

Improving End-To-End Tsunami Warning for Risk Reduction on Canada's West Coast

Peter Anderson
Simon Fraser University

Prepared By:
Peter Anderson
Simon Fraser University
8888 University Drive
Burnaby, BC V5A 1S6

Contractor's Document Number: CSSP-2013-TI-1033
CSA: Philip Dawe, DRDC Centre for Security Science, 613-995-1756

The scientific or technical validity of this Contract Report is entirely the responsibility of the Contractor and the contents do not necessarily have the approval or endorsement of the Department of National Defence of Canada.

Contract Report
DRDC-RDDC-2015-C008
January 2015

IMPORTANT INFORMATIVE STATEMENTS

CSSP 2013-TI-1033 Improving End-To-End Tsunami Warning for Risk Reduction on Canada's West Coast was supported by the Canadian Safety and Security Program which is led by Defence Research and Development Canada's Centre for Security Science, in partnership with Public Safety Canada. The project was led by Emergency Management British Columbia and Simon Fraser University.

Canadian Safety and Security Program is a federally-funded program to strengthen Canada's ability to anticipate, prevent/mitigate, prepare for, respond to, and recover from natural disasters, serious accidents, crime and terrorism through the convergence of science and technology with policy, operations and intelligence.

© Her Majesty the Queen in Right of Canada, as represented by the Minister of National Defence, 2015

© Sa Majesté la Reine (en droit du Canada), telle que représentée par le ministre de la Défense nationale, 2015



ENGAGING THE WORLD



Emergency
ManagementBC

Canadian Safety
and Security Program

Canadian Safety and Security Program

Improving End-To-End Tsunami Warning for Risk Reduction on Canada's West Coast

PROJECT NUMBER CSSP-2013-TI-1033
Task 3 Report

22 January, 2015
Version 1.2

Record of Amendments

Version Number	Section Amended	Entered By	Amendment Date
Version 1	Document created.	Peter Anderson	31 December, 2014
1.1	Minor punctuation and section number corrections	Peter Anderson	2 January, 2015
1.2	Replaced Figure 28 B.C. Over-the-air AM and FM Radio Coverage; corrected typos pages 19, 70 and 80	Peter Anderson	22 January, 2015

Document Description

This document provides reporting for Task 3 of the *Improving End-To-End Tsunami Warning for Risk Reduction on Canada's West Coast* Project (CSSP 2013-TI-1033). It provides details on work carried out in Phase 1 – Tasks 1 to 3 of the project and acts as Deliverable 3. Since Task 3 forms the basis of the technical considerations of the project, it also serves as the primary technical reference for the deliverables for Tasks 4, 5 and 6 of Phase 2.

Project Organization

Technical Authority

Philip Dawe
Portfolio Manager – Emergency Management & Disaster Resilience
Defense Research and Development Canada, Centre for Security Science
222 Nepean Street, 11th floor
Ottawa, Ontario
K1A 0K2

Province of British Columbia Representative and Project Champion

Ralph Mohrmann
Senior Regional Manager and
Assistant Director of Operations
Emergency Management British Columbia
Ministry of Justice
2261 Keating X Road
Saanichton, BC
V8M 2A5

Research Lead

Peter Anderson
Associate Professor and
Director, Telematics Research Lab
School of Communication
Simon Fraser University
8888 University Drive
Burnaby, B.C.
V5A 1S6

Research Team

Peter Anderson, Director, Telematics Research Lab, Simon Fraser University
Stephen Braham, Director, PolyLAB, School of Communication, Simon Fraser University
Olympia Koziatsek, Department of Geography, Simon Fraser University
Amanda Oldring, School of Communication, Simon Fraser University
Amanda Oye, School of Communication, Simon Fraser University
Dawn Ursulak, School of Communication, Simon Fraser University
Marc d'Aquino, Holistic Emergency Preparedness and Response

