

## **A REVISED GEOMORPHIC, SHORE PROTECTION AND NEARSHORE CLASSIFICATION OF THE CANADIAN AND UNITED STATES SHORELINES OF LAKE ONTARIO AND THE ST. LAWRENCE RIVER**

**Christian J. Stewart**

Christian J. Stewart Consulting  
1618 Candela Place, Victoria, British Columbia, CANADA V8N 5P4

### **ABSTRACT**

In 2000, the International Joint Commission (IJC) initiated the Lake Ontario – St. Lawrence River Water Level Regulation Study (LOSLRS), a comprehensive study to examine changes to the 1956 criteria for Lake Ontario-St. Lawrence River water levels and flow regulation. As part of this activity, the LOSLRS Study Board established the Coastal Processes Technical Working Group (CWG), whose goals are to: 1) determine the possible response of both Lake Ontario and St. Lawrence River shoreline types to changes in water levels and flows that may occur as a result of regulation changes; 2) determine various impacts that may result to the riparian interest group along these shorelines, and 3) using the above evaluations, provide recommendations of new regulation criteria that best considers the needs of the riparian interest group.

The CWG is making use of the Flood and Erosion Prediction System (FEPS)(developed by Baird & Associates) to conduct analyses for the Lake and the Upper River. A key input data set to the FEPS is shoreline classification information that provides details on the geomorphic shoreline type, nearshore geology and type and quality of shoreline protection that is present along the shoreline. As such a “three-tiered” shoreline classification scheme - initially developed during the 1991-1993 Great Lakes Water Level Reference Study and revised for use over the past 10 years in other regional Great Lakes shoreline studies - was further revised for use in the LOSLRS and then applied to both the Canadian and U.S. shorelines of the Lake and the River to produce a comprehensive and coordinated GIS database of coastal data. This paper will summarize the revisions and changes made to the classification scheme and highlight its application to the Canadian and U.S shorelines of the Lake and the River. A series of statistical summaries of the shore classification data are presented, and additional data inputs that were collected for input to the FEPS are also described.

### **INTRODUCTION**

In 2000, the International Joint Commission (IJC) initiated the Lake Ontario – St. Lawrence River Water Level Regulation Study (LOSLRS), a comprehensive study to assess and evaluate the current criteria used for regulating water levels on Lake Ontario and in the St. Lawrence River. The Mission of the Study is to consider, develop, evaluate and recommend updates and changes to the 1956 criteria for Lake Ontario-St. Lawrence River water levels and flow regulation, taking into account how water level fluctuations affect all interest groups and the changing conditions in the system including climate change.

As part of this activity, the LOSLRS Study Board established the Coastal Processes Technical Working Group (CWG), whose primary purpose is to develop and implement methods to measure the physical impact of water level regulation on coastal and riverine shorelines within the study area. The key goals of the CWG are to: 1) determine the possible response of both Lake Ontario and St. Lawrence River shoreline types to changes in water levels and flows that may occur as a result of changes to the operation of the existing control structures on Lake Ontario at Cornwall; 2) determine the various impacts that may result to the riparian interest group along these shorelines, including possible flooding or low water level scenarios; and 3) using the above evaluations, provide recommendations of new regulation criteria that best considers the needs of the riparian interest group.

In conducting the above evaluations, the CWG is making use of the Flood and Erosion Prediction System (FEPS) – a GIS based model for evaluating flood and erosion impacts – to conduct analyses for the Lake and the Upper River to Cornwall-Massena. The FEPS has been developed over the course of the past seven years by W.F. Baird & Associates (Baird) while working on a number of large scale projects including the Lake Michigan Potential Damages Study (LMPDS) and the Lower Great Lakes Erosion Study (LGLES), both of which are being carried out by the U.S. Army Corps of Engineers (USACE).

A key input data set to the FEPS is shoreline classification information that provides details on the geomorphic shoreline type, nearshore geology and type and quality of shoreline protection that is present along the shoreline – each of which is a component that can influence the erosion sensitivity of the shoreline. As such a “three-tiered” shoreline classification scheme - initially developed during the 1991-1993 Great Lakes Water Level Reference Study (Stewart and Pope, 1993a and b) and revised for use in the LMPDS (Stewart, 1997 and 1998a) and the LGLES (Stewart, 1999) – was further revised for use in this study and then applied to both the Canadian and U.S. shorelines of the Lake and the River to produce a comprehensive and coordinated GIS database of coastal data.

This paper will summarize the revisions and changes made to the classification scheme and its application to the Canadian and U.S shorelines of the Lake and the River. A series of statistical summaries by Shore Unit will also be presented.

## **METHODOLOGY**

### **Shore Classification Scheme Revision and Development**

The development of a revised shoreline classification database for the LOSLRS is based on and builds upon a number of previous shoreline classification efforts that have taken place for both the U.S. and Canadian shorelines of Lake Ontario and the St. Lawrence River. This includes the shore classification work conducted in the 1991-1993 Great Lakes Water Level Reference Study (Stewart and Pope, 1993a and b; Geomatics International, 1992) as well as the work conducted in the LGLES (Stewart, 1999). In addition, a number of additional classification schemes and related data were examined for use in this effort (Stewart, 2001). This included: a classification by the Ontario Ministry of Natural Resources (199?) who were developing a set of criteria and procedures for classifying the Canadian Great Lakes shoreline that would in turn support the

definition and implementation of shoreline hazard policies; a classification by the Lake Ontario Waterfront Revitalization Trust (Rob Nairn, personal communication); a classification by Environment Canada's Environmental Protection Branch who conducted a shore classification relative to oil spill sensitivity for the Lake and the River (Environment Canada and U.S. Coast Guard, 1994); and a classification created for the Quebec portion of the St. Lawrence River (Melancon, 1997).

Information from these additional classification exercises was utilized to make revisions to the "core" classification scheme and produce a comprehensive scheme for the LOSLRS that would encompass and capture all possible shoreline, nearshore and shore protection types. The LOSLRS Classification Scheme is presented below in Table 1.

