Island County Armor Mapping (Nearshore Data Collection and Synthesis) Final Technical Memorandum

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Introduction

The construction of shoreline armor — bulkheads, riprap, and other structures — greatly impedes the natural coastal processes responsible for littoral sediment supply and transport. This can have negative impacts on beach formation, forage fish spawning habitat, and the accretion shoreforms that protect barrier estuaries and lagoons. In Island County, shore armor has been mapped by several separate groups between the years 2002 and 2005, but these data are often inconsistent and have varying levels of accuracy.

In May and June of 2016, Coastal Geologic Services Inc. (CGS) used boat-based methods and a high-accuracy GPS with a laser rangefinder attachment to record the presence, location, and characteristics of marine shore armor in Island County. Previously mapped data were compared to the updated mapping to track changes in shore armor over the last 14–16 years and discover omissions in prior mapping. In doing so, CGS hopes to set a precedent for future mapping and analysis to aid in the creation of a long-term dataset for use in multiple planning and restoration projects.

Methods

Data Collection and Processing

CGS staff (Jim Johannessen, Branden Rishel, Andrea MacLennan, and Jon Waggoner) completed boat-based field mapping for nearly all of Island County's 214 miles of marine shoreline in May and June of 2016. This mapping was scheduled for some of the highest tides of the year, to maximize visibility of lower armor and armor behind drift logs, and to enable access to shallow areas. Using a mapping-grade GPS with a laser rangefinder accessory, start and end points of armor presence were recorded, along with:

- Armor condition: OK, Functional but Failing, or Derelict
- Armor material: Rock, Concrete, Wood, Creosoted Wood, or Other
- Tidal elevation of armor toe: Below Mean Sea Level, Below Mean Higher High Water (and above MSL), Below the Ordinary High Water Mark (and above MHHW), in the Dunegrass, or farther Upland
- Historical feeder bluff status: Yes, No, or Unknown

Armor segments may have more than one material, but the other attributes are mutually exclusive. Armor from different construction projects and different real estate parcels was lumped together into a single feature when it had the same condition, elevation, and historical feeder bluff status — except armor containing creosoted wood was separated. Armor condition and elevation attributes represent a snap judgement from a distance, definitely not an engineering assessment.

Points were post-processed in-house to increase accuracy using Trimble Pathfinder Office, then loaded into ArcGIS. Armor segments were digitized using the start and end points of the armor. The new line features were spatially joined to their respective starting GPS points, inheriting attributes such as time, date, post-processing method and equipment used. Areas where point location errors occurred that had not been addressed in post-processing were hand-corrected using 3-inch resolution aerial photos from 2014 and shoreline oblique aerial photos.

Several areas were impossible to map by boat, such as very shallow embayments and Davis Slough (northeast Camano). Marinas were also mapped remotely, because of traffic, privacy, and horizontal visibility issues. All of these areas were mapped remotely using 3-inch resolution aerial photographs from 2014, the CGS ground photo library, and site plans from other CGS work. Some attributes, especially armor material and condition, are often difficult to determine remotely. The remotely mapped areas are clearly noted in GIS attributes to indicate a lower confidence in the data. Remotely mapped armor totaled 6.1 miles, or 11% of mapped armor.

Field and remote mapping data were snapped to the Washington State DNR ShoreZone shoreline (2001) and a GIS topology check was performed to ensure that the lines are perfectly coincident. Pre-snap line lengths were preserved in a separate data field. The minimum mapping unit was 20 feet (FT); very short armor segments and changes in armor attributes were not recorded. See Figure 1 (attached) for an example of how laser offset GPS points were constructed into lines, attributed with armor characteristics, and snapped to the ShoreZone shoreline.

Each armor segment has a "notes" field for field and processing notes. New armor mapping may contain notes about unusual materials, anchored logs, structures, fill, and whether geometry was modified from field data. A four-digit number (or range of numbers) is the file number of a field photograph. Historical armor mapping notes and comments were copied to this field.

Data specifications and armor mapping methods followed next-generation standards developed this year by CGS for the Beach Strategies project in progress for the Estuary and Salmon Restoration Program (ESRP), in cooperation with the Washington Department of Fish and Wildlife, the Puget Sound Ecosystem Monitoring Program, and the Puget Sound Partnership. These methods were tested in over 130 miles of armor mapping in Jefferson and Mason Counties. A rigorous quality assurance and quality control process was applied to ensure that the data products are correct, consistent, and of high quality. Attribute domains were used to standardize GIS fields for elevation, condition, and historical feeder bluff status.