Table of Contents

Record of Amendments	ii
Document Description	iii
Project Organization	iii
Acknowledgements	vi
List of Tables	viii
List of Figures	viii
List of Acronyms	x
1. Introduction	1
1.1 Tsunami Hazard Risk and Changing Coastal Conditions	1
1.2 New Challenges for Tsunami Notification	5
1.3 Project Objectives	6
1.4 Project Scope	7
1.5 Impact on Outcomes	7
1.6 Excluded Work and Phase 1 Scope	7
1.7 Building Upon Previous Tsunami Notification Projects and Initiatives	8
1.8 Study Methodology and Scope	10
1.9 Report Layout	14
2. British Columbia Tsunami Hazard Zones	15
2.1 Evidence of past tsunamis	18
2.2 Wave travel time and run-up forecasting	19
2.3 Earthquakes and tsunami thresholds	19
2.4 B.C. Tsunami Zone Boundaries	20
3. Populations-At-Risk Within The Tsunami Notification Zones	22
3.1 Fixed Population Locations and Densities	22
3.2 Transient populations	24
3.2.1 Coastal Resource Industry Examples	25
4. Tsunami Notification Arrangements	28
4.1 Traditional Notification Arrangements	28
4.1.1 Detection and Initial Notification Subsystem	28
4.1.2 Emergency Management Subsystem	29
4.1.3 Public Response Notification Subsystem	30
4.2 Recent changes and revised notification processes	30
4.3 Individual Stakeholder Notification Procedures and Processes	32
4.3.1 NWS-NTWC	32
4.3.1.1 Geographical Message Targeting: Use of Breakpoints	34
4.3.1.2 Message Identifiers	35
4.3.1.3 Intended Recipients	36
4.3.1.4 Message Content	36
4.3.1.5 Message Dissemination Methods	37
4.3.2 British Columbia Provincial Emergency Notification System	40
4.3.2.1 EMBC PENS Activation Process	40
4.3.2.2 PENS Message Targeting and Content	41
4.3.2.3 Technical Components of PENS	41
4.3.3 Key PENS Partners	46

4.3.2.1 Environment Canada	46
4.3.2.2 Canadian Coast Guard – Marine Communication and Traffic Services	49
4.3.4 Additional PENS Public Safety and Security Partners	52
4.3.4.1 Royal Canadian Mounted Police	52
4.3.4.2 BC Ambulance Service	53
4.3.4.3 Fire Department Dispatch	54
4.3.4.4 Joint Task Force Pacific	55
4.3.5 Media	55
4.3.5.1 National Public Alerting System Initiative	56
4.3.5.2 National Alert Aggregation and Dissemination System	56
4.3.5.3 NPAS and Tsunami Notification	58
4.4 Underpinning Information and Communication Infrastructure for Tsunami Notification and NPAS	60
4.4.1 Broadband Coverage	62
4.5 Coastal Last Mile/Last Person Tsunami Notification	63
4.6 Other Potential Resources	64
4.6.1 MSAT EmergNet	64
4.6.2 Other Public and Private Agency Networks	65
4.7 Emerging Systems	67
4.7.1 Satellite Emergency Notification Devices	67
4.7.2 Public Safety Broadband Network	68
5. Current Local Notification Practices	70
5.1 Survey Population and Response Rate	70
5.2 Geography	72
5.3 External Notification Sources	72
5.4 Local Tsunami Notification Methods	77
5.5 Local Tsunami Notification Capabilities	80
6. Connecting the Dots	83
7. Summary	84
References	85
Appendix A GIS Data Sources	91
Appendix B NWC Tsunami Message Samples	99
Appendix C On-line Survey Questionnaire	105
Appendix D Community and Regional District Survey Participants	110

Acknowledgements

This work was supported through the Canadian Safety and Security Program, a federal program led by Defence Research and Development Canada's Centre for Security Science, in partnership with Public Safety Canada CSSP 2013-TI-1033.

