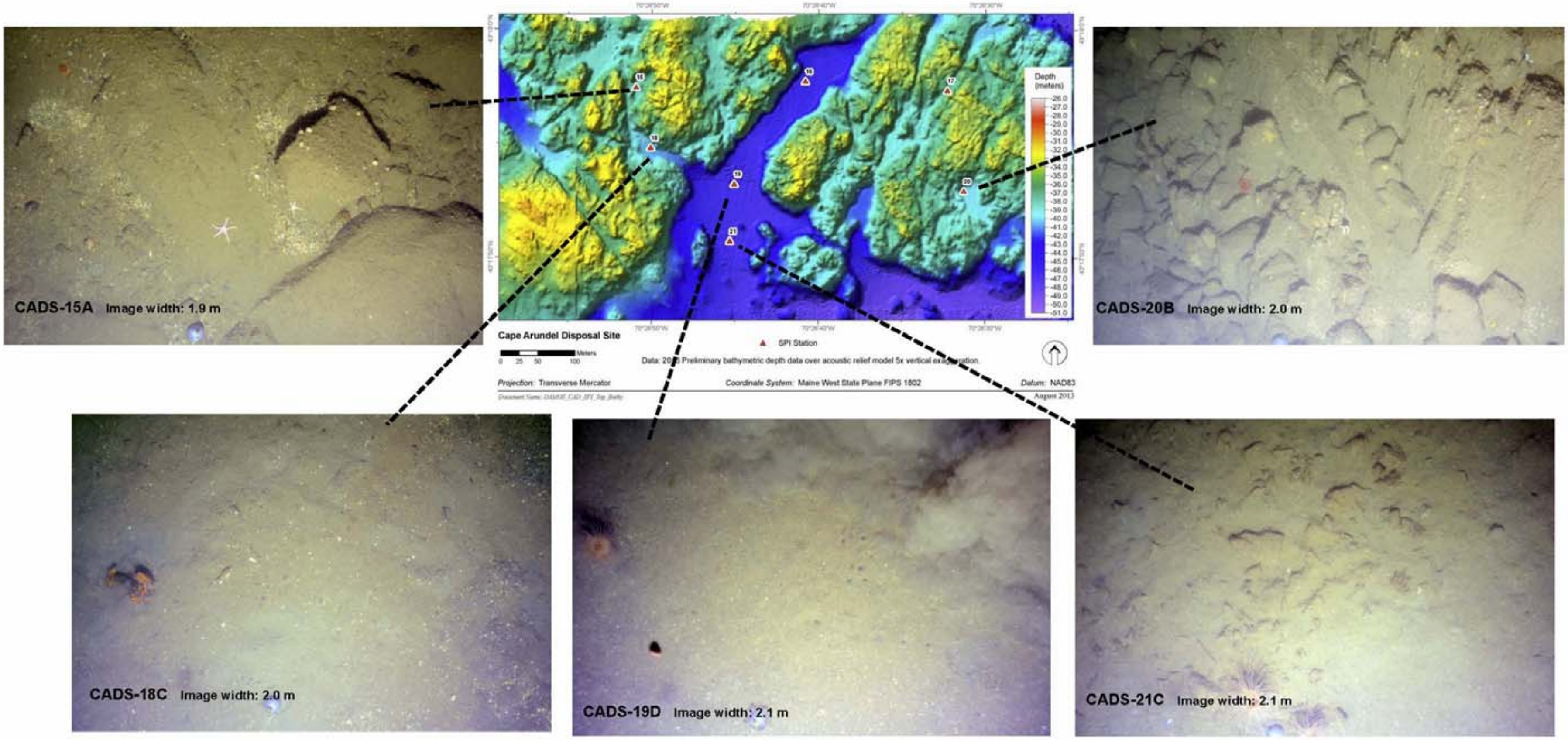


Figure 3-23. Plan-view images at selected northern expanded area stations

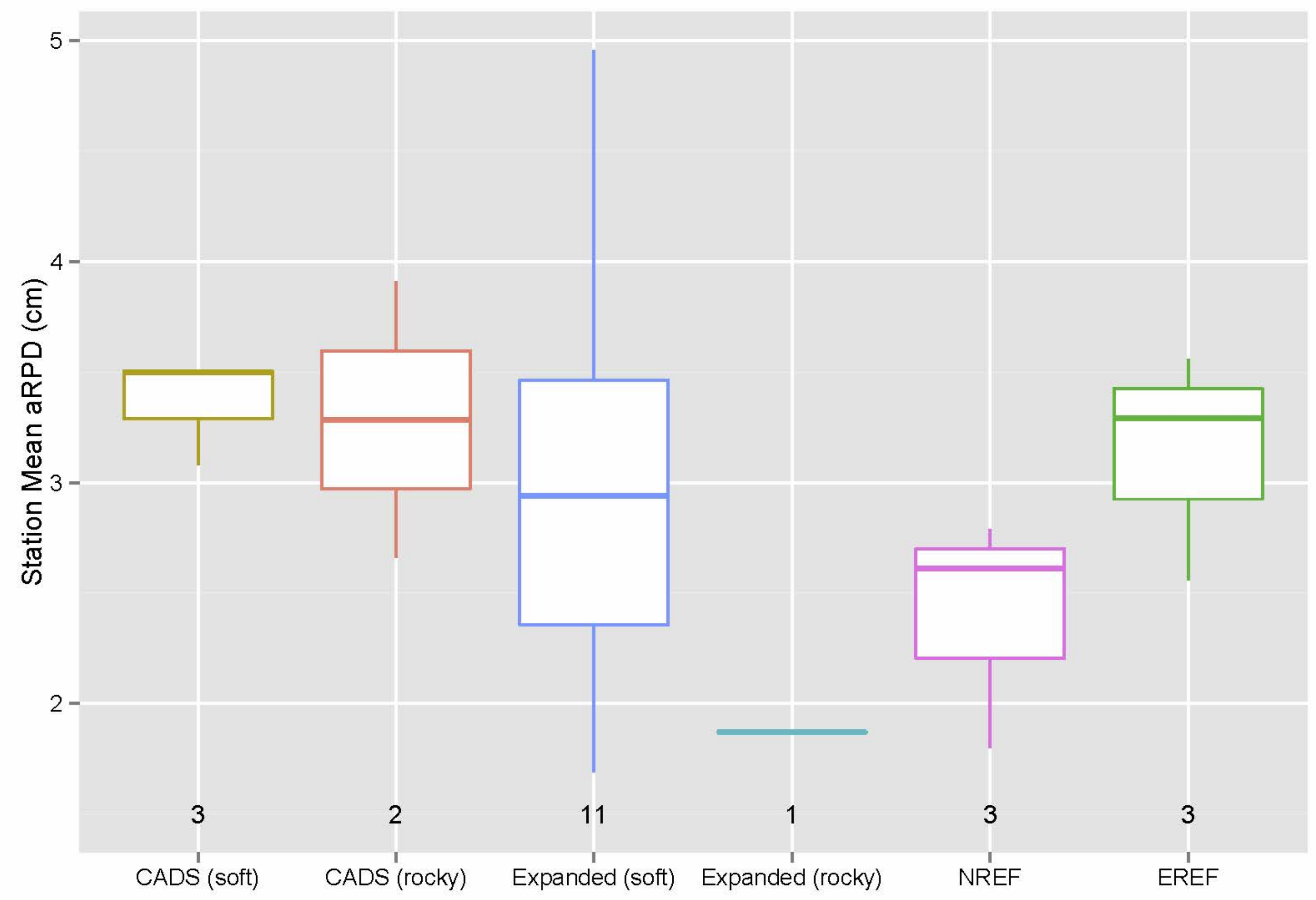


Figure 3-24. Boxplot showing distribution of station mean aRPD for 2013 CADS survey and the reference areas. Station counts shown in black are the number of stations which had determinate aRPD values.

4.0 SUMMARY

The monitoring survey at the Cape Arundel Disposal Site in August 2013 revealed a seafloor with variable topography featuring rocky promontories and deeper, soft-sediment basins. A disposal mound was not readily observable in the CADS topography, but clear acoustic evidence of dredged material placement activity was detectable throughout CADS in the form of impact craters and small-scale mounds. Acoustic backscatter contours revealed circular patterns of harder or rougher surfaces in deeper basins where soft sediment was expected. SPI/PV image analysis confirmed the presence of rock, cobble, and gravel, indicative of dredged material, at these locations.

A depth difference analysis was conducted to assess dredged material accumulation since 1997 and revealed that dredged material appeared to have accumulated primarily in the deeper, soft-bottom area surrounding the rocky outcrops near the center of the site. Dredged material deposition was also observed, to a lesser extent on rocky areas. The placement activity had not created a typical mound detectable on the flat seafloor, but there was clear evidence of 0.5 to 1.5 m of dredged material spread over flat features near the center of the disposal site. This observation of spread dredged material accumulation at CADS was consistent with the findings of 1987 and 1990 surveys conducted during the peak period of dredged material placement at CADS.

Monitoring of an expanded area to the east revealed similar observations to those of CADS in terms of topography and evidence of dredged material placement. The expanded area was deeper than CADS, with variable topography featuring rocky shallower areas and deeper basins of soft sediment. The acoustic survey revealed many impact craters and small-scale mounds and backscatter contours revealed larger circular features with hard surfaces in deeper basins. SPI/PV image analysis confirmed the presence of rock, cobble, and gravel, indicative of dredged material, at these locations. Depth difference analysis of the expanded area did not reveal large mounds of dredged material accumulation. Relatively small areas of shallow (less than 0.5 m) accumulation were observed that are likely indicative of random disposal events rather than repeated placement at specified locations.

SPI/PV analysis found no adverse ecological effects from dredged material placement activities within CADS or within the expanded area. The mean aRPD depth at CADS was deeper than the pooled mean depths at the reference areas indicating comparable or better conditions than both reference areas. The presence of Successional Stage 3 at all stations (apart from one rocky station in the expanded area) indicated an apparently robust benthic community throughout the study area.