Data Translation

Historical armor mapping data from 2002–2004, including data from the Washington State University Beach Watchers, was provided by Island County as unprocessed GPS points, lines, and polygons. This data source provides a higher resolution than the *Puget Sound Change Analysis* (Simenstad et al. 2011), which lumped armor into minimum mapping units of 30 meters (98.4 FT) and excluded shorter segments shorter than this. Only the GPS data from Beach Watchers within AS (accretion shoreform) or NAD (no appreciable drift) shoretypes were processed, to help fill in areas of the *Feeder Bluff Mapping* database (MacLennan et al. 2013) that were assessed to be of lower quality (MacLennan and Waggoner 2016).

The remaining historical armor data came from CGS' previous mapping effort, *Feeder Bluff and Accretion Shoreform Mapping in Island County* (Johannessen and Chase 2005). Armor mapping from the *Feeder Bluff Mapping* database was combined with processed 2002–2004 GPS data from AS and NAD shores to create a comprehensive, historical coverage of Island County shore armor (Figure 2).

Redundant and inapplicable 2002–2004 GPS data were discarded (e.g., outfall points, eelgrass, trails, and a duck blind). Many line features were recorded as GPS polygons, so these were converted to lines and individually checked. New fields were added and populated with the existing data gleaned from other fields in such a way as to make them comparable to the new 2016 mapping. For example, information from a general "Notes" field sometimes helped populate fields regarding the armor material or condition. Specifically, historical data fields and notes were used as follows:

- "Severe damage" or "collapsing" were considered *derelict*
- "Damaged", "moderate" damage, or "rotting" were mapped to *functional but failing*
- "Minor" damage was considered *OK*.

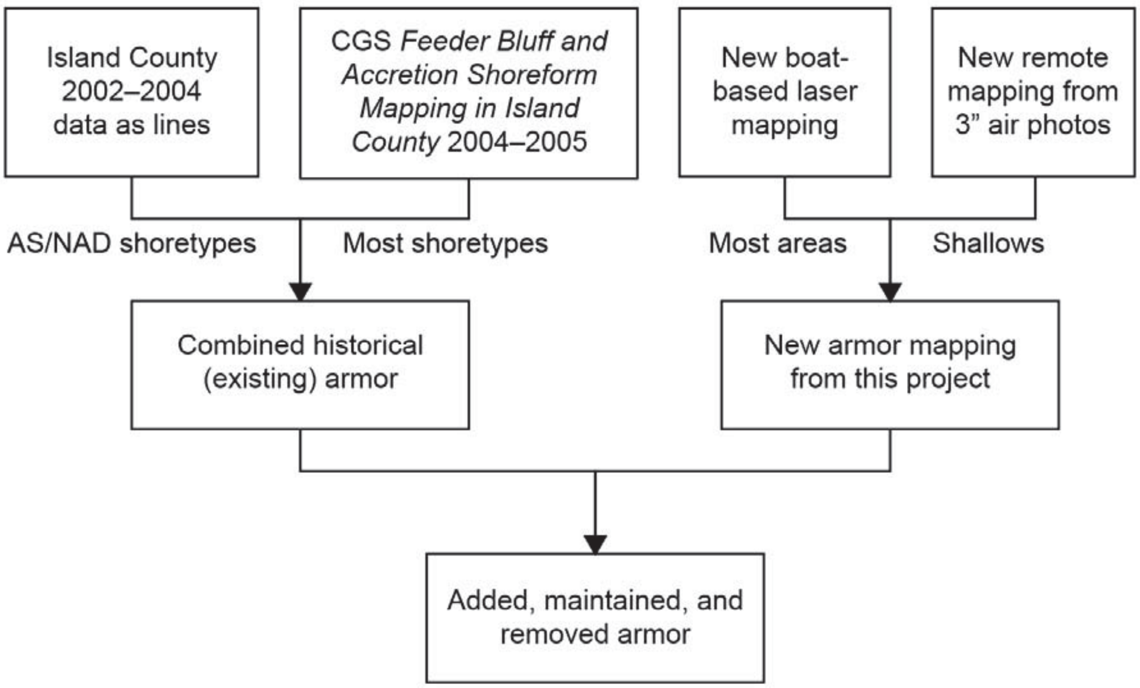

Figure 2. Data sources and comparison flowchart.

Data Comparison

The combined ShoreZone shoreline-snapped historical armor data described above were compared with new mapping from this project. Results were sorted into armor *added*, *maintained* between datasets, and *removed* (Figure 3 and Map Folio). Caution should be used in interpreting these results because of problems with the historical data and artifacts of snapping to the ShoreZone shoreline. The value and relevance of the new armor mapping likely far exceeds the value and relevance of the comparison.