Key changes to note in this version of the classification scheme relative to its previous application in the LGLES (Stewart, 1999) are:

- 1) The development of a unique numeric identifier for each category in the classification: This was required for ease of programming in the FEPS relational database. Under the previous classification scheme, some categories in the different tiers had the same alpha-numeric identifier (e.g., 1A for Shore Geology and 1A for Nearshore Geology). When querying the database, such a condition would produce errors and as such the change was required;
- 2) The removal of the "Bluff With Beach" Shore Type category: It was felt that whether a beach was present in front of a bluff was simply a function of when the photo or video being used was taken. If the beach had substantial width and was permanent, then it fell in the Beach (140) category.
- 3) The refinement of some of the shore types to reflect greater diversity of sub-shore types: For example, the Sandy Beach category (140) has been expanded to include whether it is a "relict" deposit (141), artificial deposit (142), or a natural deposit (143). Similar detail has been added to the Low Bank, Bedrock and Coarse Beach categories.
- 4) The addition of a Marine / Leda clay category in both the shore type and nearshore geology classification to reflect the occurrence of this shore type on the St. Lawrence River.
- 5) The revision of the Shore Protection "Quality Quantifier" to only 3 classes: As the FEPS model will focus primarily on the impact of Class 1 (high quality) and Class 2 (moderate quality) structures, it was felt that the previous Class 3 and Class 4 structures could simply be grouped into one category.
- 6) The addition of "Creek Bank" shore type and "Creek / River Bed" nearshore geology: The new digital shoreline for the LOSLRS encompassed many stream and river banks for some distance inshore. As these were not to be modeled in FEPS, they needed to be distinguished from the "open coast" shore types by a unique "creek/river" category.
- 7) The addition of a "Harbor Muds and Silts" nearshore type: This was to reflect the nature of many large embayments and harbors where muds and silts ("muck") are commonly deposited.

**Table 1 – LOSLR Shoreline Classification Scheme****Geomorphic Classification**

- 100 - Sand or Cohesive Bluffs (Till or Lacustrine)**  
 101 - Homogeneous Bluffs (sand content 0-20%)  
 102 - Homogeneous Bluffs (sand content 20-50%)  
 103 - Homogeneous Bluffs (sand content >50%)  
 104 - Composite Bluffs (sand content 0-20%)  
 105 - Composite Bluffs (sand content 20-50%)  
 106 - Composite Bluffs (sand content >50%)  
 107 - Sand Bluffs (composition unknown)  
 108 - Cohesive Bluffs (composition unknown)
- 110 - Marine / Leda Clay Bluffs**  
 111 - Marine / Leda Clay Bluffs  
 112 - Marine / Leda Clays with Sand Overburden
- 120 - Low Bank**  
 121 - Glacial Till Low Bank / Low Plain  
 122 - Composite Low Bank / Low Plain  
 123 - Sandy Low Bank / Low Plain  
 124 - Leda/Marine Clay Low Bank / Low Plain  
 125 - Creek Bank (applies to narrow creek channels where mapping extends inland)
- 130 - Baymouth Barrier Complex**  
 131 - Baymouth - Barrier (fronting wetlands or shallow embayments, estuaries)
- 140 - Sandy Beach / Dune Complex**  
 141 - Sandy Beach / Dune (relict deposits, areas with no new deposition)  
 142 - Artificial Depositional (e.g., jetty, groin fill)  
 143 - Natural Depositional (areas with active supply/deposition)  
 144 - Erosional Beach (beach undergoing active erosion due to LST)  
 145 - Pocket Beach
- 150 - Coarse Beaches**  
 151 - Gravel Beaches  
 152 - Shingle / Cobbles  
 153 - Boulder Beaches
- 160 - Bedrock (Resistant)**  
 161 - Bedrock (resistant) no overburden  
 162 - Bedrock (resistant) with glacial overburden  
 163 - Bedrock (resistant) with sand overburden
- 170 - Bedrock (Erosive)**  
 171 - Bedrock (Erosive) no overburden  
 172 - Bedrock (Erosive) with glacial Overburden  
 173 - Bedrock (Erosion) with sand overburden
- 180 - Open Shoreline Wetlands**  
 181 - Open Shore Wetlands  
 182 - Rivermouth / Sheltered Wetlands
- 190 - Artificial**  
 191 - Artificial (apparent, known, large scale, lakefills)

**Shore Protection Classification**

Notes: Last digit of the three digit number is the quality quantifier.

- 200 - Revetment**  
 20(1) - Revetment (Class 1, well engineered, well maintained, will last over 50 year window)  
 202 - Revetment (Class 2, moderately engineered)  
 203 - Revetment (Class 3, poorly constructed, poorly maintained)
- 210 - Seawall / Bulkhead**  
 21(1) - Seawalls / Bulkheads  
 212 - Seawalls / Bulkheads  
 213 - Seawalls / Bulkheads
- 220 - Groins\***  
 22(1) - Groins  
 222 - Groins  
 223 - Groins
- 230 - Jetties\***  
 23(1) - Jetties  
 232 - Jetties  
 233 - Jetties
- 240 - Offshore / Marina Breakwaters\***  
 24(1) - Offshore / Marina Breakwaters  
 242 - Offshore / Marina Breakwaters  
 243 - Offshore / Marina Breakwaters
- 250 - Artificial / Constructed / Perched Beaches**  
 25(1) - Artificial / Constructed / Perched Beaches  
 252 - Artificial / Constructed / Perched Beaches  
 253 - Artificial / Constructed / Perched Beaches
- 260 - Beach Nourishment**  
 26(1) - Beach Nourishment  
 262 - Beach Nourishment  
 263 - Beach Nourishment
- 270 - Vegetation Planting / Bioengineering**  
 27(1) - Vegetation Planting / Bioengineering  
 272 - Vegetation Planting / Bioengineering  
 273 - Vegetation Planting / Bioengineering
- 280 - Slope Grading / Bluff Stabilization**  
 28(1) - Slope Grading / Bluff Stabilization  
 282 - Slope Grading / Bluff Stabilization  
 283 - Slope Grading / Bluff Stabilization
- 290 - Protected Wetlands**  
 29(1) - Protected Wetlands  
 292 - Protected Wetlands  
 293 - Protected Wetlands
- 300 - Ad Hoc Concrete Rubble / Rip Rap**  
 30(1) - Ad Hoc Concrete Rubble / Rip Rap (likely will not occur)  
 302 - Ad Hoc Concrete Rubble / Rip Rap  
 303 - Ad Hoc Concrete Rubble / Rip Rap  
 (continued across in next column)