Many people contributed their valuable time and information to enable this project to be carried out successfully. We have attempted to acknowledge them below and apologize for any omissions.

Patricia McCourt, Aboriginal Affairs and Northern Development Canada
Gordon Kirk, BC Ambulance Service
Craig McGowan, BC Ambulance Service
Rod Salem, BC Ambulance Service
Sol Lancashire, BC Hydro
Nick Heath, BC Marine Trails Network Association
Jason Wood, B.C. Ministry of Transportation and Infrastructure
Steve Waugh, Bella Coola
Dave Rainnie, Canadian Broadcasting Corporation
Brian Bain, Canadian Coast Guard - Western
Clay Evans, Canadian Coast Guard – Western
Glenn Ormiston, Canadian Coast Guard – Western
Susan Pickrell, Canadian Coast Guard - Western
Ian Wade, CCG, Canadian Coast Guard - Western
Doug Allport, Canadian Public Safety Operations Organization
Brent Falkins, DFO, Canadian Hydrographic Services, Institute of Ocean Sciences
Denny Sinnott, DFO, Canadian Hydrographic Services, Institute of Ocean Sciences
Fred Stephenson, DFO, Canadian Hydrographic Services, Institute of Ocean Sciences
Aspa Kotsopoulos, Canadian Radio-television and Telecommunications Commission
Peter Ensor, Capital Regional District
Cheryl Waugh, Central Coast Regional District
Philip Dawe, Centre for Systems Science, Defense Research and Development Canada
Jack Pagotto, Centre for Systems Science, Defense Research and Development Canada
John Tidbury, District of Port Hardy
Mike Webb, E-Comm
Andrew Bryan, Emergency Management British Columbia
Ian Cunnings, Emergency Management British Columbia
Chris Duffy, Emergency Management British Columbia
Clare Fletcher, Emergency Management British Columbia
Kathryn Forge, Emergency Management British Columbia
Michael Higgins, Emergency Management British Columbia
Maurie Hurst, Emergency Management British Columbia
Michael Knauff, Emergency Management British Columbia
Robert Kennedy, Emergency Management British Columbia
Kelli Kryzanowski, Emergency Management British Columbia
Sue Launder, Emergency Management British Columbia
Cameron Lewis, Emergency Management British Columbia
Chris Mah, Emergency Management British Columbia
Ralph Mohrmann, Emergency Management British Columbia

John Oakley, Emergency Management British Columbia
 Peter Prendergast, Emergency Management British Columbia
 Pat Quealey, Emergency Management British Columbia
 Todd Smith, Emergency Management British Columbia
 Sonia Woolford, Emergency Management British Columbia
 Jennifer McLarty, Emergency Management British Columbia, Social Media Unit
 Ashley Spilak, Emergency Management British Columbia, Social Media Unit
 Michael Gismondi, Environment Canada
 Fred Voglmaier, Environment Canada
 Carol Ogborne, GeoBC
 Joshua Chan, GeoBC
 Kim Mikkelesen, Industry Canada
 Melody Meyers, Industry Canada
 Pawas Verma, Industry Canada
 Major David Proctor, MARPC/Joint Task Force Pacific
 Greg Fletcher, Mount Waddington Regional District
 Gloria Le Gal, Mount Waddington Regional District
 Monty Cook, NAV Canada
 Wilf Bangert, Network BC, Office of the Chief Information Officer
 Chris Hauff, Network BC, Office of the Chief Information Officer
 James McGrath, Network BC, Office of the Chief Information Officer
 Howard Randell, Network BC, Office of the Chief Information Officer
 John Carrick, NOAA National Tsunami Warning Center
 Paul Haung, NOAA National Tsunami Warning Center
 Paul Whitmore, NOAA National Tsunami Warning Center
 Nathan Becker, NOAA Pacific Tsunami Warning Center
 Stuart Weinstein, NOAA Pacific Tsunami Warning Center
 Randy Zaleshuck, North Island 911
 Garry Rogers, NRCAN, Pacific Geoscience Centre
 Chuck Lok, Port McNeil
 Cindy Jeromin, Port Metro Vancouver
 Wayne Hirlehey, Public Safety Canada
 Glenn Alsaker, Rogers Wireless
 Clement Cheung, Rogers Wireless
 Michelle Alton, RCMP
 Dennis Crowe, RCMP
 Debbie Letkemann, RCMP
 John Clague, Earth Sciences, Simon Fraser University
 Nick Hedley, Department of Geography, Simon Fraser University
 Howie Siemens, Strathcona Regional District and City of Campbell River
 Jeff Hortobagyi, Telus Communications
 Jennifer Conner, Telus Mobility
 Mouti Wali, Telus Mobility
 Tim Webb, Tofino
 Robin Neale, Transport Canada
 Madeline McDonald, Village of Port Alice