Figure 4 shows the following three examples of problems with the data comparison:

- *Added* armor areas certainly include armor that was missed in previous mapping efforts. For example, there is 4,123 FT of armor east of Oak Harbor that was not mapped as armor, but it is visible in aerial photos going back decades. Some low height, high elevation armor may have been missed in 2005 CGS mapping if it was obscured by drift logs — this mapping did not always take place at higher tides. Much of the *added* armor looked like new construction, but it is impossible to say how much is actually new since 2002–2004.
- *Maintained* armor may represent armor that was unchanged between mapping efforts, or armor that was rebuilt. Because of differences in mapping accuracy, minimum mapping units,

and ShoreZone shoreline snapping, some maintained armor may be transposed slightly along the shoreline. Figure 4 shows an example of this. For this reason, data users may decide to exclude from future analysis armor segments shorter than 20 FT, the minimum mapping unit. This totals about 3,125 FT of armor, or 0.28% of the total shore length.

- *Removed* armor segments may also represent armor that was erroneously mapped in historical armor mapping. Areas in marinas, especially, show many separate armor removals that seem unlikely. Better resolution aerial photos may have helped correctly mark unarmored areas that were previously considered armored.

Results

About 53.8 miles (25%) of Island County shores are armored (Table 1). Larger concentrations of armor are found in areas with dense, narrow residential parcels, such as southwestern Camano and Utsalady Bay (Figures 3 and 5). The shores of the Naval Air Station near Ault Field and in Crescent Harbor have very long stretches of homogenous armor. These areas also have the most armor below mean sea level.

Table 1. Total armor length comparison.

	Removed, FT	Maintained, FT	Added, FT	Current (Maintained + Added)
Totals	31,997	198,597	85,364	283,961
In miles	6.1	37.6	16.2	53.8
As percent of total shoreline	2.8%	17.3%	7.4%	24.7%

It is difficult to draw conclusions from the armor comparison. Several miles of *added* and *removed* armor probably represent problems with historical armor data. The reasons for comparison problems include:

- Some 2002–2004 GPS data collected with low-accuracy receivers
- 2002–2004 data did not cover all AS and NAD shores
- Boat-based mapping in Johannessen and Chase (2005) may not have taken place at higher tides, so shorter armor and armor behind drift logs may have escaped notice
- 2005 boat-based mapping did not use a laser offset rangefinder
- 2005 remote mapping could not use high-resolution aerial photos
- The way the data snapped to the ShoreZone shoreline
- Differences between the ShoreZone shoreline and the real shoreline

The armor comparison also shows where new armor has been installed since 2005 (e.g., Dave Mackie Park) and armor was removed (e.g., Deception Pass State Park's Cornet Bay Day Use Area).

Table 2 shows recorded characteristics of armor mapped during this project. A minority of historical armor segments contained enough information to make a comparison, so apparent changes in armor characteristics were not analyzed. Only the location of the armor was considered for the purposes of placing armor in the *maintained* or *added* columns of this table.

In 2016, half of the armor was found to extend below mean higher high water. Of the armor that appeared to extend below mean sea level, about 9,276 FT was along shores of the Naval Air Station, both in Crescent Harbor and west of Ault Field. Armor at upland elevations may be underrepresented in the data. In field mapping, it is sometimes difficult to distinguish upland retaining walls from armor that may never be reached by waves — both of which have little effect on coastal processes.

Although armor materials and elevation were unlikely to have changed between historical and current armor mapping, it is quite possible that armor condition has degraded for some segments. The 13,281 FT of added derelict armor may mostly consist of newly mapped old armor, but it also included some poorly constructed new armor and armor damaged by recent landslides. Many of the derelict armor GIS features have "notes" which reference field photos in the attached Photo Collection.

About 4.8 miles of Island County shores are armored with creosoted wood, which is toxic to marine life.

Table 2. Attributes of armor mapped in this project. *Note that an armor segment may have more than one material, so material types add to more than 100%.

	Category	Maintained, FT	Added, FT	Current (Maintained + Added)	Percent of Current
Elevation	Below MSL	18,036	4,060	22,095	8%
	MSL-MHHW	97,611	20,697	118,308	42%
	MHHW-OHWM	78,030	53,302	131,332	46%
	Dunegrass	4,917	6,725	11,643	4%
	Upland	3	580	583	0%
Condition	Derelict	10,376	13,281	23,657	8%
	Functional but failing	22,513	12,893	35,406	12%
	OK	165,708	59,189	224,898	79%
Material	Rock	83,660	48,662	132,321	47%*
	Concrete	120,981	40,166	161,146	57%*
	Wood	95,535	37,163	132,698	47%*
	Creosoted wood	20,046	5,224	25,270	9%*
	Other	20,044	3,892	23,936	8%*

Table 3 shows armor totals by net shore-drift cell, including the percent of each drift cell that is armored. Six net shore-drift cells were more than half-armored. An astounding 71% of one cell is armored, in Utsalady Bay. Figure 5 shows the locations of these cells.