5.0 REFERENCES

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6.0 DATA TRANSMITTAL

Data transmittal to support this data report will be provided as a separate deliverable for inclusion in a Technical Support Notebook. The data submittal will include:

- Report figures and associated files, including an ArcGIS geo-database
- Raw and adjusted SPI/PV images
- Raw and processed acoustic survey data
- Field notes
- Field pictures
- Pop-up and Pull-out image files

Appendix A

Table of Common Conversions

Metric Unit Conversion to English Unit		English Unit Conversion to Metric Unit	
1 meter 1 m	3.2808399 ft	1 foot 1 ft	0.3048 m
1 square meter 1 m^2	10.7639104 ft^2	1 square foot 1 ft^2	0.09290304 m^2
1 kilometer 1 km	0.621371192 mi	1 mile 1 mi	1.609344 km
1 cubic meter 1 m^3	1.30795062 yd^3	1 cubic yard 1 yd^3	0.764554858 m^3
1 centimeter 1 cm	0.393700787 in	1 inch 1 in	2.54 cm

Appendix B

CADS 2013 Survey

Actual SPI/PV Replicate Locations

CADS 2013 Survey Actual SPI/PV Replicate Locations

SPI/PV Replicate Locations					
Replicate	**Latitude (N)**	**Longitude (W)**	**Replicate**	**Latitude (N)**	**Longitude (W)**
7A	43° 17.919'	70° 27.182'	15C	43° 17.956'	70° 26.852'
7B	43° 17.920'	70° 27.180'	15D	43° 17.955'	70° 26.854'
7C	43° 17.920'	70° 27.178'	16A	43° 17.963'	70° 26.680'
7D	43° 17.917'	70° 27.178'	16B	43° 17.958'	70° 26.677'
8A	43° 17.900'	70° 27.148'	16C	43° 17.960'	70° 26.675'
8B	43° 17.901'	70° 27.146'	16D	43° 17.960'	70° 26.676'
8C	43° 17.904'	70° 27.145'	17A	43° 17.956'	70° 26.538'
8D	43° 17.902'	70° 27.145'	17B	43° 17.955'	70° 26.533'
9A	43° 17.901'	70° 27.107'	17C	43° 17.953'	70° 26.536'
9B	43° 17.903'	70° 27.106'	17D	43° 17.953'	70° 26.540'
9C	43° 17.907'	70° 27.106'	18A	43° 17.914'	70° 26.834'
9D	43° 17.911'	70° 27.108'	18B	43° 17.910'	70° 26.833'
10A	43° 17.874'	70° 27.121'	18C	43° 17.910'	70° 26.831'
10B	43° 17.874'	70° 27.120'	18D	43° 17.911'	70° 26.832'
10C	43° 17.871'	70° 27.124'	19A	43° 17.887'	70° 26.751'
10D	43° 17.864'	70° 27.131'	19B	43° 17.888'	70° 26.755'
11A	43° 17.855'	70° 27.089'	19C	43° 17.888'	70° 26.758'
11B	43° 17.857'	70° 27.088'	19D	43° 17.889'	70° 26.761'
11C	43° 17.856'	70° 27.089'	20A	43° 17.883'	70° 26.521'
11D	43° 17.855'	70° 27.090'	20B	43° 17.887'	70° 26.524'
12A	43° 17.828'	70° 27.031'	20C	43° 17.885'	70° 26.523'
12B	43° 17.829'	70° 27.029'	20D	43° 17.884'	70° 26.524'
12C	43° 17.831'	70° 27.027'	21A	43° 17.846'	70° 26.755'
12D	43° 17.829'	70° 27.031'	21B	43° 17.846'	70° 26.758'
13A	43° 17.749'	70° 27.161'	21C	43° 17.849'	70° 26.751'
13B	43° 17.743'	70° 27.166'	21D	43° 17.848'	70° 26.749'
13C	43° 17.746'	70° 27.160'	22A	43° 17.753'	70° 26.924'
13D	43° 17.742'	70° 27.166'	22B	43° 17.752'	70° 26.928'
14A	43° 17.827'	70° 27.265'	22C	43° 17.752'	70° 26.930'
14B	43° 17.827'	70° 27.262'	22D	43° 17.755'	70° 26.931'
14C	43° 17.824'	70° 27.265'	22E	43° 17.755'	70° 26.919'
14D	43° 17.825'	70° 27.263'	22F	43° 17.756'	70° 26.921'
15A	43° 17.958'	70° 26.849'	22G	43° 17.758'	70° 26.922'
15B	43° 17.957'	70° 26.851'	22H	43° 17.762'	70° 26.924'

CADS 2013 Survey Actual SPI/PV Replicate Locations (continued)

SPI/PV Replicate Locations			SPI/PV Replicate Locations		
Replicate	**Latitude (N)**	**Longitude (W)**	**Replicate**	**Latitude (N)**	**Longitude (W)**
23A	43° 17.756'	70° 26.740'	27A	43° 17.700'	70° 26.674'
23B	43° 17.756'	70° 26.740'	27B	43° 17.699'	70° 26.676'
23C	43° 17.756'	70° 26.743'	27C	43° 17.699'	70° 26.677'
23D	43° 17.757'	70° 26.744'	27D	43° 17.696'	70° 26.681'
24A	43° 17.764'	70° 26.623'	28A	43° 17.672'	70° 26.751'
24B	43° 17.761'	70° 26.624'	28B	43° 17.671'	70° 26.751'
24C	43° 17.763'	70° 26.620'	28C	43° 17.672'	70° 26.748'
24D	43° 17.766'	70° 26.618'	28D	43° 17.672'	70° 26.751'
25A	43° 17.768'	70° 26.491'	29A	43° 17.628'	70° 26.850'
25B	43° 17.769'	70° 26.493'	29B	43° 17.629'	70° 26.851'
25C	43° 17.769'	70° 26.496'	29C	43° 17.627'	70° 26.852'
25D	43° 17.770'	70° 26.497'	29D	43° 17.630'	70° 26.847'
26A	43° 17.726'	70° 26.603'	30A	43° 17.669'	70° 26.640'
26B	43° 17.730'	70° 26.603'	30B	43° 17.671'	70° 26.640'
26C	43° 17.731'	70° 26.605'	30C	43° 17.672'	70° 26.641'
26D	43° 17.728'	70° 26.604'	30D	43° 17.674'	70° 26.639'
Reference Replicate Locations			**Reference Replicate Locations**		
Replicate	**Latitude (N)**	**Longitude (W)**	**Replicate**	**Latitude (N)**	**Longitude (W)**
NREF-1A	43° 18.306'	70° 27.195'	EREF-4A	43° 18.333'	70° 26.120'
NREF-1B	43° 18.305'	70° 27.198'	EREF-4B	43° 18.334'	70° 26.122'
NREF-1C	43° 18.304'	70° 27.200'	EREF-4C	43° 18.332'	70° 26.119'
NREF-1D	43° 18.305'	70° 27.203'	EREF-4D	43° 18.330'	70° 26.114'
NREF-2A	43° 18.311'	70° 27.136'	EREF-4E	43° 18.331'	70° 26.118'
NREF-2B	43° 18.311'	70° 27.139'	EREF-4F	43° 18.332'	70° 26.120'
NREF-2C	43° 18.311'	70° 27.137'	EREF-4G	43° 18.332'	70° 26.120'
NREF-2D	43° 18.313'	70° 27.139'	EREF-4h	43° 18.332'	70° 26.117'
NREF-3A	43° 18.253'	70° 27.166'	EREF-5A	43° 18.295'	70° 26.116'
NREF-3B	43° 18.254'	70° 27.167'	EREF-5B	43° 18.295'	70° 26.115'
NREF-3C	43° 18.255'	70° 27.169'	EREF-5C	43° 18.296'	70° 26.116'
NREF-3D	43° 18.256'	70° 27.171'	EREF-5D	43° 18.294'	70° 26.115'
			EREF-6A	43° 18.311'	70° 26.151'
			EREF-6B	43° 18.312'	70° 26.155'
			EREF-6C	43° 18.314'	70° 26.154'
			EREF-6D	43° 18.316'	70° 26.155'

Notes:
1) Coordinate system NAD83
2) This table reflects all attempts to collect replicates at each target station. The three replicates with the best quality images were used for analysis.

Appendix C

Sediment-Profile and Plan-View Image Analysis Results for CADS Survey, August 2013

SPI Image Analysis Results for CADS Survey, August 2013

Location	Station	Replicate	Date	Time	Stop Collar Setting (in)	# of Weights (per side)	Water Depth (ft)	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	aRpd Area (sq. cm)	Mean aRpd (cm)
CADS	7	A	8/23/2013	10:12:48	14	2	138	14.485207	4 to 3	>4	0	117.0	8.1	7.2	8.7	1.5	Biological	42.9	3.0
CADS	7	C	8/23/2013	10:14:43	14	2	138	14.485207	4 to 3	>4	0	104.4	7.2	6.7	7.9	1.2	Biological	35.6	2.5
CADS	7	D	8/23/2013	10:15:52	14	2	138	14.485207	4 to 3	>4	0	82.9	5.7	5.2	6.4	1.2	Biological	55.2	3.8
CADS	8	A	8/23/2013	10:36:35	14	3	138	14.485207	4 to 3	>4	0	212.8	14.7	13.7	15.4	1.7	Biological	59.1	4.1
CADS	8	B	8/23/2013	10:37:36	14	3	138	14.485207	4 to 3	>4	0	156.5	10.8	9.6	12.2	2.6	Physical	39.0	2.7
CADS	8	C	8/23/2013	10:38:36	14	3	138	14.485207	4 to 3	>4	1	146.9	10.1	9.1	11.0	1.8	Biological	54.1	3.7
CADS	9	A	8/23/2013	10:53:11	14	3	140	14.485207	-	-	-	-	-	-	-	-	-	-	-
CADS	9	B	8/23/2013	10:54:07	14	3	140	14.485207	-	-	-	-	-	-	-	-	-	-	-
CADS	9	C	8/23/2013	10:55:11	14	3	140	14.485207	-	-	-	-	-	-	-	-	-	-	-
CADS	10	B	8/23/2013	10:47:44	14	3	138	14.485207	4 to 3	>4	1	100.9	7.0	6.3	7.5	1.2	Biological	25.5	1.8
CADS	10	C	8/23/2013	10:48:41	14	3	138	14.485207	3 to 2	>4	1	68.0	4.7	3.8	5.4	1.6	Physical	68.0	4.7
CADS	10	D	8/23/2013	10:49:40	14	3	138	14.485207	3 to 2	>4	1	59.2	4.1	3.0	5.1	2.1	Physical	59.2	4.1
CADS	11	A	8/23/2013	10:59:58	14	3	136	14.485207	3 to 2	>4	1	44.9	3.1	1.7	4.5	2.8	Biological	44.9	3.1
CADS	11	B	8/23/2013	11:00:54	14	3	136	14.485207	3 to 2	>4	0	47.2	3.3	2.8	3.9	1.1	Physical	37.1	2.6
CADS	11	C	8/23/2013	11:01:50	14	3	136	14.485207	3 to 2	>4	1	33.5	2.3	1.7	2.7	1.0	Physical	33.5	2.3
CADS	12	A	8/23/2013	11:24:15	15	5	123	14.485207	-	-	-	-	-	-	-	-	-	-	-
CADS	12	B	8/23/2013	11:25:43	15	5	123	14.485207	-	-	-	-	-	-	-	-	-	-	-
CADS	12	C	8/23/2013	11:26:43	15	5	123	14.485207	-	-	-	-	-	-	-	-	-	-	-
CADS	13	A	8/23/2013	11:43:31	15	5	131	14.485207	3 to 2	>4	1	54.7	3.8	2.3	4.3	2.0	Physical	54.7	3.8
CADS	13	C	8/23/2013	11:45:48	15	5	131	14.485207	4 to 3	>4	1	83.6	5.8	5.2	6.2	1.1	Biological	50.2	3.5
CADS	13	D	8/23/2013	11:46:47	15	5	131	14.485207	3 to 2	>4	1	64.8	4.5	4.1	4.7	0.6	Biological	64.8	4.5
CADS	14	A	8/23/2013	11:34:14	15	5	113	14.485207	0 to -1	>4	-6	12.6	0.9	0.0	1.4	1.4	Physical	ind	ind
CADS	14	B	8/23/2013	11:35:18	15	5	113	14.485207	3 to 2	>4	1	74.8	5.2	4.1	6.5	2.4	Physical	ind	ind
CADS	14	D	8/23/2013	11:37:25	15	5	113	14.485207	0 to -1	>4	-4	100.0	6.9	5.7	7.4	1.7	Physical	ind	ind