We would especially like to thank the 84 communities and regional districts for enabling their local authorities to participate in our on-line location tsunami notification survey. We have attached a list of the participating locations in Appendix D.

List of Tables

Table 1	Original and Derived GIS Data Sets	13
Table 2	Recommended Tsunami Run-up Planning Levels	20
Table 3	Estimates of Fixed Location Populations Residing Within B.C. Tsunami Zones	23
Table 4	NTWC and EMBC Tsunami Alert Levels	29
Table 5	NTWC Message Identifiers and Intended Recipients	36
Table 6	Message Dissemination Methods at the National Tsunami Warning Center	37
Table 7	Entries by Zones and Local Authority	72
Table 8	External Notification Sources	
Table 9	Source Organization	75
Table 10	Source Media	76
Table 11	Local Notification Methods	78
Table 12	Local Plans and Capabilities for all Local Authorities	80

List of Figures

Figure 1	Sub-regions that have generated distant tsunamis sufficient to reach B.C.	15
Figure 2	BC Coastal Major Fault and Plate Boundaries	16
Figure 3	Pacific Northwest Identified Submarine and Land-side Landslide-generated Tsunamis	17
Figure 4	Locations of Tsunami Deposits Located in the Cascadia Region	18
Figure 5	British Columbia Tsunami Notification Zones	21
Figure 6	Fixed Population Locations within B.C. Tsunami Notification Zones	23
Figure 7	B.C. Coastal Population Densities	24
Figure 8	Coastal Logging Tenures	25
Figure 9	B.C. Saltwater Finfish Farms	26
Figure 10	Camping, Diving, Recreational Cruising and Cruise Ship Travel Routes	27
Figure 11	Traditional Flow of Tsunami Notifications	28
Figure 12	Present Flow of Tsunami Notifications	32
Figure 13	Pacific Ocean Dart and Tide Gauge Stations	34
Figure 14	NTWC Notification Breakpoints	35
Figure 15	Locations of Sampled @NWS_NTWC Twitter Followers	39
Figure 16	Provincial Emergency Notification System Automated Email Recipient Locations	42
Figure 17	Provincial Emergency Notification System Automated Telephone Recipient Locations	43
Figure 18	Provincial Emergency Notification System Automated Facsimile Recipient Locations	44
Figure 19	Locations of Sampled @EmergencyInfoBC Twitter Followers	45
Figure 20	Environment Canada Weatheradio Coverage	47