\*Denotes shore perpendicular protection

**Nearshore Subaqueous Classification**

- 500 - Cohesive (Till)**  
 501 - Thick Sand Cover (>200 m<sup>3</sup>/m)  
 502 - Moderate Sand Cover (50-200 m<sup>3</sup>/m)  
 503 - Thin Sand Cover (<50 m<sup>3</sup>/m)
- 510 - Cohesive (Lacustrine Clay)**  
 511 - Thick Sand Cover (>200 m<sup>3</sup>/m)  
 512 - Moderate Sand Cover (50-200 m<sup>3</sup>/m)  
 513 - Thin Sand Cover (<50 m<sup>3</sup>/m)
- 520 - Marine / Leda Clay**  
 521 - Thick Sand Cover (>200 m<sup>3</sup>/m)  
 522 - Moderate Sand Cover (50-200 m<sup>3</sup>/m)  
 523 - Thin Sand Cover (<50 m<sup>3</sup>/m)
- 530 - Cobble / Boulder Lag Over Cohesive\***  
 531 - Thick Lag Cover (>200 m<sup>3</sup>/m)  
 532 - Moderate Lag Cover (50-200 m<sup>3</sup>/m)  
 533 - Thin Lag Cover (<50 m<sup>3</sup>/m)
- 540 - Sandy Lake Bed**  
 541 - Sand
- 550 - Bedrock (Resistant)**  
 551 - Bedrock (Resistant)
- 560 - Bedrock (Erosive)**  
 561 - Bedrock (Erosive)
- 570 - Creek / River / Harbor Sediments**  
 571 - Creek / River Bed  
 572 - Harbor Muds / Silts

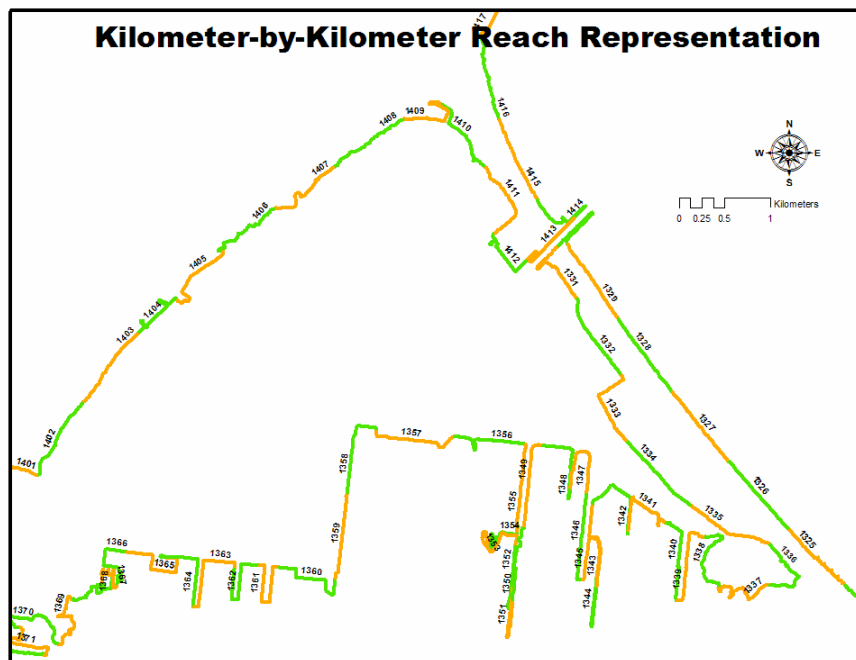
Shore Protection (continued from previous column)

- 310 - Ad Hoc Other Materials**  
 31(1) - Ad Hoc Other Materials (likely will not occur)  
 312 - Ad Hoc Other Materials  
 313 - Ad Hoc Other Materials
- 320 - Boat Docks Private\***  
 32(1) - Boat Docks Private  
 322 - Boat Docks Private  
 323 - Boat Docks Private
- 330 - Boat Docks Marina\***  
 33(1) - Boat Docks Marina  
 332 - Boat Docks Marina  
 333 - Boat Docks Marina
- 340 - Commercial / Industrial Docks/Piers/Wharves\***  
 34(1) - Commercial / Industrial Docks/Piers/Wharves  
 342 - Commercial / Industrial Docks/Piers/Wharves  
 343 - Commercial / Industrial Docks/Piers/Wharves
- 350 - Boat Launch Ramp Docks (Public or Private)\***  
 35(1) - Boat Launch Ramp Docks Private/Public  
 352 - Boat Launch Ramp Docks Private/Public  
 353 - Boat Launch Ramp Docks Private/Public
- 360 - Boat Launch Ramps**  
 36(1) - Boat Launch Ramps  
 362 - Boat Launch Ramps  
 363 - Boat Launch Ramps
- 400 - No Shore Protection**

## Kilometer-by-Kilometer Spatial Resolution

To record shore classification information, a kilometer-by-kilometer spatial resolution was selected. This spatial resolution was consistent with the resolution at which other data collection activities within the CWG are being conducted (e.g., land use, historic recession rates), as well as with the preferred spatial resolution for modeling within the FEPS environment.

As such, a first step was to develop a kilometer-by-kilometer shoreline for the entire study area. This was done within the GIS simply by segmenting the digital Study shoreline (provided by Environment Canada and USACE) into a series of equal 1000 meter segments. This is depicted for a portion of the Lake Ontario shoreline in Figure 1.



**Figure 1 - Kilometer-by-Kilometer Reach Delineation**

Reaches were numbered consecutively beginning at the New York-Quebec border on the St. Lawrence River and moving clockwise around the River and Lake to the Queenston-Lewiston Bridge on the Niagara River (Reach 1213-1214) and ending at the Ontario-Quebec border (Reach 3152). Island shorelines that were included in the digital shoreline provided were also segmented into 1 kilometer segments. These were numbered starting in the St. Lawrence River at Cornwall and then proceeding up the river to the Lake, then clockwise around the U.S. shore and then the Canadian shore until all islands were segmented. This added another 863 reaches to the total (Reach 3200-4063) for a total of 4015 reaches<sup>1</sup>.