SPI Image Analysis Results for CADS Survey, August 2013

Location	Station	Replicate	Date	Time	Stop Collar Setting (in)	# of Weights (per side)	Water Depth (ft)	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	aRpd Area (sq. cm)	Mean aRpd (cm)
CADS	15	A	8/23/2013	15:26:06	14	4	120	14.485207	-	-	-	-	-	-	-	-	-	-	-
CADS	15	B	8/23/2013	15:27:00	14	4	120	14.485207	-	-	-	-	-	-	-	-	-	-	-
CADS	15	C	8/23/2013	15:27:52	14	4	120	14.485207	-	-	-	-	-	-	-	-	-	-	-
CADS	16	A	8/23/2013	15:35:44	14	4	155	14.485207	4 to 3/>4	>4	0	229.5	15.8	15.4	16.5	1.1	Biological	70.7	4.9
CADS	16	C	8/23/2013	15:37:24	14	4	155	14.485207	4 to 3/>4	>4	0	263.8	18.2	16.9	19.4	2.4	Biological	46.6	3.2
CADS	16	D	8/23/2013	15:38:16	14	4	155	14.485207	4 to 3/>4	>4	0	218.3	15.1	14.4	16.3	1.9	Biological	30.3	2.1
CADS	17	A	8/23/2013	15:56:41	14	4	118	14.485207	-	-	-	-	-	-	-	-	-	-	-
CADS	17	B	8/23/2013	15:57:36	14	4	118	14.485207	-	-	-	-	-	-	-	-	-	-	-
CADS	17	C	8/23/2013	15:58:24	14	4	118	14.485207	-	-	-	-	-	-	-	-	-	-	-
CADS	18	A	8/23/2013	15:15:36	14	4	140	14.485207	3 to 2/>4	>4	-1	69.9	4.8	4.3	5.3	1.1	Biological	32.9	2.3
CADS	18	B	8/23/2013	15:16:26	14	4	140	14.485207	3 to 2	>4	-2	70.4	4.9	4.3	5.5	1.3	Biological	25.2	1.7
CADS	18	C	8/23/2013	15:17:13	14	4	140	14.485207	3 to 2/>4	>4	0	96.0	6.6	6.3	7.1	0.8	Biological	23.0	1.6
CADS	19	A	8/23/2013	15:03:04	14	4	157	14.485207	>4	>4	1	251.9	17.4	16.8	17.8	1.0	Biological	55.4	3.8
CADS	19	C	8/23/2013	15:04:37	14	4	157	14.485207	>4	>4	1	228.5	15.8	15.2	16.5	1.3	Biological	48.0	3.3
CADS	19	D	8/23/2013	15:05:25	14	4	157	14.485207	>4	>4	1	209.7	14.5	13.9	15.0	1.0	Biological	50.0	3.5
CADS	20	A	8/23/2013	16:04:22	14	4	132	14.485207	-1 to -2	>4	-4	-	-	-	-	-	-	-	-
CADS	20	B	8/23/2013	16:05:03	14	4	132	14.485207	ind	ind	ind	-	-	-	-	-	-	-	-
CADS	20	C	8/23/2013	16:05:54	14	4	132	14.485207	ind	ind	ind	-	-	-	-	-	-	-	-
CADS	21	A	8/23/2013	14:54:34	14	4	157	14.485207	ind	ind	ind	-	-	-	-	-	-	-	-
CADS	21	B	8/23/2013	14:55:25	14	4	157	14.485207	ind	ind	ind	-	-	-	-	-	-	-	-
CADS	21	C	8/23/2013	14:56:13	14	4	157	14.485207	4 to 3/>4	>4	0	134.4	9.3	8.7	9.9	1.2	Biological	24.5	1.7
CADS	22	F	8/23/2013	16:14:37	14	2	148	14.485207	>4	>4	1	236.5	16.3	15.2	17.1	1.9	Biological	56.6	3.9
CADS	22	G	8/23/2013	16:15:27	14	2	148	14.485207	>4	>4	1	201.7	13.9	13.6	14.2	0.6	Biological	20.8	1.4
CADS	22	H	8/23/2013	16:16:20	14	2	148	14.485207	>4	>4	1	251.1	17.3	16.5	18.3	1.7	Biological	50.5	3.5

SPI Image Analysis Results for CADS Survey, August 2013

Location	Station	Replicate	Date	Time	Stop Collar Setting (in)	# of Weights (per side)	Water Depth (ft)	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	aRpd Area (sq. cm)	Mean aRpd (cm)
CADS	23	B	8/23/2013	14:37:35	14	4	160	14.485207	>4	>4	1	278.8	19.2	18.8	20.3	1.5	Biological	105.6	7.3
CADS	23	C	8/23/2013	14:38:30	14	4	160	14.485207	>4	>4	1	263.6	18.2	17.6	19.2	1.6	Biological	52.9	3.7
CADS	23	D	8/23/2013	14:39:24	14	4	160	14.485207	>4	>4	1	254.3	17.6	17.1	18.1	1.0	Biological	56.9	3.9
CADS	24	A	8/23/2013	14:27:15	14	4	164	14.485207	>4	>4	1	218.7	15.1	14.8	16.0	1.1	Biological	71.8	5.0
CADS	24	B	8/23/2013	14:28:04	14	4	164	14.485207	>4	>4	1	244.6	16.9	15.6	17.9	2.3	Biological	43.4	3.0
CADS	24	C	8/23/2013	14:28:58	14	4	164	14.485207	>4	>4	2	239.4	16.5	16.1	17.1	1.0	Biological	53.1	3.7
CADS	25	A	8/23/2013	14:19:30	14	4	164	14.485207	4 to 3/>4	>4	1	140.7	9.7	9.2	10.0	0.8	Biological	34.5	2.4
CADS	25	B	8/23/2013	14:20:28	14	4	164	14.485207	4 to 3	>4	1	77.6	5.4	4.7	5.9	1.2	Biological	31.5	2.2
CADS	25	C	8/23/2013	14:21:26	14	4	164	14.485207	4 to 3	>4	-4	103.0	7.1	6.0	8.2	2.2	Biological	22.1	1.5
CADS	26	B	8/23/2013	13:31:05	14	4	164	14.485207	>4	>4	-6	57.7	4.0	3.5	4.9	1.4	Biological	26.7	1.8
CADS	26	C	8/23/2013	13:31:55	14	4	164	14.485207	>4	>4	1	147.9	10.2	9.4	10.9	1.5	Biological	46.2	3.2
CADS	26	D	8/23/2013	13:32:48	14	4	164	14.485207	>4	>4	1	96.7	6.7	5.9	7.2	1.4	Biological	34.6	2.4
CADS	27	B	8/23/2013	13:13:25	14	4	163	14.485207	-6	>4	-8	60.1	4.2	2.5	5.4	3.0	Biological	60.1	4.2
CADS	27	C	8/23/2013	13:14:25	14	4	163	14.485207	ind	>4	-8	-	-	-	-	-	-	-	-
CADS	27	D	8/23/2013	13:15:18	14	4	163	14.485207	4 to 3	>4	-6	53.9	3.7	2.2	4.8	2.6	Biological	12.8	0.9
CADS	28	A	8/23/2013	13:03:04	14	4	163	14.485207	4 to 3/>4	>4	0	224.1	15.5	14.4	16.2	1.7	Biological	42.9	3.0
CADS	28	C	8/23/2013	13:04:56	14	4	163	14.485207	4 to 3/>4	>4	2	232.4	16.0	15.7	16.4	0.6	Biological	45.5	3.1
CADS	28	D	8/23/2013	13:05:53	14	4	163	14.485207	4 to 3/>4	>4	1	244.2	16.9	16.7	17.0	0.3	Biological	49.7	3.4
CADS	29	A	8/23/2013	12:53:18	14	4	154	14.485207	-6	>4	-8	23.0	1.6	0.0	3.4	3.4	Physical	ind	ind
CADS	29	B	8/23/2013	12:54:05	14	4	154	14.485207	-6	>4	-8	76.8	5.3	4.2	6.7	2.5	Physical	ind	ind
CADS	29	C	8/23/2013	12:55:01	14	4	154	14.485207	-8	>4	???	0.0	0.0	-	-	-	-	-	-
CADS	30	A	8/23/2013	13:21:16	14	4	164	14.485207	4 to 3/>4	>4	0	221.3	15.3	14.9	15.8	0.9	Biological	34.2	2.4
CADS	30	B	8/23/2013	13:22:14	14	4	164	14.485207	4 to 3/>4	>4	1	237.3	16.4	15.7	16.7	1.0	Biological	32.4	2.2
CADS	30	D	8/23/2013	13:23:53	14	4	164	14.485207	4 to 3/>4	>4	1	228.5	15.8	15.3	16.1	0.9	Biological	30.6	2.1

SPI Image Analysis Results for CADS Survey, August 2013

Location	Station	Replicate	Date	Time	Stop Collar Setting (in)	# of Weights (per side)	Water Depth (ft)	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	aRpd Area (sq. cm)	Mean aRpd (cm)
NREF	NREF-01	A	8/23/2013	18:11:03	14	2	133	14.485207	4 to 3/>4	>4	0	142.7	9.9	8.4	11.5	3.2	Physical	39.1	2.7
NREF	NREF-01	B	8/23/2013	18:11:48	14	2	133	14.485207	4 to 3/>4	>4	0	151.3	10.4	9.2	11.1	2.0	Biological	32.8	2.3
NREF	NREF-01	C	8/23/2013	18:12:37	14	2	133	14.485207	4 to 3/>4	>4	0	160.6	11.1	10.4	11.3	0.9	Biological	41.4	2.9
NREF	NREF-02	B	8/23/2013	17:59:02	14	2	136	14.485207	4 to 3/>4	>4	0	164.2	11.3	10.9	11.8	0.9	Biological	26.5	1.8
NREF	NREF-02	C	8/23/2013	17:59:55	14	2	136	14.485207	4 to 3/>4	>4	0	168.3	11.6	10.9	12.0	1.0	Biological	27.6	1.9
NREF	NREF-02	D	8/23/2013	18:00:49	14	2	136	14.485207	4 to 3/>4	>4	0	158.6	11.0	10.3	11.6	1.2	Biological	24.1	1.7
NREF	NREF-03	A	8/23/2013	18:19:13	14	2	136	14.485207	>4	>4	1	155.2	10.7	10.4	10.9	0.6	Biological	33.7	2.3
NREF	NREF-03	B	8/23/2013	18:20:03	14	2	136	14.485207	>4	>4	1	163.3	11.3	10.7	12.3	1.6	Biological	27.5	1.9
NREF	NREF-03	C	8/23/2013	18:20:53	14	2	136	14.485207	>4	>4	1	180.8	12.5	12.0	13.1	1.1	Biological	60.0	4.1
EREF	EREF-04	F	8/23/2013	17:33:00	14	2	151	14.485207	>4	>4	1	219.3	15.1	14.4	16.0	1.5	Biological	63.9	4.4
EREF	EREF-04	G	8/23/2013	17:33:49	14	2	151	14.485207	>4	>4	0	198.5	13.7	13.3	14.9	1.5	Biological	44.7	3.1
EREF	EREF-04	H	8/23/2013	17:34:37	14	2	151	14.485207	>4	>4	1	221.4	15.3	14.8	15.7	0.9	Biological	46.0	3.2
EREF	EREF-05	A	8/23/2013	17:40:00	14	2	155	14.485207	>4	>4	2	236.7	16.3	15.7	16.8	1.2	Biological	49.3	3.4
EREF	EREF-05	B	8/23/2013	17:40:49	14	2	155	14.485207	>4	>4	2	227.9	15.7	15.1	16.5	1.3	Biological	62.8	4.3
EREF	EREF-05	C	8/23/2013	17:41:41	14	2	155	14.485207	>4	>4	2	234.2	16.2	15.1	16.9	1.8	Biological	30.9	2.1
EREF	EREF-06	A	8/23/2013	17:44:57	14	2	150	14.485207	>4	>4	1	210.7	14.5	13.7	15.4	1.7	Biological	22.3	1.5
EREF	EREF-06	B	8/23/2013	17:45:57	14	2	150	14.485207	>4	>4	1	217.0	15.0	14.8	15.5	0.7	Biological	39.5	2.7
EREF	EREF-06	D	8/23/2013	17:47:44	14	2	150	14.485207	>4	>4	2	226.5	15.6	15.1	16.5	1.5	Biological	49.3	3.4