Figure 21	EC Alert Me Tsunami Alert Sub-Regions	48
Figure 22	Canadian Coast Guard Pacific Coast VHF Coverage	50
Figure 23	Canadian Coast Guard Pacific Coast NAVTEX Coverage	51
Figure 24	RCMP Coastal Detachment Tsunami Message Reception Locations	53
Figure 25	B.C. Ambulance Service Tsunami Message Reception Locations	54
Figure 26	Mid and Northern Vancouver Island Fire Dispatched Tsunami Notification Locations	55
Figure 27	NPAS Communications Model	56
Figure 28	B.C. Over-the-air AM and FM Radio Coverage	59
Figure 29	B.C. Over-the-air Television Coverage	60
Figure 30	B.C. Coastal Fixed and Cellular Broadband Service Locations	62
Figure 31	B.C. Coastal EMERGNET MSAT Locations	65
Figure 32	Northwestern Vancouver Island Weatheradio, CCG and Cellular Coverage	66
Figure 33	Northwestern Vancouver Island Weatheradio, CCG and Cellular Coverage with MOTI Coverage Added	67
Figure 34	Survey Respondents	71
Figure 35	External Tsunami Notification Sources by Local Authority Category	74
Figure 36	Source Organizations by Local Authority Category	75
Figure 37	Source Media by Local Authority Category	77
Figure 38	Sum total for Local Notification Methods for all Local Authorities	78
Figure 39	Sum Total for Local Notification Methods by Local Authority Category	79
Figure 40	Percent total of Local Notification Methods Local Authority Category	79
Figure 41	Sum Total for Tsunami Plans and Notification Capabilities for All Local Authorities	81
Figure 42	Percent Total for Tsunami Plans and Notification Capabilities by Local Authority Category	81
Figure 43	Kayaking Locations with Marginal Tsunami Notification Coverage	83

List of Acronyms

ADSL	Asymmetric digital subscriber line
AWIPS	Advanced Weather Interactive Processing System
AOR	Area of Responsibility
ASCII	American Standard Code for Information Interchange
B.C.	British Columbia
BCAS	BC Ambulance Service
BCEHS	BC Emergency Health Services
BDU	Broadcasting distribution undertaking
CAF	Canadian Armed Forces
CAP	Common Alerting Protocol
CCG	Canadian Coast Guard
CHS	Canadian Hydrographic Service
CLC	Canadian Location Code
CMB	Continuous Marine Broadcast
CPIC	Canadian Police Information Centre
CRTC	Canadian Radio-television and Telecommunications Commission
CSSP	Canadian Safety and Security Program
CSV	Comma Separated Value
CSZ	Cascadia Subduction Zone
DA	Dissemination Areas
DART	Deep-ocean Assessment and Reporting of Tsunamis
DCP	Designated contact person
DEM	Digital Elevation Model
DSC	Digital Selective Calling
DTH	Direct-to-home
EAS	Emergency Alert system
EC	Environment Canada
ECC	Emergency Coordination Centre
EIDS	Earthquake Information Distribution System
EMBC	Emergency Management British Columbia
EMO	Emergency Management Organization
ERMS	Emergency Response Management System
EMWIN	Emergency Managers Weather Information Network
FEMA	Federal Emergency Management Agency
FPT	Federal, Provincial, Territorial
HSPA	High Speed Packet Access
GMDSS	Global Maritime Distress and Safety System
GPS	Geographical Positioning Satellite
GOC	Government of Canada Operations Centre
HF	High Frequency
ICT	Information and Communication Technology
IPTV	Internet Protocol television
ITM	Irregular Terrain Model
IPAWS	Integrated Public Alert and Warning System