<sup>1</sup> It should be noted that the gap in the numbering sequence from the end of the continuous shoreline (Reach 3152) to the start of the island shorelines (Reach 3200) was purposely left in the event that additional island or shoreline reaches needed to be added. This was ultimately not required and as such this numbering discrepancy remains in the database.

## **Application to the Lake Ontario – St. Lawrence River Shoreline**

### ***Data Acquisition***

A number of activities took place in early 2002 to facilitate the re-classification of the Lake Ontario and St. Lawrence River shorelines using the new shoreline classification scheme and the new reach delineations. First, a range of background data was collected and reviewed for key classification information. This included lithology data, geological reports, bathymetry charts, land-use maps, recent aerial photography, video, topographic maps, etc.

Second, a "shirtsleeve" classification workshop was held in February 2002 with key members and consultants of the CWG. At the workshop, all available materials including the video tapes, recent color aerial photography, topographic maps, land use maps, reports and other data were made available. Proceeding kilometer-by-kilometer along the shoreline, the reclassification team examined all the data and recorded new classification information on hardcopy maps with reach boundaries noted on them.

### ***GIS Database Development***

Once this was complete, the hardcopy data was verified and entered into an ArcView/ArcMap GIS for further analysis and visualization purposes.

In developing the GIS database, a number of key fields were set up for recording the classification information. This included the basic information for the three tiers in the classification system, but also fields for recording additional details on shore protection and primary land use. Brief definitions of the key fields (attributes) utilized are found below.

#### ***Attribute\_Label: REACH\_1***

***Attribute\_Definition:*** The Reach Number. Reaches begin at 1 at the New York – Quebec border and proceed clockwise around the lake and river. Open coast reaches end at 3152 at the Ontario – Quebec border. Islands were also segmented and numbered from Reach 3200-4063.

#### ***Attribute\_Label: LENGTH***

***Attribute\_Definition:*** This is the length of the reach segment. Generally each reach is exactly 1000 meters in length. However, in some instances edits to the reaches were required that resulted in a reach length slightly longer or shorter than 1000 meters. In addition, where islands were segmented into reaches, there was always one reach that was a "short" reach (i.e., less than 1000m). Also, those islands less than 2000 meters in length were not segmented and their length will be some value less than 2000 meters.

#### ***Attribute\_Label: SHORETYPE***

***Attribute\_Definition:*** This is the geologic shoreline type (geomorphic) classification. Each reach is classified with the numeric identifier found in the classification scheme in Table 1.

***Attribute\_Label: SP1, SP2, SP3, SP4, SP5, SP6***

***Attribute\_Definition:*** SP1 to SP6 represent the shoreline protection classification for each kilometer reach. SP1 to SP4 allow for up to 4 types of "parallel" shore protection to be recorded for each reach. SP5 and SP6 are fields that allow for up to 2 "perpendicular" shore protection types (e.g., groins, jetties, breakwaters, boat docks, wharves, piers) to be recorded for each reach. The shore protection classification is comprised of a 3 digit number where the first two digits represent the type of structure (see Table 1) and the last digit is a "quality" quantifier, where 1 = Class 1 Structure (well engineered, well maintained, institutional, will last over 50 years); 2 = Class 2 Structure (moderately engineered, most private shore protection, should last 5-15 years); 3 = Class 3 structure (poorly or non-engineered, 0-5 year lifespan).

***Attribute\_Label: PERCENTCLA***

***Attribute\_Definition:*** The percentage of each reach that is protected by Class 1 or Class 2 shore protection structures. The FEPS model will only consider Class 1 and 2 protection as having any influence on erosion processes. As such, there was a need to estimate, for each reach, the percentage of the reach protected by these Class 1 and 2 structures.

***Attribute\_Label: NEARSHOREG***

***Attribute\_Definition:*** This is the nearshore geology classification (i.e., the geology that is occurring under the water). Each reach is classified with the numeric identifier found in the classification scheme in Table 1.

***Attribute\_Label: LANDUSE***

***Attribute\_Definition:*** This is the primary land use occurring within the first 50-100 meters for each kilometer reach. In order to assess impacts along the shoreline, there is a need to know what use is currently occurring. As such, a very basic land use assessment was conducted in order to identify the basic land use occurring in each kilometer reach. The classification has been set up to be consistent with the three digit unique identifier used in previous tiers of the classification and is as follows:

- 601 - Residential / Urban / Seasonal / Cottage;
- 602 - Industrial / Institutional / Commercial;
- 603 - Transportation;
- 604 - Agricultural;
- 605 - Parks and Recreational Areas;
- 606 - Natural / Undeveloped / Open Space / Forest

***Attribute\_Label: COMMENTS***

***Attribute\_Definition:*** Provides additional notes or comments on the reach. Usually provides a place name for reference purposes.

**QA / QC of Shoreline Classification**

In order to ensure that the shoreline classification data being developed was as accurate as possible, two key activities took place.

First, much of the shore classification data acquisition was conducted prior to the receipt of new digital orthophotos that were being flown for large sections of the Canadian and U.S. shorelines.

As such, once these photos were obtained, they were imported into the GIS, along with the shore classification data, and were examined to note any changes or differences that were originally recorded. As these photos were flown in 2001 and 2002, this gave us a very accurate “snapshot” of the most current shoreline conditions for these areas.

Second, through a series of meetings, the shore classification and land use data was presented to, and reviewed by, various government and local shoreline authorities for accuracy. This included all Ontario Conservation Authorities on Lake Ontario, as well as all but one on the St. Lawrence River, and representatives from the New York Department of Environmental Conservation for the majority of the south shore of Lake Ontario. Comments from these meetings led to a number of revisions being made to the shore classification data.

## SHORE CLASSIFICATION MAPPING AND SUMMARY STATISTICS

### GIS Mapping

For each level of the classification scheme, as well as for land use and the percent of Class 1 and 2 shore protection structures, ArcView GIS coverages were created and have been mapped for the entire Study area. These are presented graphically in Figures 2-6 below.