Note:
1) "ind" indicates that the sample result was indeterminate
2) "mean" indicates the mean value across a single sediment profile image

SPI Image Analysis Results for CADS Survey, August 2013

Location	Station	Replicate	Mud Clast Number	Mud Clast State	Methane?	Low DO?	Comment	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
CADS	7	A	0	-	n	n	Silty very fine sand; tubes at SWI and in background; evidence of burrowing in aRPD	0	-	-	-	2 -> 3
CADS	7	C	0	-	n	n	Silty very fine sand; tubes on surface; bivalve shells on surface; evidence of burrowing to depth of image	0	-	-	-	1 on 3
CADS	7	D	0	-	n	n	Silty very fine sand; aRPD extends below penetration depth at center, so minimum measurement; bivalve shells on surface, burrow openings in PV image	0	-	-	-	1 on 3
CADS	8	A	0	-	n	n	Silty very fine sand; tubes and organic debris on surface; burrowing through aRPD; two voids at depth	2	10.5	13.3	11.9	1 on 3
CADS	8	B	0	-	n	n	Silty very fine sand; rippled surface; aRPD is deeper on right; more evidence of burrowing on right; polychaete against faceplate near base of aRPD	0	-	-	-	2 on 3
CADS	8	C	0	-	n	n	Silty very fine sand; tubes at SWI and in background; evidence of larger burrowers in aRPD at center; large void at depth	1	7.4	9.9	8.7	1 on 3
CADS	9	A	-	-	-	-	No penetration in any replicates- in C and D at bit of surface is visible, possible pebbles and tubes on surface	-	-	-	-	ind
CADS	9	B	-	-	-	-	Rocky bottom - no penetration	-	-	-	-	ind
CADS	9	C	-	-	-	-	Rocky bottom - no penetration	-	-	-	-	ind
CADS	10	B	0	-	n	n	Silty, very fine sand; organic debris on surface; bioturbation greater than prism penetration depth	1	0.0	3.6	1.8	1 on 3
CADS	10	C	0	-	n	n	Fine sand; sand ripple; tubes on surface & aRPD exceeds penetration depth; penetration too shallow to determine successional stage	0	-	-	-	ind
CADS	10	D	0	-	n	n	Fine sand; sand ripple; tubes on surface & aRPD exceeds penetration depth; penetration too shallow to determine successional stage	0	-	-	-	ind
CADS	11	A	0	-	n	n	Fine sand; tubes & debris on surface & aRPD exceeds penetration depth; penetration too shallow to determine successional stage	0	-	-	-	ind

SPI Image Analysis Results for CADS Survey, August 2013

Location	Station	Replicate	Mud Clast Number	Mud Clast State	Methane?	Low DO?	Comment	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
CADS	11	B	0	-	n	n	Silty fine sand with shell debris; surface covered with tubes & organic debris; penetration too shallow to determine successional stage	0	-	-	-	ind
CADS	11	C	0	-	n	n	Fine sand with shallow amplitude ripples; tubes on surface & aRPD exceeds penetration depth; penetration too shallow to determine successional stage	0	-	-	-	ind
CADS	12	A	-	-	-	-	No penetration in any replicates- bits of surface visible, covered with med to large rocks- small tubes	-	-	-	-	ind
CADS	12	B	-	-	-	-	No penetration in any replicates- bits of surface visible, covered with med to large rocks- small tubes	-	-	-	-	ind
CADS	12	C	-	-	-	-	No penetration in any replicates- bits of surface visible, covered with med to large rocks- small tubes	-	-	-	-	ind
CADS	13	A	0	-	n	n	Silty fine sand; few tubes at surface; penetration too shallow to determine successional stage, aRPD exceeds prism penetration depth	0	-	-	-	ind
CADS	13	C	0	-	n	n	Silty very fine sand; tubes on surface; evidence of burrowing in aRPD; void at base of aRPD on left; burrow openings in PV image	1	4.6	5.5	5.0	1 on 3
CADS	13	D	0	-	n	n	Silty fine sand; tubes at SWI; evidence of burrowing in upper cms; evidence of transected burrows & burrow openings in PV image; aRPD > prism penetration depth.	0	-	-	-	1 on 3
CADS	14	A	0	-	n	n	Poorly sorted very coarse sand with pebbles; very shallow penetration	0	-	-	-	ind
CADS	14	B	0	-	n	n	Very fine to fine sand; few tubes on surface in background; penetration too shallow to determine stage, and lack of silt-clay makes aRPD indeterminate	0	-	-	-	ind
CADS	14	D	0	-	n	n	Poorly sorted granules and very coarse sand; small shell frag; tubes in background	0	-	-	-	ind
CADS	15	A	-	-	-	-	Large rocks, no penetration in any replicates- surface visible in A, very large rock in foreground with sea star and other epifauna; large open bivalve shell and pebbles/small rocks on surface	-	-	-	-	ind
CADS	15	B	-	-	-	-	Large rocks, no penetration.	-	-	-	-	ind

SPI Image Analysis Results for CADS Survey, August 2013

Location	Station	Replicate	Mud Clast Number	Mud Clast State	Methane?	Low DO?	Comment	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
CADS	15	C	-	-	-	-	Large rocks, no penetration.	-	-	-	-	ind
CADS	16	A	0	-	n	n	Silt, grading upward to silty very fine sand; tubes at SWI; three polychaetes against faceplate near base of aRPD; large void at depth	1	13.1	15.8	14.5	1 on 3
CADS	16	C	1	oxidized	n	n	Silt, grading upward to silty very fine sand; large polychaete at base of aRPD; voids at depth, polychaete below void	3	12.1	18.4	15.3	2 on 3
CADS	16	D	0	-	n	n	Silt, grading upward to silty very fine sand; thin tube at SWI; thin polychaete near base of aRPD on right; voids at depth on left	2	7.1	14.1	10.6	1 on 3
CADS	17	A	-	-	-	-	Hard bottom, no penetration	-	-	-	-	ind
CADS	17	B	-	-	-	-	Hard bottom, no penetration	-	-	-	-	ind
CADS	17	C	-	-	-	-	Hard bottom, no penetration	-	-	-	-	ind
CADS	18	A	0	-	n	n	Poorly sorted silty fine sand, shell frag on surface; some debris on surface; penetration too shallow to determine stage	0	-	-	-	ind
CADS	18	B	0	-	n	n	Silty fine sand, coarser near surface; shell frag and few pebbles on surface; void at center; polychaete to left of void	1	2.4	4.4	3.4	2 on 3
CADS	18	C	0	-	n	n	Silt, grading upward to silty fine to medium sand, coarser grains near surface; shell frag on surface, organic debris on surface.	0	-	-	-	1 -> 2
CADS	19	A	0	-	n	n	Silt-clay with minor fraction of very fine sand at surface; small tubes at SWI and in background; burrowing in upper 3 cm; small void near surface on left; void at depth on right; long organism against faceplate on left	1	1.3	1.7	1.5	1 on 3
CADS	19	C	10+	reduced	n	n	Silt-clay with minor fraction of very fine sand at surface; small tubes; camera artifact mud clasts at SWI; small void in aRPD; small polychaetes just below aRPD; voids at depth	3	1.3	15.0	8.1	1 on 3
CADS	19	D	7	both	n	n	Silt-clay with minor fraction of very fine sand at surface; few small mud clasts at SWI (camera artifact); shallow burrowing; polychaete below aRPD at center; very small void at depth center	1	11.9	11.8	11.9	1 on 3

SPI Image Analysis Results for CADS Survey, August 2013

Location	Station	Replicate	Mud Clast Number	Mud Clast State	Methane?	Low DO?	Comment	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
CADS	20	A	-	-	-	-	Poorly sorted coarse pebble and granule with larger rocks (see PV images) -- no penetration	-	-	-	-	ind
CADS	20	B	-	-	-	-	Hard bottom, no penetration	-	-	-	-	ind
CADS	20	C	-	-	-	-	Hard bottom, no penetration	-	-	-	-	ind
CADS	21	A	-	-	-	-	Hard bottom, no penetration	-	-	-	-	ind
CADS	21	B	-	-	-	-	Hard bottom, no penetration	-	-	-	-	ind
CADS	21	C	0	-	n	n	Silt, grading upward to silty very fine sand, coarser grains in upper cms; small tubes and tubiculous fauna at SWI and in background; evidence of deeper burrowing.	0	-	-	-	1 on 3
CADS	22	F	0	-	n	n	Silt-clay with minor fraction of very fine sand at surface; small tubes at SWI; burrowing through aRPD, one small polychaete; small void at base of aRPD in center; other voids at depth	3	3.6	15.5	9.5	1 on 3
CADS	22	G	0	-	n	n	Silt-clay with minor fraction of very fine sand at surface; burrowing through aRPD; few thin polychaete at base of aRPD; burrow openings in PV image	0	-	-	-	1 on 3
CADS	22	H	0	-	n	n	Silt-clay with minor fraction of very fine sand at surface; tubes at SWI; burrowing in aRPD; thin polychaetes at base of aRPD and at depth; voids at depth	5	10.6	17.7	14.1	1 on 3
CADS	23	B	6	both	n	n	Silt-clay with minor fraction of very fine sand at surface; small to med mud clasts on surface (camera artifacts); tubes at SWI; burrowing in aRPD; one void in aRPD, one at base, one at depth	3	2.9	13.5	8.2	1 on 3
CADS	23	C	2	reduced	n	n	Silt-clay with minor fraction of very fine sand at surface; tubes and tubiculous fauna at SWI and in background; burrowing in aRPD; long polychaete at base of aRPD on right; voids at depth on left	2	13.2	17.6	15.4	1 on 3
CADS	23	D	2	reduced	n	n	Silt-clay with minor fraction of very fine sand at surface; med to large mud clasts on surface (wiper blade artifacts); burrowing in aRPD; large polychaete against faceplate below aRPD.	3	3.5	14.6	9.1	1 on 3