The attached Map Folio reveals changes in armor, countywide, at a 1:24,000 scale. Figure 3 provides an index grid for the Map Folio. For further detail, please explore the attached GIS data and Photo Collection.

Table 3. Summary of changes in mapped armor by net shore-drift cell. Unarmored cells omitted. Also see Figure 5.

Net Shore-Drift Cell	Removed, ft	Maintained, ft	Added, ft	Current (Maintained + Added)	Cell Length	Percent Armored
CAM-1	78	870	173	1,043	8,260	13%
CAM-1/CAM-13	747	1,369	316	1,685	18,704	9%
CAM-2	97	2,950	992	3,942	5,548	71%
CAM-3	2,019	24,951	3,760	28,711	71,143	40%
CAM-4	80	841	187	1,028	3,886	26%
CAM-5	486	13,206	2,832	16,039	28,986	55%
CAM-6	346	1,169	370	1,540	6,897	22%
CAM-7	144	2,597	1,128	3,725	7,273	51%
CAM-8	381	24,027	3,321	27,348	65,950	41%
CAM-8/CAM-9	639	1,320	48	1,368	13,589	10%
CAM-10	150	3,437	540	3,977	22,337	18%
CAM-11		355	309	664	8,020	8%
CAM-12	57	1,360	618	1,978	5,350	37%
IS-1	353	8,875	9,991	18,866	52,734	36%
IS-1/IS-3	1,385	1,603	-	1,603	2,987	54%
IS-2	267	1,415	2,002	3,417	8,316	41%
IS-2/IS-3	2,862	557	-	557	10,330	5%
IS-3	584	3,462	-	3,462	10,235	34%
IS-4	188	1,596	4,908	6,504	44,592	15%
IS-4/IS-5	5,490	3,729		3,729	9,218	40%
IS-5	39	1,314	1,737	3,051	13,151	23%
IS-6	74	3,631	5,243	8,874	37,786	23%
WHID-1	525	4,788	1,137	5,925	20,699	29%
WHID-2	377	3,806	1,731	5,537	19,417	29%
WHID-3	487	10,424	647	11,071	31,349	35%
WHID-4	178	1,646	1,229	2,874	11,541	25%
WHID-5	19	-	50	50	1,204	4%
WHID-6	58	-	350	350	1,295	27%
WHID-7	502	4,171	1,399	5,571	11,472	49%
WHID-8.1	912	9,122	4,908	14,029	78,275	18%
WHID-8.2	-	-	284	284	3,124	9%
WHID-8.3	65	1,277	165	1,442	3,763	38%
WHID-8-NAD	-	-	139	139	13,163	1%
WHID-9	386	2,658	1,210	3,868	14,463	27%
WHID-10	42	1,016	724	1,740	5,989	29%
WHID-11	36	1,298	350	1,648	3,373	49%
WHID-11-NAD	-	8	24	32	3,118	1%
WHID-12	166	1,957	601	2,557	5,911	43%
WHID-12/WHID-13	-	-	1,132	1,132	4,043	28%
WHID-13	411	2,055	2,105	4,161	23,059	18%
WHID-14	267	1,948	3,124	5,073	16,386	31%
WHID-14/WHID-15	1,704	6,498	730	7,229	19,101	38%
WHID-14-NAD	781	529		529	1,310	40%
WHID-15	62	423	363	786	7,846	10%
WHID-16	-	4,681	905	5,587	11,099	50%
WHID-17	-	1,478	5,340	6,818	24,731	28%
WHID-18	-	-	528	528	3,310	16%
WHID-19	8	204	99	303	6,150	5%
WHID-20	611	3,457	5,845	9,303	43,071	22%
WHID-20-NAD	2,809	2,749	-	2,749	5,558	49%
WHID-21	171	971	471	1,441	7,363	20%
WHID-22	514	759	62	821	10,331	8%
WHID-23	-		648	648	5,704	11%
WHID-24	665	946	620	1,567	12,810	12%
WHID-24/WHID-25	-	-	181	181	13,517	1%
WHID-25	431	7,633	6,958	14,590	76,817	19%
WHID-26	28	1,065	1,187	2,252	55,056	4%
WHID-26-NAD	694	1,098		1,098	1,792	61%
WHID-27	299	3,114	437	3,551	25,016	14%
WHID-28	2,318	12,185	1,203	13,388	45,493	29%

Data Utility

These 2016 armor mapping data are made accessible and comparable to other shoreline data by transposing the data to the Washington State DNR ShoreZone shoreline. The non-transposed, true location lines are also provided within the project geodatabase. By thoroughly documenting field data collection and processing methods for this project, CGS hopes to develop a more efficient and high-quality mapping method for future use in tracking changes in shoreline armoring. Shorelines are dynamic systems; developing consistent mapping methods is the most accurate way to observe changes in shoreline armor.