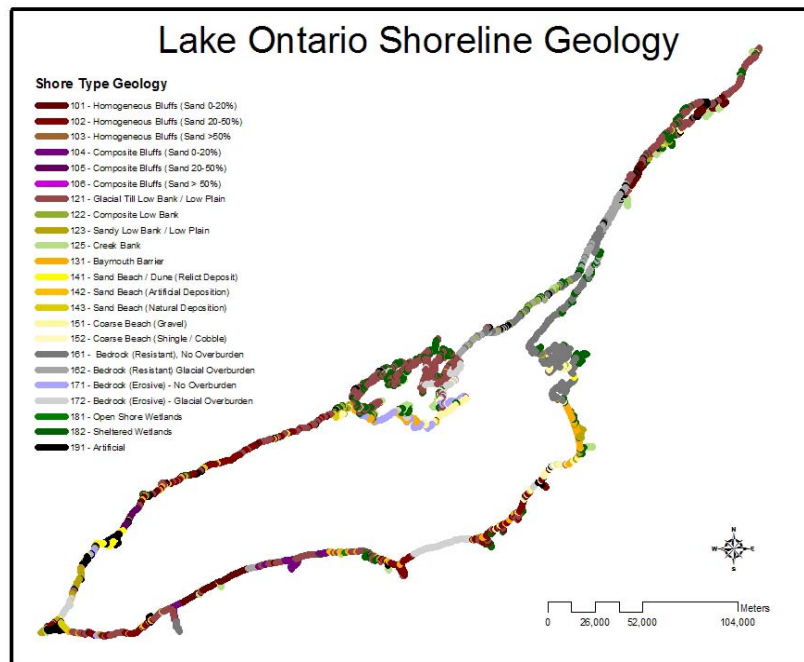


Figure 2 - Lake Ontario – St. Lawrence River Geomorphic Shoreline Type



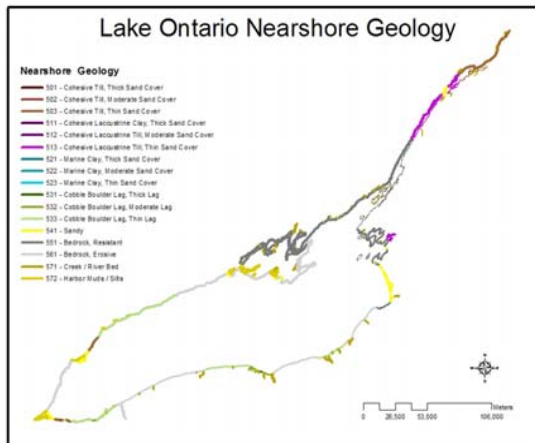


Figure 3 - Nearshore Geology

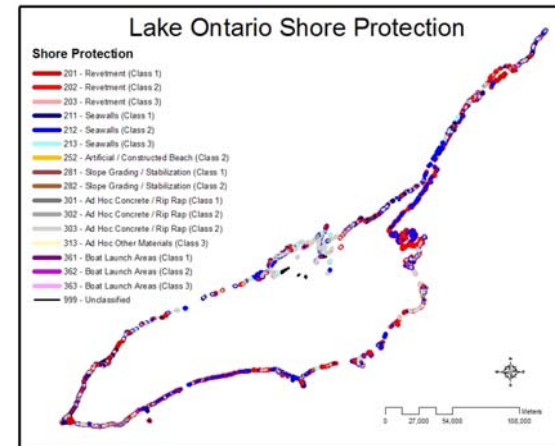


Figure 4 - Shore Parallel Protection

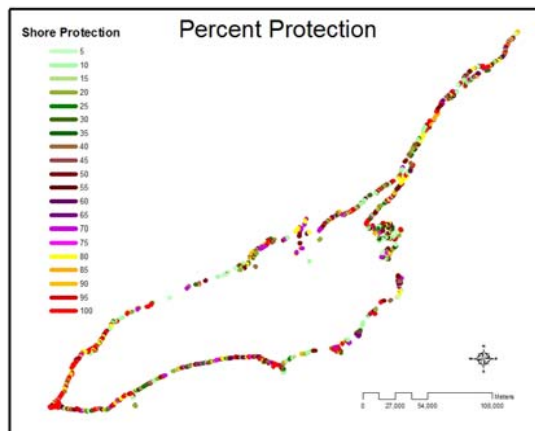


Figure 5 - Percent Class 1 and 2 Protection

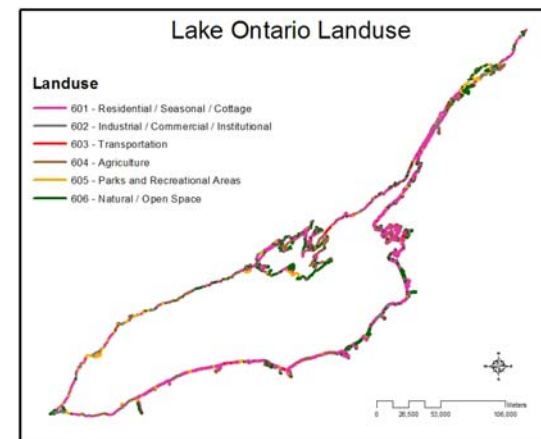


Figure 6 - Primary Land Use

## Summary Statistics and Graphics

Shoreline classification data generated during the reclassification activities was also used to create a series of summary statistics and related “pie-chart” graphics (courtesy of Baird & Associates). These are presented below for each of the main levels of the classification scheme as well as for the land use classification that was conducted. Full page versions of these graphics as well as a series of summary graphics for each Shoreline Unit in the lake and river (in either JPEG or PDF versions) may be obtained from the LOSLR FTP site as follows:

FTP: wtoftpa.on.ec.gc.ca

User ID: ijcstudy

Password: mike\_747

Directory and File: /ijcstudy/coastal/maps/Shore Classification/Completed Classification of Shore Unit Maps 1200dpi.pdf

**Note: This is a ~40MB file**

### *Geologic Shore Type*

Summary statistics for the geologic shoreline type are presented in the top left pie chart shown in Figure 7, as well as on a Shore Unit by Shore Unit basis in Figure 8. The most dominant shore type on the Lake and River is the Low Bank category which accounts for approximately 28% of the total shoreline. This shore type is distributed fairly evenly throughout the basin, occurring in the majority of Shoreline Units, but with a predominance in Shore Units CND8, CND11, CND1 and R3 (see Figure 8). Bedrock shorelines occupy approximately 27% of the shoreline with the majority of these falling in the Resistant Bedrock category (22%) and occurring primarily in the Jefferson County portion of Lake Ontario (US8) and the Thousand Islands portion of the St. Lawrence River (CND 12 and R1). Open shoreline wetlands occupy approximately 19% of the shore and are distributed in the central and eastern portions of the basin. Sand or Cohesive bluffs occupy 10% of the shore and are found along most of the U.S. shore and the central part of the Canadian shoreline of Lake Ontario. Artificial shorelines comprise 7% of the shore and are concentrated in the western portion of the basin in the developed areas of Hamilton, Burlington, Oakville, Mississauga and Toronto.