JRCC	Joint Rescue Co-ordination Centre Victoria
JTFP	Joint Task Force Pacific
KML	Keyhole Markup Language
LMD	Last Mile Distributor
LTE	Long Term Evolution
MVTS	Marine Communications and Traffic Services
MARPAC	Maritime Forces Pacific
MMSI	Maritime Mobile Service Identity
MF	Medium Frequency
NAADS	National Alert Aggregation and Dissemination System
NADIN2	FAA NADIN2 Aeronautical Fixed Telecommunications Network
NAVTEX	Navigational Telex
NAWAS	NAtional WArning System
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Survey
NPAS	National Public Alerting System
NRCAN	National Resources Canada
NTWC	National Tsunami Warning Center
NWS	National Weather Service
NWSTG	National Weather Service Telecommunication Gateway
OTA	Over-the-air
PTWC	Pacific Tsunami Warning Center
PDM	Provincial Duty Manager
PECC	Provincial Emergency Coordination Centre
PENS	Provincial Emergency Notification System
PEP	Provincial Emergency Program
PERCS	Provincial Emergency Radio Communications Service
PREOC	Provincial Regional Emergency Operations Centre
PSBN	Public Safety Broadband Network
PTWC	Pacific Tsunami Warning Center
RCMP	Royal Canadian Mounted Police
RJOC	Regional Joint Operations Centre
RSS	Really Simple Syndication or Rich Site Summary
RTCM	Radio Technical Commission for Maritime Services
SAME	Specific Area Message Encoding
SEND	Satellite Emergency Notification Device
SFU	Simon Fraser University
SMS	Short Message Service
SMU	EMBC Social Media Unit
TIP	Tsunami Integrated Preparedness
TNZ	Tsunami Notification Zone
TXT	Plain Text File
UGC	Universal Generic Codes
UNESCO	United Nations Educational, Scientific and Cultural Organization
USGS	United States Geological Survey
VTEC	Valid Time Event Codes

VHF	Very High Frequency
VOD	Video-on-demand
VoIP	Voice over Internet Protocol
WMO	World Meteorological Organization
XLSX	Excel Microsoft Office Open XML Format

1. Introduction

1.1 Tsunami Hazard Risk and Changing Coastal Conditions

Tsunamis pose a significant hazard along Canada's Pacific West Coast. Although relatively infrequent in occurrence, they are among the most destructive forces in nature and can cause enormous loss of life, injury and property damage. Tsunamis are a series of unusually large waves formed by a large-scale displacement of water. Among the most widely recognized causes of tsunamis are earthquakes, but tsunamis can also be produced by shoreline and underwater landslides, shoreside and underwater volcanoes, and even by asteroids impacting water bodies.

Within the Pacific Ocean region, earthquakes are the most prevalent sources of tsunamis due to the large number of tectonic subduction zones found there. Along the western coast of North America, tsunamis generally are divided into two threat categories: distant (far-field) and local (near-field), depending on the point of origin of the earthquake and size of the area affected (British Columbia, 2013b). Distant tsunamis are classified as those generated 1000 kilometres or farther away in the Pacific Ocean, and can severely impact British Columbia's outer coastal regions. The second threat is from tsunamis that are generated in local waters. These tsunamis can be triggered by earthquakes and shoreside and submarine landslides within a 1000 kilometre range and can have an impact on other B.C. coastal areas.

Several factors make tsunami hazard prediction and risk mitigation especially challenging along B.C.'s coast. These include the broad geographical scope of Pacific Ocean originated tsunamis that can affect B.C., the complex characteristics of B.C.'s coastline, the diversity of coastal populations and infrastructures and the varying options and capabilities for warning those at-risk.

For distant tsunamis, locations within many sub-regions of the Pacific Rim are capable of generating large enough waves to impact B.C. shorelines. Between 1997 and 2014, 22 tsunamis that have reached locations along the B.C. coast have been recorded (Stephenson, F.E. et al, 2009 and personal communication).

While distant-generated tsunamis pose significant risk to many B.C. coastal areas, local tsunamis present even greater risk. Along the southern portions of the B.C. coast, the Cascadia subduction zone represents the greatest tsunami hazard area, with the most extreme potential wave run-up. Local tsunami hazard for the northern B.C. coastline is largely attributed to thrust (strike-slip) sources occurring along the Explorer and Queen Charlotte Plate margins. For the more sheltered inner coasts of Juan de Fuca Strait and Georgia Strait, the hazard is attributed mostly to Cascadia subduction zone events (Leonard, et al, 2012). The potential for landslide-caused tsunamis in all coastal regions, and specifically to the Georgia Strait has also been identified (Rabonivich et al, 2003; Bobrowsky and Dominguez, 2010; Leonard, et al, 2012).