SPI Image Analysis Results for CADS Survey, August 2013

Location	**Station**	**Replicate**	**Mud Clast Number**	**Mud Clast State**	**Methane?**	**Low DO?**	**Comment**	**# of Feeding Voids**	**Void Minimum Depth (cm)**	**Void Maximum Depth (cm)**	**Void Average Depth (cm)**	**Successional Stage**
CADS	24	A	0	-	n	n	Silt-clay with minor fraction of very fine sand at surface; tubes at SWI; shallow burrowing; large void at depth; two small polychaetes on left below aRPD	2	5.7	15.8	10.7	1 on 3
CADS	24	B	3	reduced	n	n	Silt-clay with minor fraction of very fine sand at surface; cluster of fecal pellets; couple tubes at SWI; few polychaetes (capitellids) at various depths from base of aRPD	1	7.3	7.9	7.6	1 on 3
CADS	24	C	0	-	n	n	Silt-clay with reduced fecal pellets on surface; shallow burrowing; small void in aRPD on right; large back-filled void at depth	2	2.0	16.5	9.3	3
CADS	25	A	0	-	n	n	Silt, grading upward to silty very fine sand; fecal pellets, tubes at SWI and in background; few small polychaetes at base of aRPD on left; burrow openings in PV image and evidence of burrowing at depth in profile image	0	-	-	-	1 on 3
CADS	25	B	0	-	n	n	Silty very fine sand; fecal pellets, shallow burrowing in upper cm of aRPD	0	-	-	-	2 -> 3
CADS	25	C	0	-	n	n	Silty very fine sand; small rocks/debris on surface; tubes at surface in background shallow burrowing; polychaete at depth; small void on depth	1	5.8	6.1	5.9	1 on 3
CADS	26	B	0	-	n	n	Poorly sorted very fine sandy silt; clumps of sed and rock in background; tubes on rocks in background; penetration too shallow to determine successional stage	0	-	-	-	ind
CADS	26	C	0	-	n	n	Poorly sorted very fine sandy silt; clumps of sed/rocks on surface; tubes on rock in background; void at depth connected to SWI by large burrow; red algae in dragdown against faceplate.	1	5.1	7.8	6.5	1 on 3
CADS	26	D	0	-	n	n	Poorly sorted very fine sandy silt; clumps of sed/rocks on surface; tubes on rock in background; couple small polychaetes against faceplate at depth at center.	0	-	-	-	1 on 3
CADS	27	B	0	-	n	n	Poorly sorted very fine sandy silt; clumps/rocks on surface; tubes on surface and on rocks; penetration too shallow to determine stage, aRPD exceeds penetration depth	0	-	-	-	ind
CADS	27	C	-	-	-	-	Hard bottom, no penetration	-	-	-	-	ind

SPI Image Analysis Results for CADS Survey, August 2013

Location	Station	Replicate	Mud Clast Number	Mud Clast State	Methane?	Low DO?	Comment	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
CADS	27	D	0	-	n	n	Poorly sorted very fine sandy silt, opening of large burrow at SWI on left; clumps and rocks in background, tubes on rocks, one med shell frag, too shallow to determine successional stage	0	-	-	-	ind
CADS	28	A	0	-	n	n	Silt, grading upward to silty very fine sand; tubes on surface in background; polychaetes in aRPD and below; void just below aRPD	1	4.8	5.4	5.1	1 on 3
CADS	28	C	0	-	n	n	Silt, grading upward to silty very fine sand; short tubes on surface in background; two small polychaetes just below aRPD; one small, one large void at depth	2	11.7	14.8	13.2	1 on 3
CADS	28	D	0	-	n	n	Silt, grading upward to silty very fine sand; few tubes at SWI; three polychaetes at base and below aRPD; void at depth on right	4	9.6	16.9	13.2	1 on 3
CADS	29	A	0	-	n	n	Silty rocky bottom, cobbles with tubes, jumbled on surface; penetration too shallow to determine stage	0	-	-	-	ind
CADS	29	B	0	-	n	n	Poorly sorted silty sand with rocks of various size on surface, tubes on rocks; uneven surface; possibly some activity from larger burrowers	0	-	-	-	ind
CADS	29	C	-	-	-	-	Hard bottom, no penetration	-	-	-	-	ind
CADS	30	A	0	-	n	n	Silt, grading upward to silty very fine sand; tubes and tubiculous fauna at SWI and in background; small burrow at depth	1	8.6	9.0	8.8	1 on 3
CADS	30	B	0	-	n	n	Silt, grading upward to silty very fine sand; few tubes at SWI; small former void or burrow in aRPD at left; voids at depth	2	9.2	15.4	12.3	1 on 3
CADS	30	D	0	-	n	n	Silt, grading upward to silty very fine sand; shallow burrowing; two small polychaete at base of aRPD on left; transected burrows at depth	0	-	-	-	1 on 3
NREF	NREF-01	A	0	-	n	n	Silt, grading upward to silty very fine sand; uneven surface, mounds and ridges in background; fecal pellets; lots of tubes at SWI and in background; small polychaete below aRPD at center; parts of larger on at center below aRPD and at depth	0	-	-	-	1 on 3

SPI Image Analysis Results for CADS Survey, August 2013

Location	Station	Replicate	Mud Clast Number	Mud Clast State	Methane?	Low DO?	Comment	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
NREF	NREF-01	B	1	oxidized	n	n	Silt, grading upward to silty very fine sand; fecal pellets; burrowing through aRPD; two polychaetes near base of aRPD on right; burrow openings in PV, large fecal pellets from subsurface deposit feeders @ SWI	0	-	-	-	3
NREF	NREF-01	C	0	-	n	n	Silt, grading upward to silty very fine sand; fecal pellets; few tubes at surface; 3 thin-med polychaetes below aRPD; void at depth	1	9.9	10.3	10.1	1 on 3
NREF	NREF-02	B	0	-	n	n	Silt, grading upward to silty very fine sand; fecal pellets, old tubes; few small tubes in background; small shell frag in upper cms; small polychaete against faceplate at center below aRPD; polychaete near large void at depth.	4	5.0	11.0	8.0	1 on 3
NREF	NREF-02	C	1	reduced	n	n	Silt, grading upward to silty very fine sand; large clump of sed on surface; small shell frag in upper cms; voids at depth; burrowing anemone at depth against faceplate.	3	6.9	10.6	8.8	1 on 3
NREF	NREF-02	D	0	-	n	n	Silt, grading upward to silty very fine sand; tubes and tubiculous fauna at SWI; small shell frag in upper cm; very thin polychaetes near base of aRPD; polychaete below aRPD at center	1	6.8	7.1	7.0	1 on 3
NREF	NREF-03	A	2	oxidized	n	n	Very fine sandy silt; fecal pellets, tubes at SWI and in background-polychaete wrapped around large tube in background; few thin polychaetes near base of aRPD; burrow openings in PV image	0	-	-	-	1 on 3
NREF	NREF-03	B	0	-	n	n	Very fine sandy silt; fecal pellets; burrowing through aRPD; few thin polychaetes at base of aRPD; transected burrows of errantia at depth.	0	-	-	-	3
NREF	NREF-03	C	0	-	n	n	Very fine sandy silt; fecal pellets, tubes and tubiculous fauna at SWI and in background; burrowing through aRPD; thin polychaetes below aRPD; sign of larger burrowers at base of aRPD in center	0	-	-	-	1 on 3
EREF	EREF-04	F	8	both	n	n	Silt-clay with minor fraction of VFS at surface; small tubes at surface; small to large mud clasts on surface (camera base artifacts); couple very thin polychaetes in aRPD; void at depth	1	12.0	12.7	12.3	1 on 3

SPI Image Analysis Results for CADS Survey, August 2013

Location	Station	Replicate	Mud Clast Number	Mud Clast State	Methane?	Low DO?	Comment	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
EREF	EREF-04	G	10+	both	n	n	Silt, grading upward to silty very fine sand, more uneven grains at surface; small to medium mud clasts at surface (camera artifact); few tubes; evidence of burrowing in aRPD; very large burrow extending vertically ~8.5 cm	3	4.2	12.4	8.3	3
EREF	EREF-04	H	10+	both	n	n	Silt, grading upward to silty very fine sand; small to large mud clasts on surface (camera artifact); several small tubes at surface; few thin polychaetes near base of aRPD; evidence of burrowing throughout depth of profile	0	-	-	-	1 on 3
EREF	EREF-05	A	0	-	n	n	Silt-clay with minor fraction of VFS at surface; small tubes at SWI; evidence of larger burrowers near base of aRPD; thin polychaetes near base of aRPD; polychaetes below aRPD at center, larger polychaete at depth on right	4	4.1	16.8	10.5	1 on 3
EREF	EREF-05	B	10+	both	n	n	Silt-clay with minor fraction of very fine sand at surface; one small tube at SWI; mud clasts (wiper blade artifacts) on surface; shallow burrowing and through aRPD, couple polychaetes at depth, transected burrow at base of image	0	-	-	-	1 on 3
EREF	EREF-05	C	2	reduced	n	n	Silt-clay with minor fraction of very fine sand at surface; few small tubes on surface; small mud clasts on surface from camera; evidence of deeper burrowers; void at depth	1	15.5	16.0	15.8	1 on 3
EREF	EREF-06	A	10+	both	n	n	Silt-clay with minor fraction of very fine sand at surface; fecal pellets; small to med mud clasts at surface (camera frame artifacts); several thin polychaetes near base of aRPD; void at base of aRPD and at depth	2	6.6	13.8	10.2	1 on 3
EREF	EREF-06	B	0	-	n	n	Silt-clay with minor fraction of very fine sand at surface; few tubes in background; burrowing in aRPD; polychaetes at base of aRPD, evidence of burrowing throughout depth of profile	0	-	-	-	1 on 3
EREF	EREF-06	D	7	both	n	n	Silt-clay with minor fraction of very fine sand at surface; small-med tubes at SWI and in background; burrowing through aRPD; thin polychaetes at base of aRPD; void at base of aRPD on left, polychaete at depth on left, mud clasts are wipe blade artifacts	3	3.3	7.0	5.2	1 on 3

Note: 1) "ind" indicates that the sample result was indeterminate

Plan-view Image Analysis Results for CADS Survey, August 2013

Location	Station	Replicate	Date	Time	Image Width (cm)	Image Height (cm)	Field-of-View Imaged (m^2)	Sediment Type	Bedforms	Burrows	Tubes	Tracks	Epifauna	Mud Clasts	Debris	Comment
CADS	7	A	8/23/2013	10:12:53	192.4	127.4	2.5	muddy sand	n	y	y	y	n	n	n	sandy sed; open bivalve shells scattered across surface; small burrows; tracks
CADS	7	D	8/23/2013	10:15:57	199.9	132.4	2.6	muddy sand	n	y	y	y	n	n	n	sandy sed; open bivalve shells scattered across surface; small to med burrows, thin tracks
CADS	8	A	8/23/2013	10:36:40	196.2	130.0	2.6	muddy sand	n	y	y	y	n	n	n	sandy sed; few bivalve shells open on surface; small burrows; tubes; tracks in upper left corner
CADS	8	C	8/23/2013	10:38:40	197.4	130.8	2.6	muddy sand	n	y	y	y	n	n	n	sandy sed; bivalve shells on surface; small burrows; tubes
CADS	9	A	8/23/2013	10:53:14	188.1	124.6	2.3	boulders on sand	n	n	y	n	y	n	n	boulders on sand; tubes on some boulders; tunicates; fish
CADS	9	C	8/23/2013	10:55:15	183.6	121.6	2.2	boulders on sand	n	n	ind	n	y	n	n	boulders on sand; suspended sed obscures fine details, portion of fish visible at right edge of image
CADS	9	D	8/23/2013	10:56:17	203.4	134.7	2.7	boulders on sand	n	n	y	n	y	n	n	boulders on sand; tubes, hydroids & bryozoans on some boulders; shell frag
CADS	10	A	8/23/2013	10:46:48	208.7	138.2	2.9	sandy mud	n	y	y	n	n	n	y	sandy mud; small burrows; tubes; bit of shell frag and debris
CADS	10	C	8/23/2013	10:48:46	206.3	136.7	2.8	sandy mud	n	y	y	y	y	n	n	sandy mud; small burrows; tubes; crab, shell fragments
CADS	10	D	8/23/2013	10:49:45	207.0	137.1	2.8	sandy mud	n	y	y	y	n	y	y	sandy mud; small burrows; tubes; open mussel shells on surface
CADS	11	A	8/23/2013	11:00:02	199.9	132.4	2.6	sandy mud; boulders	n	y	y	n	y	y	y	sandy mud and boulders; small/med burrows; tubes; mud clasts; lots of mussel shells; fish
CADS	11	B	8/23/2013	11:00:59	203.1	134.5	2.7	sandy mud; boulders	n	n	y	n	n	y	y	sandy mud and boulders; surface covered with mussel shells; some tubes on boulders
CADS	12	A	8/23/2013	11:24:21	214.3	141.9	3.0	sandy, rocky	n	n	y	n	y	n	n	sand covered with small rocks; sea star on a rock; small tubes on some rocks