### *Nearshore Geologic Classification*

Summary statistics for the nearshore geologic shoreline type are presented in the top right pie chart shown in Figure 7, as well as on a Shore Unit by Shore Unit basis in Figure 9 and 10. Figure 9 presents the data with creek and small embayment/harbor reaches included. Figure 10 excludes these from the calculation and summarizes open coast reaches only. Resistant bedrock is the dominant nearshore type (36%) and occurs primarily in the eastern portion of the basin and river (US6-8; CND11-12; R1-2). Erosive bedrock is also predominant along much of the shoreline particularly CND4, CND8-10, US1 and US3-5. Cobble / Boulder lag deposits over cohesive material are focused in the Niagara (CND1) and Central Lake Ontario (CND7) portions of Ontario as well as in the Monroe, Wayne and Cayuga County areas of New York (US2-4). Sandy nearshore deposits tend to be found in small localized areas including Burlington Beach (CND2), Toronto Islands (CND5), Prince Edward County (CND9) and the Eastern Lake Ontario Sand Dunes area (US7). Cohesive till deposits occur in the Scarborough Bluffs and Niagara Region of Lake Ontario (CND6 and CND1) as well as in the eastern most portion of the Upper

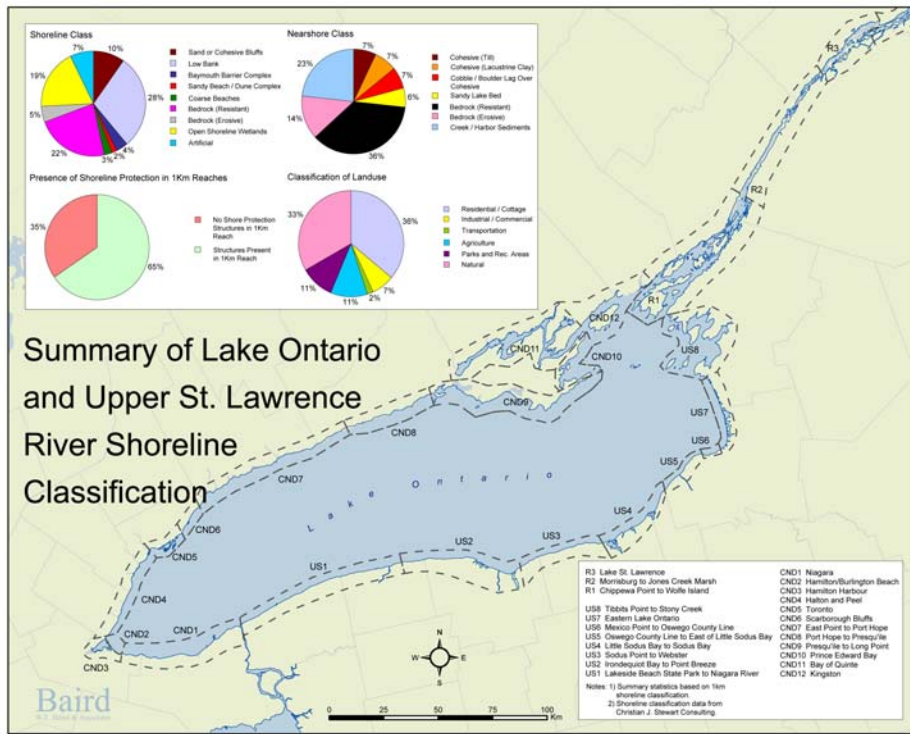


Figure 7 - Summary of Lake Ontario and Upper St. Lawrence River Shoreline Classification