CGS also hopes the results of this project will guide future shore restoration. Net shore-drift cells with a greater proportion of armor may be prioritized for restoration. In particular, removal of unnecessary armor near the origin of net shore-drift cells and armor with creosoted wood may provide the best restoration benefit.

CGS linearly referenced net shore-drift cells may be used to find down-drift ecological benefits, such as documented forage fish spawning beaches. This *Island County Armor Mapping* data may be combined with other CGS data products, such as digitized feeder bluff crests and adjacent structures, to discover feasible restoration projects. Armor data can also be used to select parcels for conservation (also called preservation). In particular, unarmored shore segments with mapped feeder bluffs that are up-drift of important habitat areas would be of higher conservation value.

Funding

This project made possible with funding from the Salmon Recovery Funding Board, the NOAA Pacific Coastal Salmon Recovery Fund, and the United States Environmental Protection Agency under Assistance Agreement [PC-00J90301] National Estuary Program funds.

References

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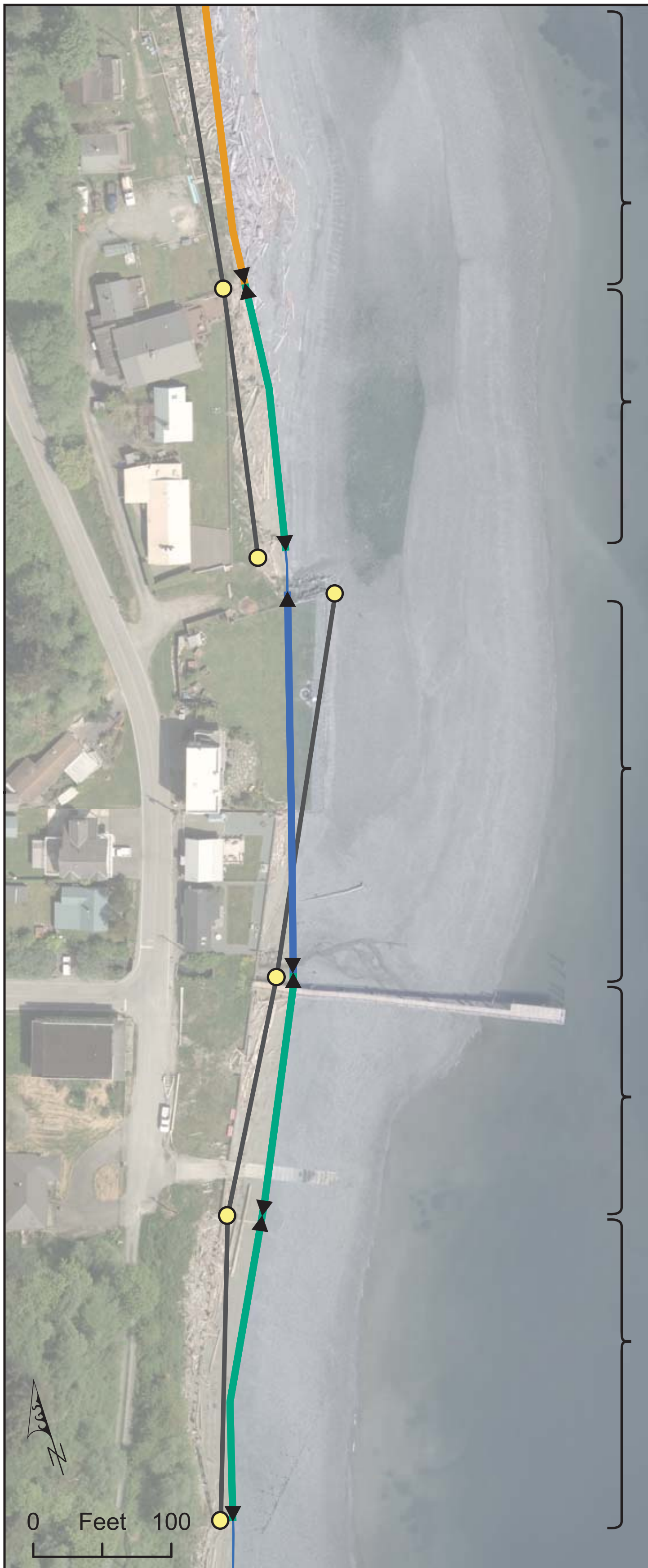
Attachments:

Figure 1. Schematic example to help explain field mapping methods.
Figure 2. Data sources and comparison flowchart (above in text, not attached).
Figure 3. County-scale map showing mapped armor changes, with an index grid for the Map Folio.
Figure 4. Armor comparison problems.
Figure 5. Island County net shore-drift cells by percent armored, for use with Table 3.
Map Folio. 50 sheets of 1:24,000 maps showing removed, maintained, and added armor. See Figure 3 for index grid.
Photo Collection. Field photos referenced by "notes" fields in GIS data.



Material					Historical Feeder Bluff	Condition	Pre-Snap Length	Armor Elevation
Rock	Concrete	Wood	Creosoted	Other				
0	1	1	0	1	No	Ok	588'	OHWM-Upland
0	1	0	0	0	No	Ok	197'	OHWM-MHHW
0	1	1	1	0	No	Ok	281'	MHHW-MSL
0	1	0	0	0	No	Ok	176'	OHWM-MHHW
0	0	1	0	0	Yes	Derelict	221'	OHWM-MHHW

- Laser offset GPS points with constructed lines
- Snapped to ShoreZone shoreline, OHWM-upland
- Snapped to ShoreZone shoreline, OHWM-MHHW
- Snapped to ShoreZone shoreline, MHHW-MSL

Figure 1. Schematic example showing laser offset GPS points, constructed lines, and snapped lines with table of attributes (data slightly modified for clarity).

Island County Armor Mapping

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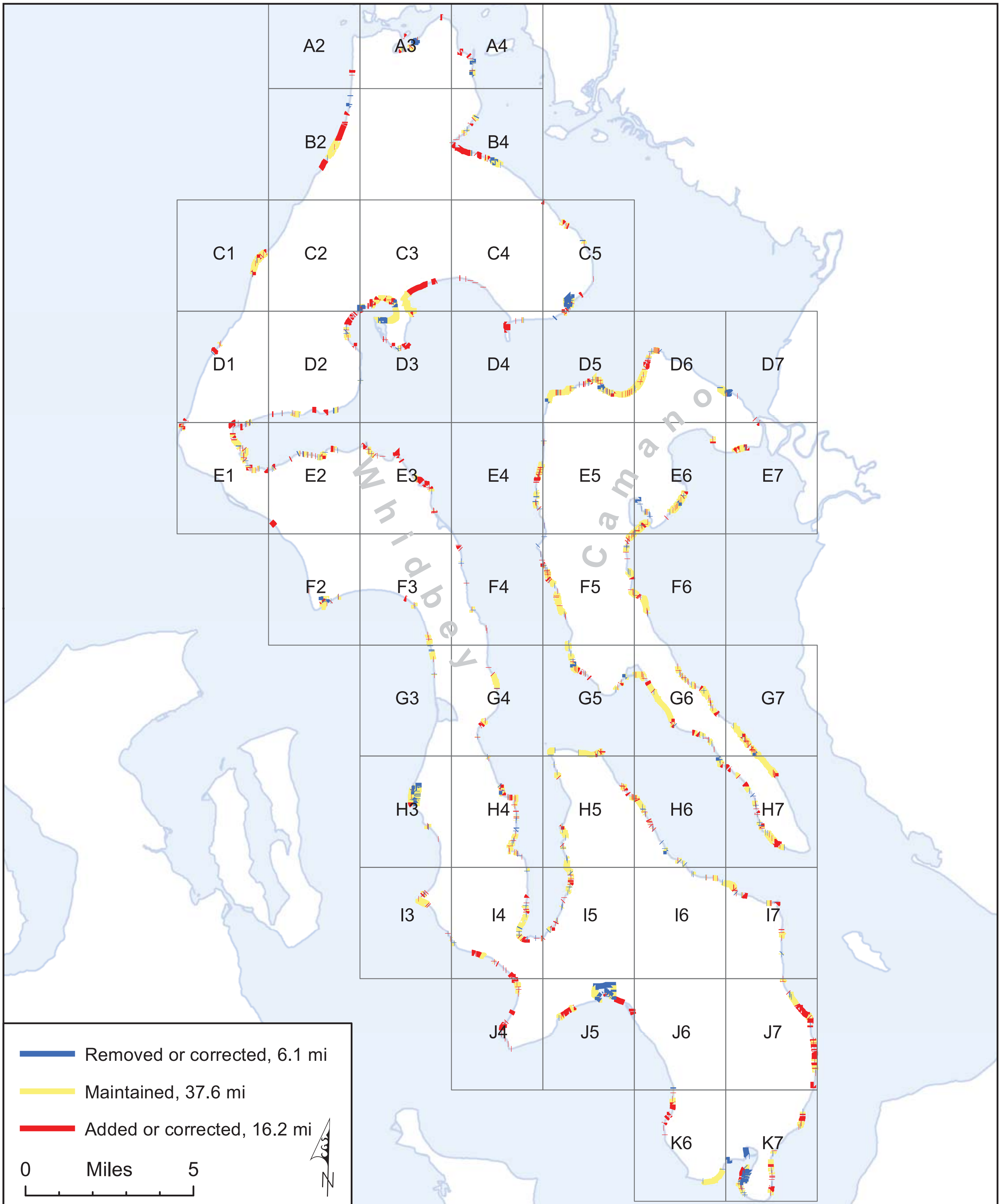