Plan-view Image Analysis Results for CADS Survey, August 2013

Location	Station	Replicate	Date	Time	Image Width (cm)	Image Height (cm)	Field-of-View Imaged (m^2)	Sediment Type	Bedforms	Burrows	Tubes	Tracks	Epifauna	Mud Clasts	Debris	Comment
CADS	12	B	8/23/2013	11:25:49	201.8	133.6	2.7	sandy, rocky	n	n	y	n	y	n	n	sand covered with small rocks; small tubes on some rocks, crab
CADS	12	C	8/23/2013	11:26:47	204.7	135.6	2.8	sandy, rocky, boulders	n	n	y	n	y	n	n	sand covered with small rocks; sea star on a rock; small tubes on some rocks
CADS	13	A	8/23/2013	11:43:36	205.0	135.8	2.8	muddy sand	n	y	y	y	n	n	y	sandy sed; small burrows; tubes; some open mussel shells, org plant debris in upper right corner
CADS	13	B	8/23/2013	11:44:36	201.5	133.4	2.7	muddy sand	n	y	y	y	n	n	n	sandy sed; small/med burrows; short tracks; few open mussel shells
CADS	13	D	8/23/2013	11:46:51	205.0	135.8	2.8	sandy mud	n	y	ind	n	n	n	n	sandy mud; small/med burrows; mussel and clam shells
CADS	14	A	8/23/2013	11:34:18	211.8	140.3	3.0	sandy, pebbles, with rocks, boulders	n	n	y	n	n	n	n	sandy, pebbles, rocks, boulders- uneven, boulders on right; lots of shell frag and mussel shells.
CADS	14	B	8/23/2013	11:35:22	213.9	141.7	3.0	sandy mud	n	y	y	y	n	n	n	sandy mud; small patch of shell frag in upper corner; small burrows, short tracks
CADS	14	C	8/23/2013	11:36:31	203.7	134.9	2.7	sandy, pebbles, w/ rocks	n	n	y	n	n	n	n	sandy, pebbles with few rocks; high % of shell fragments and mussel shells, razor clam shell
CADS	15	A	8/23/2013	15:26:13	193.3	128.0	2.5	muddy, rocky	n	n	y	n	y	n	n	large boulders, muddy; shell frag; tubes on some rocks; sea stars, anemones, lobster under rock on right
CADS	15	C	8/23/2013	15:27:57	195.0	129.2	2.5	muddy, rocky	n	n	y	n	y	n	n	muddy, large boulders on right; tubes; sea stars
CADS	15	D	8/23/2013	15:28:55	206.7	136.9	2.8	muddy, rocky	n	n	y	n	y	n	n	large boulders, muddy; tubes on some rocks; sea stars, anemones
CADS	16	A	8/23/2013	15:35:50	200.2	132.6	2.7	sandy mud	n	y	y	y	n	n	n	sandy mud; small to med burrows; short tracks; burrowing anemones

Plan-view Image Analysis Results for CADS Survey, August 2013

Location	Station	Replicate	Date	Time	Image Width (cm)	Image Height (cm)	Field-of-View Imaged (m^2)	Sediment Type	Bedforms	Burrows	Tubes	Tracks	Epifauna	Mud Clasts	Debris	Comment
CADS	16	C	8/23/2013	15:37:29	201.1	133.2	2.7	sandy mud	n	y	y	y	y	n	n	sandy mud; small to med-large burrows; short tracks; crab
CADS	17	A	8/23/2013	15:56:44	174.3	115.5	2.0	sandy mud; boulders	n	n	y	n	y	n	n	sandy mud with boulders; tubes, sea stars, anemones
CADS	17	C	8/23/2013	15:58:29	187.9	124.4	2.3	sandy mud; boulders	n	n	y	n	y	n	n	sandy mud with boulders; tubes, sea stars, anemones
CADS	17	D	8/23/2013	15:59:21	166.2	110.1	1.8	sandy; boulders	n	n	y	n	y	n	n	sandy, boulders; sea stars, lobster; lots of suspended sediment
CADS	18	A	8/23/2013	15:15:42	198.6	131.6	2.6	sandy mud	n	y	y	n	n	n	n	sandy mud; small rocks upper left; patch of shell frag lower center; small burrows
CADS	18	B	8/23/2013	15:16:30	196.2	130.0	2.6	sandy mud	n	n	y	n	n	n	n	sandy mud; patches of dense shell fragments, couple mussel shells
CADS	18	C	8/23/2013	15:17:19	203.7	134.9	2.7	sandy mud	n	y	y	y	y	y	n	sandy mud; patches of dense shell fragments on right; small burrows; fish; lobster
CADS	19	A	8/23/2013	15:03:08	197.7	131.0	2.6	sandy mud	n	y	y	y	n	n	n	sandy mud; small to large burrows; high density of foraging tracks
CADS	19	B	8/23/2013	15:03:54	199.6	132.2	2.6	sandy mud	n	y	y	y	y	n	n	sandy mud; small to med-large burrows; tracks; lobster
CADS	19	D	8/23/2013	15:05:30	205.0	135.8	2.8	sandy mud	n	y	y	y	y	n	n	sandy mud; small to med-large burrows, short tracks; anemone on rock at left edge of image
CADS	20	A	8/23/2013	16:04:27	203.7	134.9	2.7	cobble on muddy sand	n	n	y	n	y	n	y	sandy mud; rocks; one large burrow; patches of shell frag, bryozoans on rocks
CADS	20	B	8/23/2013	16:05:10	202.1	133.9	2.7	rocky bottom	n	n	y	n	y	n	n	hard bottom ledge, large rocks, tubes on rocks; sea stars, anemones
CADS	20	D	8/23/2013	16:05:58	195.3	129.4	2.5	rocky bottom	n	n	y	n	y	n	n	sandy mud; large boulders; tubes on rocks; sea stars, anemones, fish

Plan-view Image Analysis Results for CADS Survey, August 2013

Location	Station	Replicate	Date	Time	Image Width (cm)	Image Height (cm)	Field-of-View Imaged (m^2)	Sediment Type	Bedforms	Burrows	Tubes	Tracks	Epifauna	Mud Clasts	Debris	Comment
CADS	21	A	8/23/2013	14:54:39	203.1	134.5	2.7	sandy mud; rocks; boulders	n	y	y	n	y	n	n	sandy mud; rocks, boulders; tubes, hydroids, bryozoans on rocks; small burrows
CADS	21	B	8/23/2013	14:55:28	206.3	136.7	2.8	sandy mud; rocks; boulders	n	y	y	n	y	n	n	sandy mud, rocks, boulders; med burrow at center; fish in center and upper right
CADS	21	C	8/23/2013	14:56:18	205.3	136.0	2.8	sandy mud; rocks; boulders	n	y	y	y	y	n	n	sandy mud; rocks; small burrows; burrowing anemones
CADS	22	E	8/23/2013	16:13:56	189.5	125.5	2.4	sandy mud	n	y	y	y	n	y	n	sandy mud; small to large burrows; short tracks
CADS	22	F	8/23/2013	16:14:40	196.8	130.4	2.6	sandy mud	n	y	y	y	n	y	n	sandy mud; small to large burrows; short tracks
CADS	22	H	8/23/2013	16:16:22	200.2	132.6	2.7	sandy mud	n	y	y	y	n	n	n	sandy mud; small to large burrows; high density of foraging tracks
CADS	23	A	8/23/2013	14:36:49	194.4	128.8	2.5	sandy mud	n	y	y	y	y	n	n	sandy mud; small to large burrows; short tracks; tubes; sea robin (head only) at top of image
CADS	24	A	8/23/2013	14:27:20	204.4	135.3	2.8	sandy mud	n	y	y	y	y	n	n	sandy mud; small to med burrows; tracks; fish (sea robin), crab
CADS	24	C	8/23/2013	14:29:02	201.1	133.2	2.7	sandy mud	n	y	y	y	n	n	n	sandy mud; small to med burrows; short tracks; burrowing anemone
CADS	24	D	8/23/2013	14:29:53	197.1	130.6	2.6	sandy mud	n	y	y	y	n	y	n	sandy mud; small to med burrows; high density of short tracks
CADS	25	A	8/23/2013	14:19:36	196.8	130.4	2.6	sandy mud	n	y	y	y	y	n	n	sandy mud; small to med-large burrows, tubes, short tracks, burrowing anemones, shrimp
CADS	26	A	8/23/2013	13:29:52	195.0	129.2	2.5	rocky bottom	n	n	y	n	y	n	n	sandy mud, small to large rocks and boulders; small patch of shell frag; barnacle, tunicate
CADS	27	A	8/23/2013	13:12:35	198.3	131.4	2.6	rocky bottom	n	n	y	n	y	n	n	sandy mud, rocks, large boulders; tubes on some rocks; sea star, fish