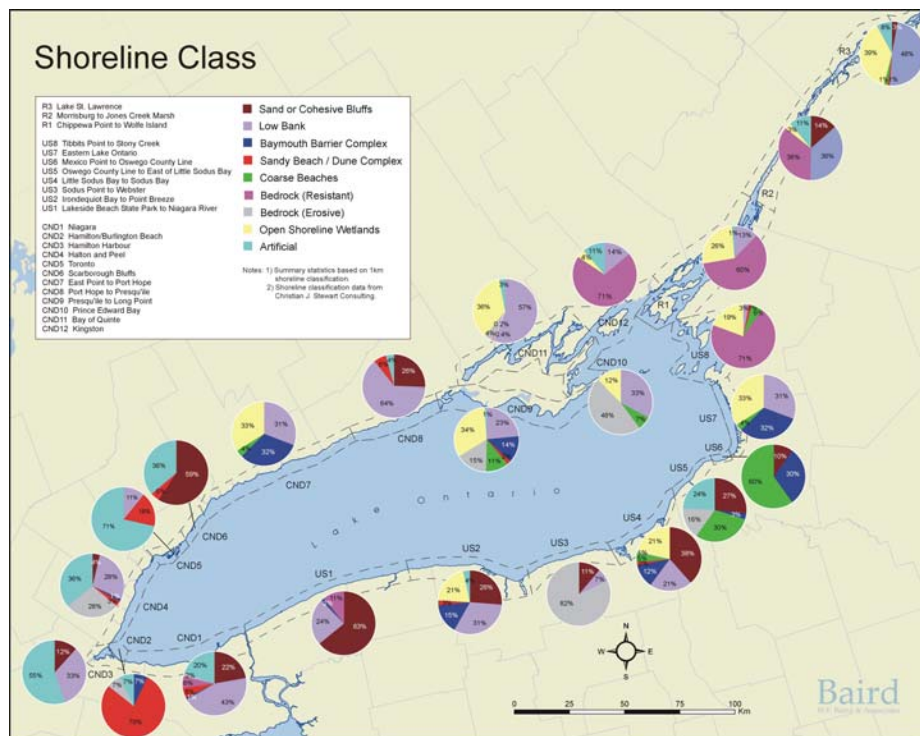


Figure 8 - Shoreline Type Classification Summary Statistics by Shore Unit

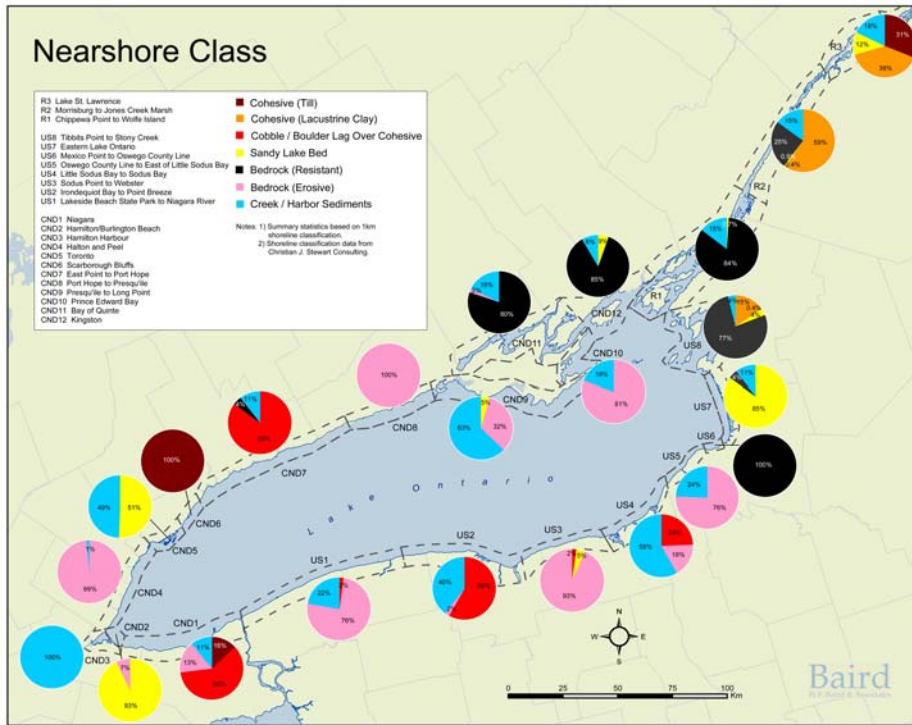


Figure 9 - Nearshore Summary Statistics by Shore Unit (Includes Creek and Harbor Sediments)

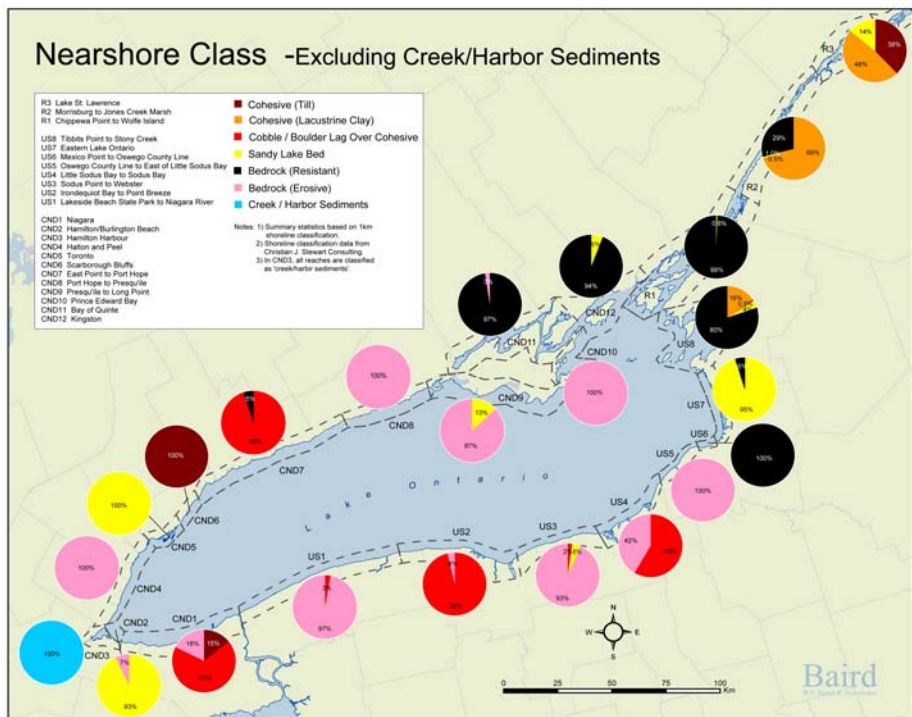


Figure 10 - Nearshore Summary Statistics By Shore Unit (Excluding Creek and Harbor Sediments)

River (R3). Cohesive Lacustrine deposits are found predominantly in the Upper River (R2 and R3) with small amounts also present in US8.

### ***Shore Protection Classification***

The GIS mapping coverages presented in Figures 4 and 5 show that there is a significant level of shore protection in place along the majority of the Lake Ontario and St. Lawrence River shoreline. Approximately 65% of all reach segments have some type of protection structure present (see bottom left pie-chart in Figure 7). As one would expect, most of the shore protection coincides with the heaviest areas of development along the shore particularly the western portion of Lake Ontario (Niagara to Toronto). In examining the percentage of reaches in each Shore Unit that are protected by Class 1 and 2 structures (Figure 11), a similar pattern emerges, with the more developed areas having higher percentages of Class 1 and 2 structures present.