Figure 3. Change in mapped armor throughout Island County, with index grid of map folio pages.

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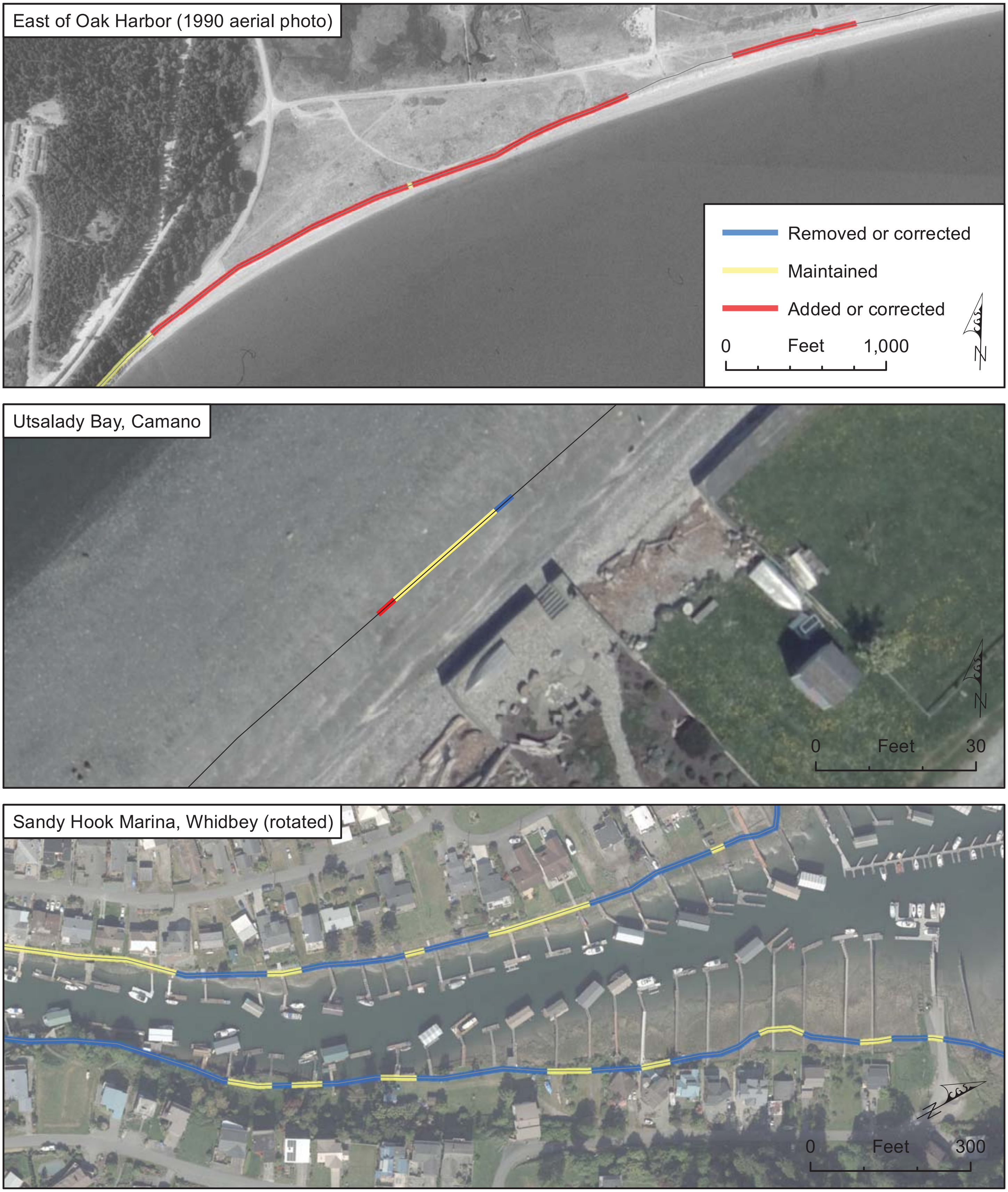

Figure 4. Armor comparison problems. Armor omitted from historical data (top), Armor sliding alongshore due to snapping or accuracy differences (middle). Armor mapped as removed, likely a historical commission error (bottom).