Plan-view Image Analysis Results for CADS Survey, August 2013

Location	Station	Replicate	Date	Time	Image Width (cm)	Image Height (cm)	Field-of-View Imaged (m^2)	Sediment Type	Bedforms	Burrows	Tubes	Tracks	Epifauna	Mud Clasts	Debris	Comment
CADS	27	C	8/23/2013	13:14:30	198.0	131.2	2.6	rocky bottom	n	n	y	n	y	n	n	sandy mud; rocks, boulders; tubes, hydroids, bryozoans on rocks; patch of shell frag
CADS	27	D	8/23/2013	13:15:22	203.4	134.7	2.7	rocky bottom	n	y	y	n	y	n	n	mud, rocks, boulders; small burrows, fouling community of epifauna on rocks
CADS	28	A	8/23/2013	13:03:07	197.4	130.8	2.6	sandy mud	n	y	y	y	n	n	n	sandy mud; small to med burrows, tubes, short tracks
CADS	28	B	8/23/2013	13:04:00	199.0	131.8	2.6	sandy mud	n	y	y	y	y	n	n	sandy mud; small to med burrows, tubes, short tracks; fish
CADS	29	A	8/23/2013	12:53:21	199.0	131.8	2.6	rocky bottom	n	n	y	n	y	n	n	sandy mud, rocks, boulders; tubes on rocks; barnacles; sea star; patch of shell frag
CADS	29	B	8/23/2013	12:54:09	196.5	130.2	2.6	rocky bottom	n	n	y	n	y	n	y	sandy mud, rocks, boulders; tubes on rocks; burrowing anemone; patch of shell frag
CADS	29	D	8/23/2013	12:55:05	200.8	133.0	2.7	rocky bottom	n	n	y	n	y	n	n	sandy mud, rocks, boulders; tubes on rocks; patches of shell frag; sea star, fish
CADS	30	A	8/23/2013	13:21:19	184.6	122.3	2.3	sandy mud	n	y	y	y	n	n	n	sandy mud; small to large burrows; high density of foraging tracks
CADS	30	B	8/23/2013	13:22:18	197.4	130.8	2.6	sandy mud	n	y	y	y	n	n	n	sandy mud; small to med-large burrows; tubes; short tracks, lobster trap line on bottom
CADS	30	D	8/23/2013	13:23:57	205.3	136.0	2.8	sandy mud	n	y	y	y	n	n	n	sandy mud; small to med burrows; tubes; short tracks; burrowing anemones
EREF	EREF-04	A	8/23/2013	16:52:42	201.3	130.6	2.6	sandy mud	n	y	y	y	y	n	n	sandy mud with noticeable biogenic mounding and one crab in left lower quadrant; multiple burrow openings
EREF	EREF-04	E	8/23/2013	17:31:08	197.4	130.8	2.6	sandy mud	n	y	y	y	y	n	n	sandy mud; small to med/large burrows; tracks; crab
EREF	EREF-05	A	8/23/2013	17:38:56	201.8	133.6	2.7	sandy mud	n	y	y	y	n	n	n	sandy mud; small to med/large burrows; tracks
EREF	EREF-05	C	8/23/2013	17:40:35	193.5	128.2	2.5	sandy mud	n	y	y	y	n	n	n	sandy mud; small to med/large burrows

Plan-view Image Analysis Results for CADS Survey, August 2013

Location	Station	Replicate	Date	Time	Image Width (cm)	Image Height (cm)	Field-of-View Imaged (m^2)	Sediment Type	Bedforms	Burrows	Tubes	Tracks	Epifauna	Mud Clasts	Debris	Comment
EREF	EREF-06	A	8/23/2013	17:43:52	194.4	128.8	2.5	sandy mud	n	y	y	y	n	n	n	sandy mud; small to large burrows; tubes and dense arthropod foraging tracks
EREF	EREF-06	B	8/23/2013	17:44:52	199.0	131.8	2.6	sandy mud	n	y	y	y	n	n	n	sandy mud; small to med burrows; short tracks; tubes
NREF	NREF-01	A	8/23/2013	18:09:59	201.3	130.6	2.6	sandy mud	n	y	y	y	n	n	n	details obscured by suspended sediment, burrow openings & some foraging tracks visible
NREF	NREF-01	B	8/23/2013	18:10:45	196.8	127.6	2.5	sandy mud	n	y	y	y	n	n	n	sandy mud with small-scale biogenic relive and multiple burrow openings
NREF	NREF-01	D	8/23/2013	18:12:19	204.3	133.7	2.7	sandy mud	n	y	y	y	n	n	n	sandy mud with multiple shrimp foraging tracks, shell fragment, burrow openings, and tubes visible
NREF	NREF-02	A	8/23/2013	17:57:11	199.6	132.2	2.6	sandy mud	n	y	y	y	y	n	n	sandy mud; small-med burrows; short tracks in upper left corner; couple burrowing anemones
NREF	NREF-03	A	8/23/2013	18:18:08	200.2	132.6	2.7	sandy mud	n	y	y	y	n	n	n	sandy mud; small to med burrows; several cerianthids visible

Note: 1) “ind” indicates that the sample result was indeterminate

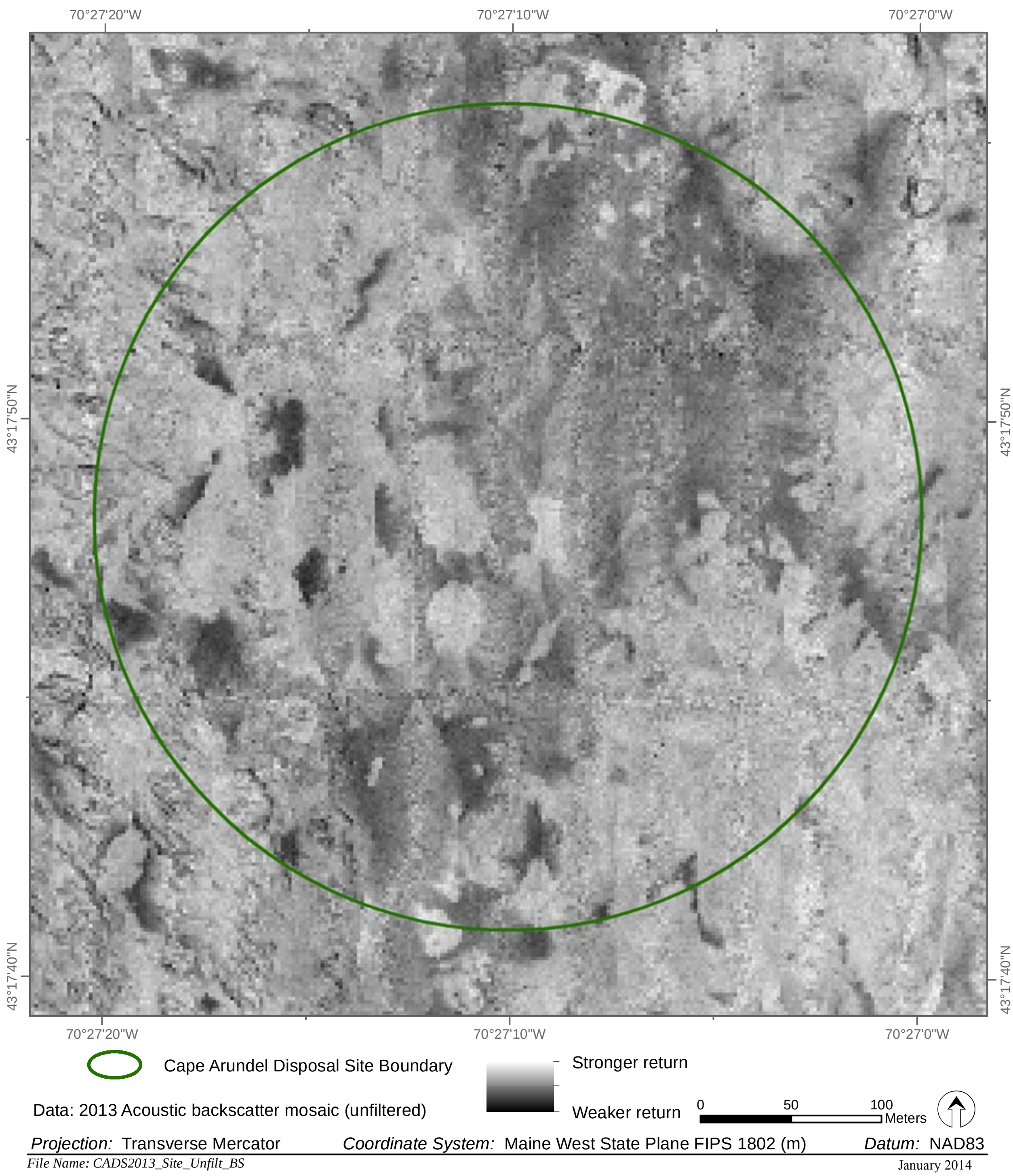
Appendix D

Grain Size Scale for Sediments

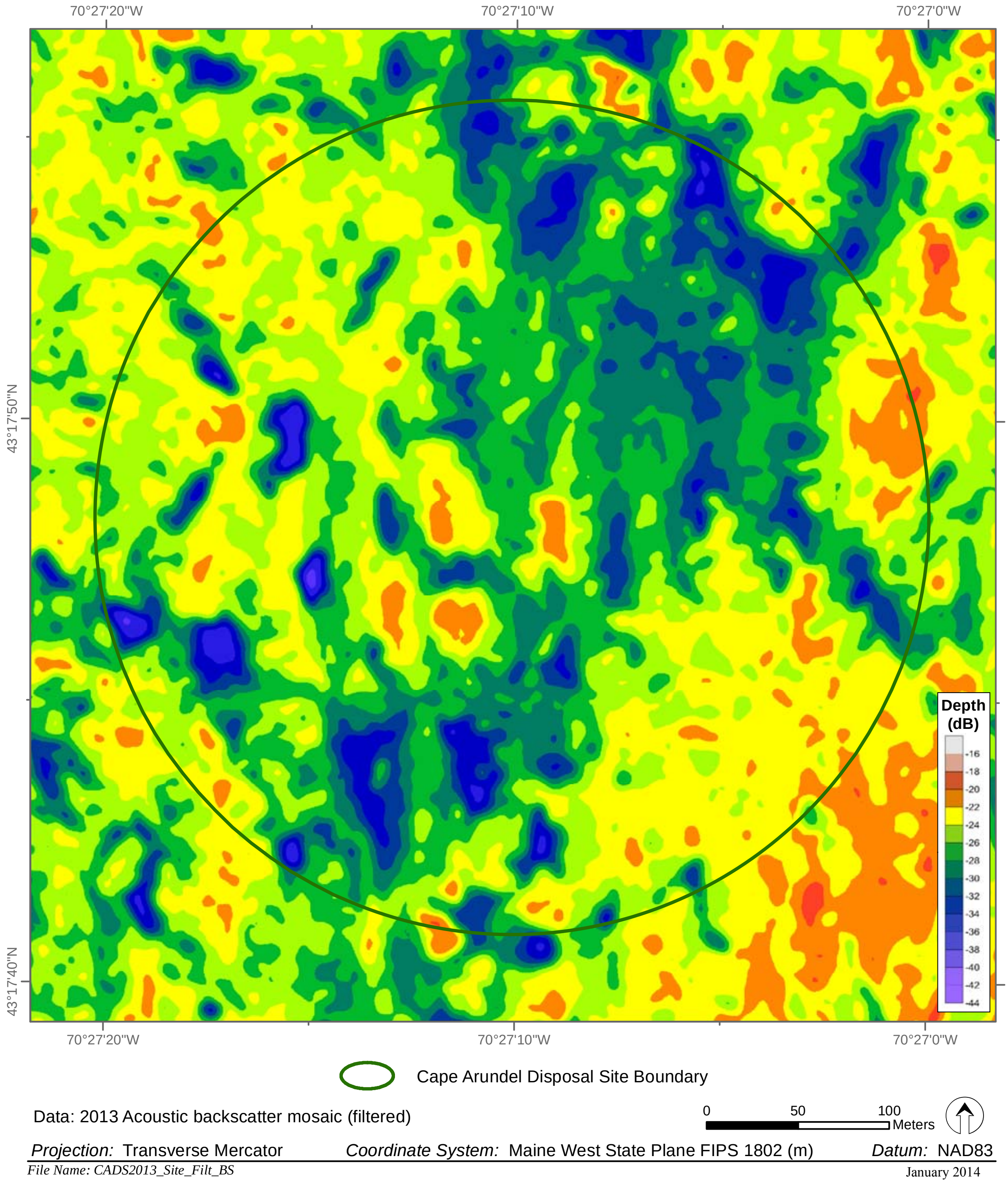
Phi (Φ) Size	Size Range (mm)	Size Class (Wentworth Class)
<-1	>2	Gravel
0 to –1	1 to 2	Very coarse sand
1 to 0	0.5 to 1	Coarse sand
2 to 1	0.25 to 0.5	Medium sand
3 to 2	0.125 to 0.25	Fine sand
4 to 3	0.0625 to 0.125	Very fine sand
>4	<0.0625	Silt/clay