### ***Primary Land Use***

Summary statistics for the primary land use in each kilometer reach are presented in the bottom right pie chart shown in Figure 7, as well as on a Shore Unit by Shore Unit basis in Figure 12. Residential land use dominates and occupies approximately 36% of the entire shoreline. Residential use is heaviest along the U.S. shore of the Lake and the River (US1-8; R1-2) as well as in the Niagara to Toronto region of Canada (CND1-6). Natural / Open Space is the next most predominant use, comprising 33% of the shoreline. Highest concentrations of natural areas are found in CND7-9, CND11, US7 and R3. Parks and Recreational areas occupy 11% of the shoreline and surprisingly, a large amount of this occurs in the more heavily developed western end of the Lake (CND1-6). Agricultural uses also account for 11% of the shoreline and are predominant in CND8, CND10, US1 and US3. Industrial and commercial uses occupy approximately 7% of the shoreline and are concentrated around the major urban areas of St. Catherines (CND1), Hamilton (CND3), Toronto (CND5) and Oswego (US5).

## **SUMMARY**

The reclassification of the Lake Ontario and St. Lawrence River shoreline has accomplished a number of important things relative to the goals and specific task objectives of the CWG. First, the level and comprehensiveness of the revised classification has greatly added to our knowledge of the physical settings of these shorelines, particularly with reference to the level of detail regarding shore type and nearshore geology. This provides an excellent baseline data set for future analysis within the LOSLRS as well as in any future studies where such data may be required. Second, the development of the shore protection and land use classification categories adds greatly to our knowledge and understanding of existing “landside” issues that exist along this shoreline. This will be a critical data set for use in making ultimate impact assessments within the study. Third, there is now a common (U.S.-Canadian), consistent, basin-wide coastal zone database of the above information which can be used in a common format in any modeling and impact assessment activities that are undertaken. This may also serve as a model for bi-national GIS data development for other parts of the Great Lakes basin.

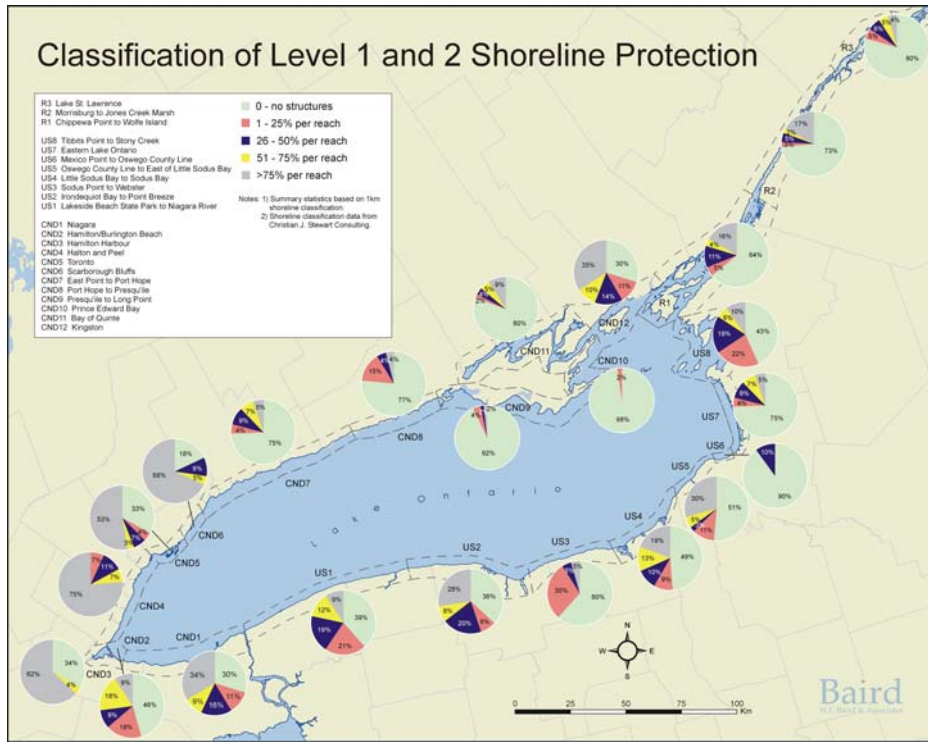


Figure 11 - Classification of Level 1 and 2 Shore Protection Structures by Shore Unit

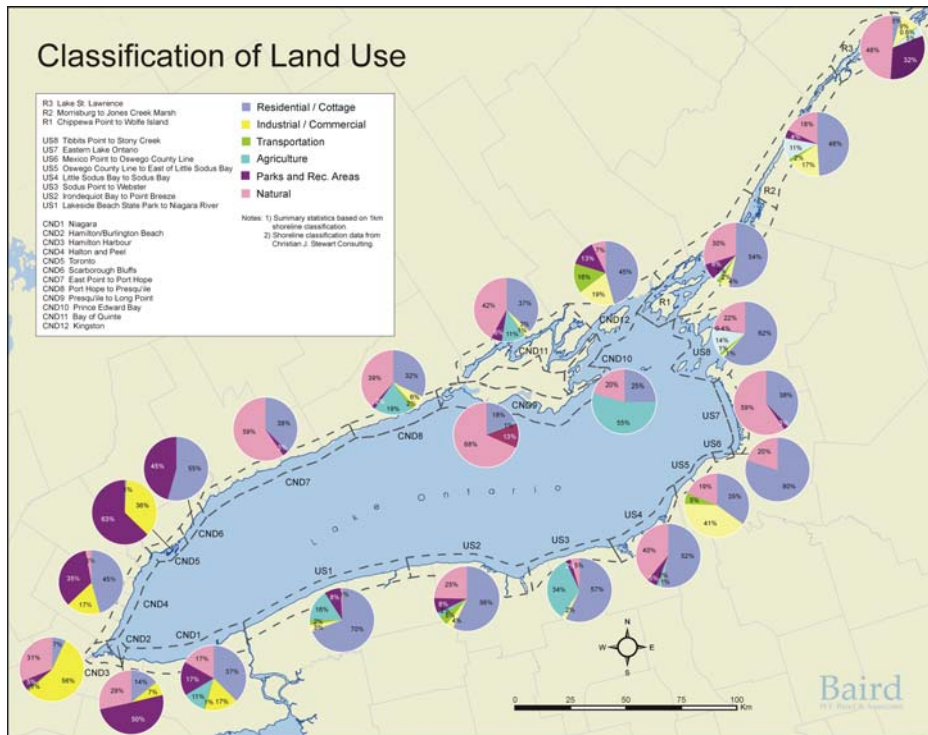


Figure 12 - Primary Land Use Classification Summary Statistics by Shore Unit

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