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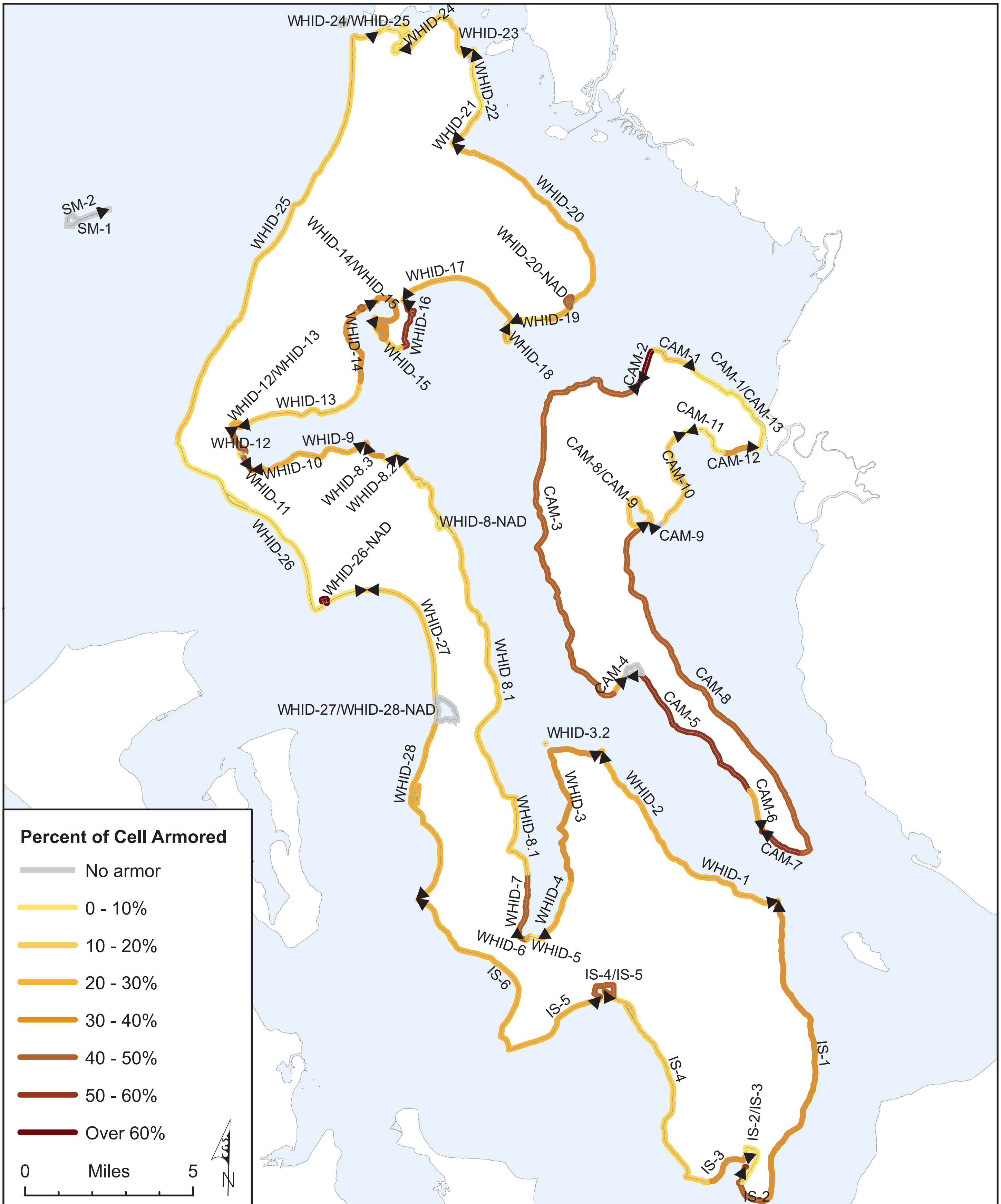

Figure 5. Net shore-drift cells in Island County.

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