Appendix E

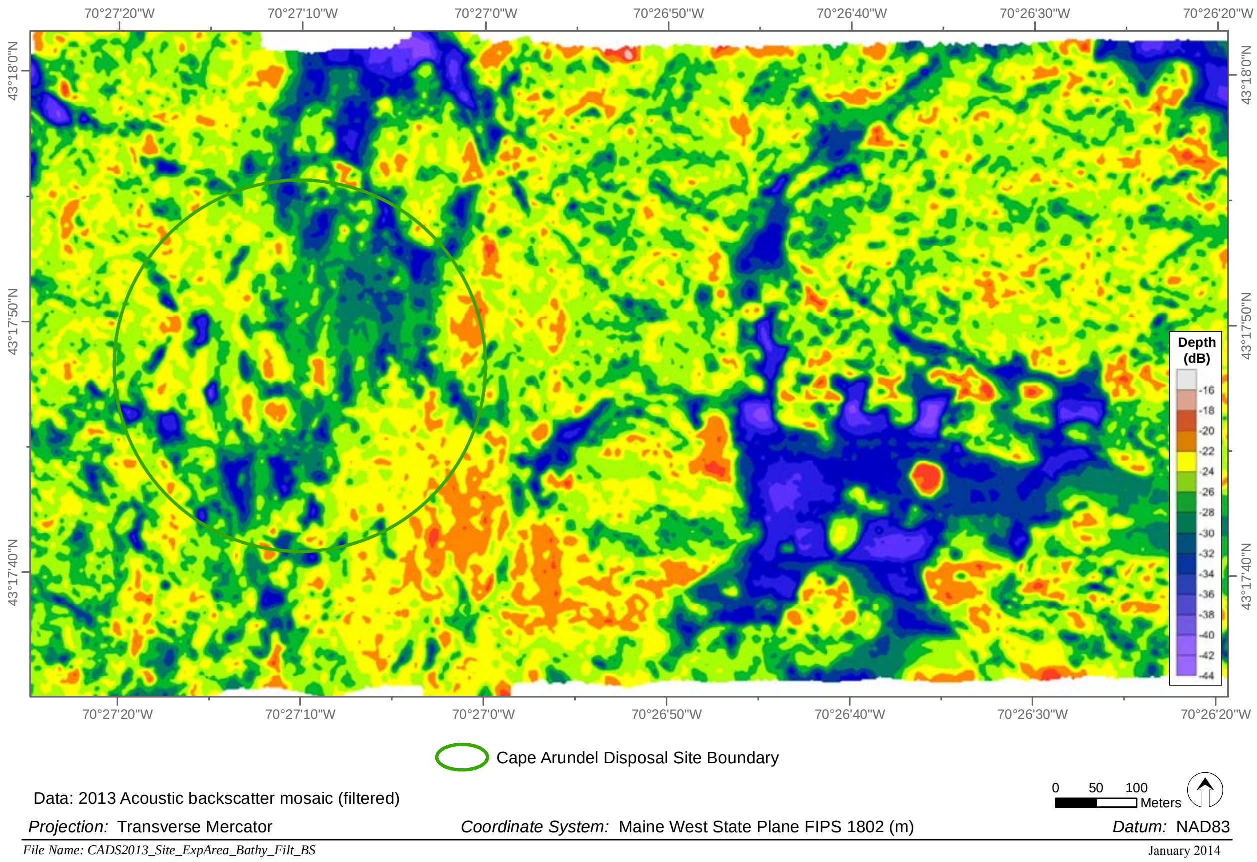
Additional Figures



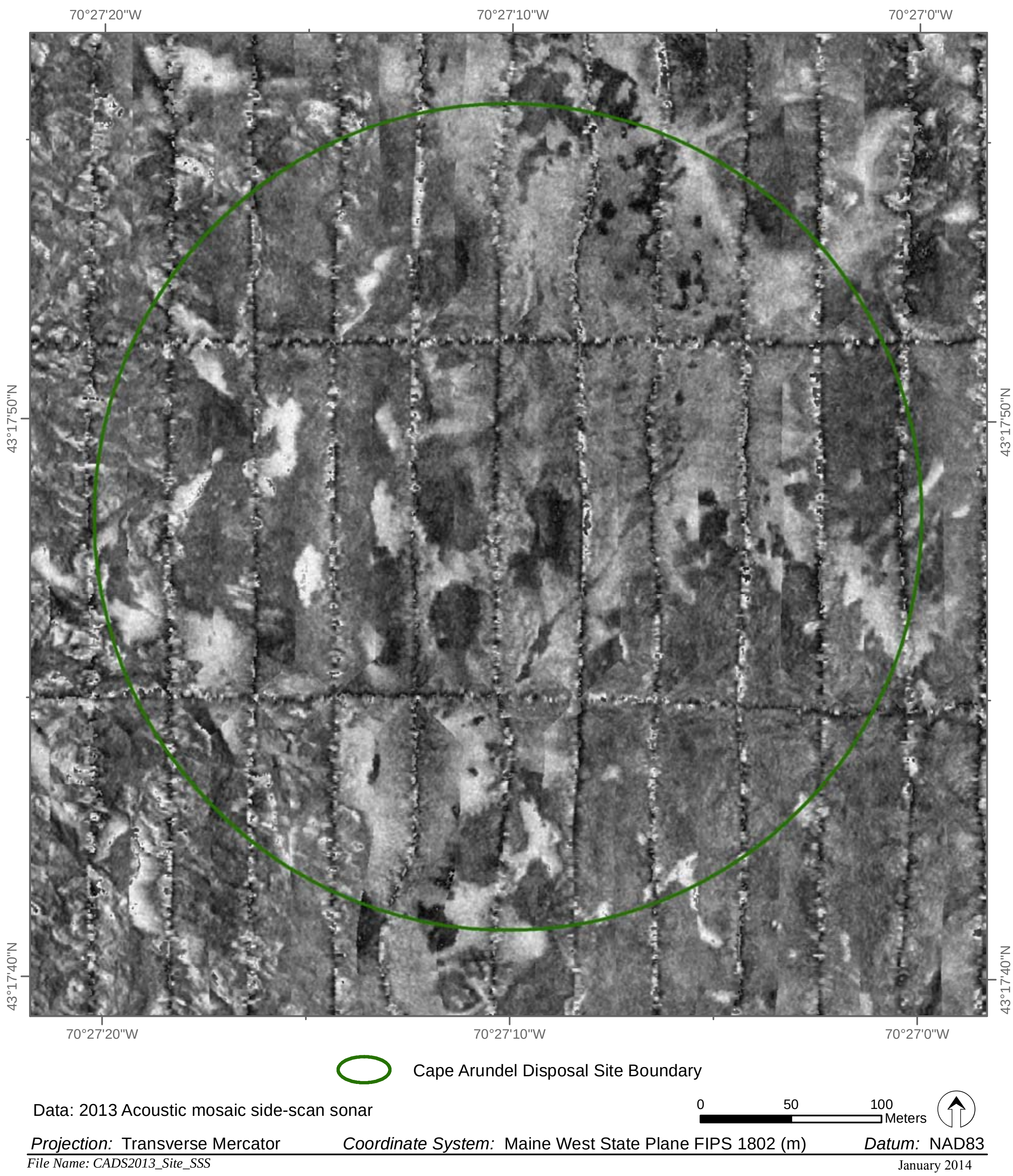
Mosaic of unfiltered backscatter data of CADS - August 2013



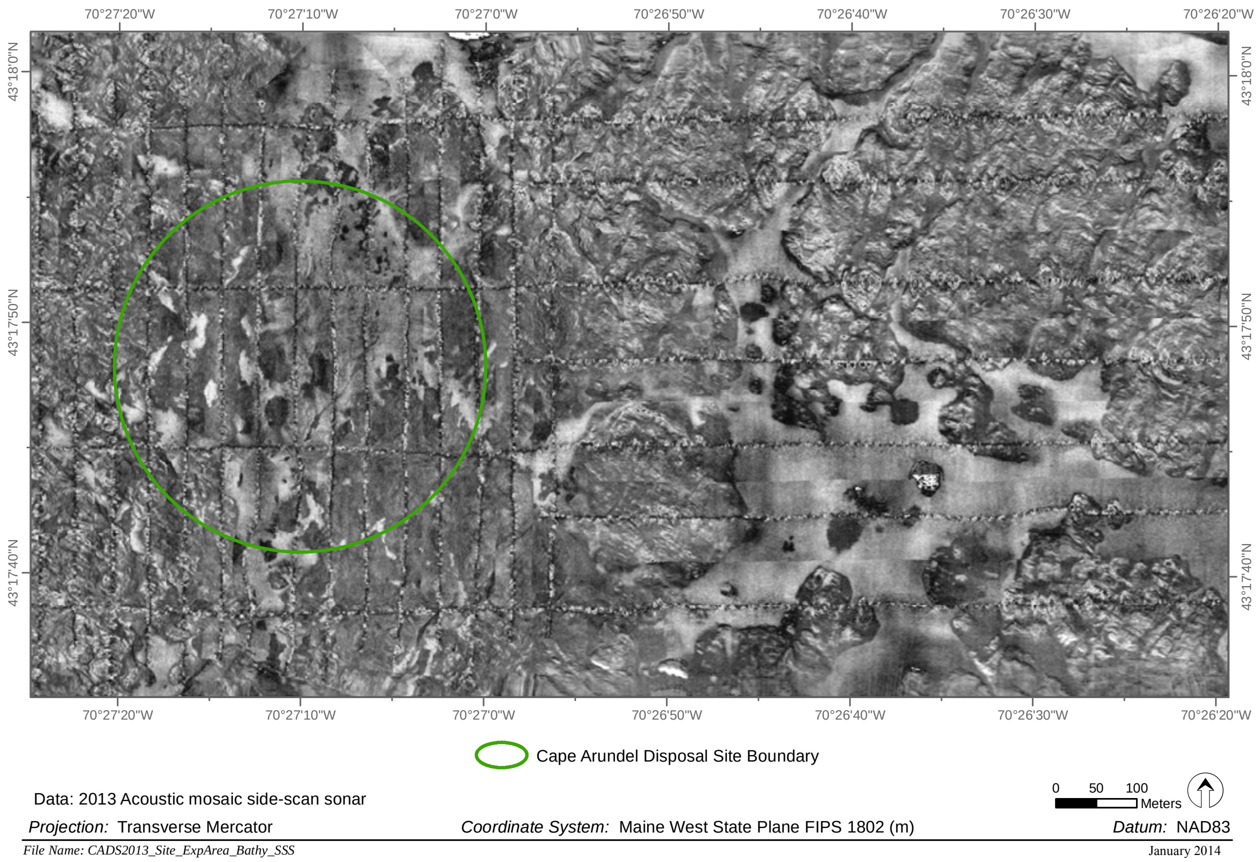
Mosaic of filtered backscatter data of CADS – August 2013



Mosaic of filtered backscatter data of CADS and expanded area - August 2013



Side-scan sonar mosaic of CADS - August 2013



Side-scan sonar mosaic of CADS and expanded area - August 2013