Injury and loss of life can be minimized if coastal populations at-risk are warned that a tsunami is approaching. Under current notification arrangements, it is expected that a distant tsunami should allow sufficient time for an official tsunami message to be given to populations at-risk, but a local tsunami can reach the shoreline within minutes and may not allow for any official warning to take place. In such a case, natural signs, such as the strong shaking from the

earthquake, a receding ocean, or a loud roaring sound, may be the only local warnings to allow for appropriate action (British Columbia, 2013b). However, even in these instances and depending upon local conditions, people on floating marine platforms or vessels may not feel the shaking or witness other signs and may remain unaware of the hazard.

Further, modeling tsunami wave run-ups and putting in place effective public tsunami notification systems along B.C.'s coastline is complicated by its unique geography and population distribution. While the aerial or linear distance from Victoria on the Strait of Juan de Fuca to Stewart, B.C. on the Alaska border is 965 kilometres, because of its heavily indented coastline with fjords and complicated shorelines of some 40,000 islands of varying sizes, the total length of British Columbia's coast is actually over 25,725 kilometres (Sebert and Munro, 1972). The coastline's mountainous spine that runs its whole length, breaking into long mountain fjords, is often compared to Norway.

Due to this geography, landside settlements tend to reside in low-lying valley bottoms and along shorelines. Outside the more heavily populated and infrastructure rich regions of south and eastern Vancouver Island and southwestern British Columbia, transportation, housing and infrastructure arrangements are heavily affected by terrain and remoteness, with the majority of settlements only accessible by single mountainous roadways or by marine or air transport as weather permits. A substantial number of temporary and permanent residents live onboard floating houses, vessels, resorts and multi-tenant work campsites. Similarly, the underpinning infrastructures that service these regions vary considerably according to factors such as population density, geographical complexity, economic activity and access and distance from other communities.

In the past half century, and corresponding with the tsunami events described above, significant coastal socio-economic and cultural transformations have taken place and continue to unfold affecting where both more settled and transient populations are likely to reside during different periods of the year. These changes, in turn, further complicate hazard event and warning notification in these regions. The most significant changes, especially in the outer regions, have been driven by economic transformations. During this period, B.C.'s forest sector's performance has declined significantly, as have traditional salmon and herring fisheries and seafood processing. Mining activity has also fluctuated significantly. Concerned about reliance on traditional resource-based practices for employment has motivated coastal residents to recognize that long-term survival of their communities and livelihoods rests on balancing sustainability of these industries with increased diversification of coastal economies. Consequently, several new initiatives have been launched by federal, provincial, regional and local authorities, First Nations, conservation and private sector organizations in order to refine and redirect economic growth in coastal regions.

Since the late 1990s, some of the most noteworthy areas of new economic activity to emerge have been aquaculture, recreation and tourism, research and oil, gas and other resource exports. In the case of aquaculture, the British Columbia coastline is a sought-after location because of a coastline that is unique in North America with its many fjords and protected inlets and bays, ice-free areas, and suitable water temperature for fish and shellfish production. By 2010 some 2,500 people were employed directly and indirectly in the finfish and shellfish industries, with an

annual value of output over \$590 million (Fisheries and Oceans Canada, 2013).

Tourism, historically, was a relatively minor component of the economy of much of mid and northern coastal B.C. and northern Vancouver Island, characterized by relatively small numbers of visitors to the areas, limited transportation and a dominance of primary resource industries. However, over the last three decades, tourism has grown steadily all along the coast coinciding with much improved personal and commercial transportation, global economic ties, environmental awareness and protection concerns, new tourism social trends and demographic shifts.

In particular, eco and adventure tourism has emerged as a major source of employment and contribution to local economies, fueled by rising national and international awareness about the region's inspiring natural land and seascapes, untouched wildernesses and enormous ecological wealth and diversity. The region encompasses a variety of unique biophysical and ecological conditions. It supports hundreds of species of marine fish, internationally significant seabird colonies, shorebirds and migratory waterfowl. It is renowned for its sea and land mammal populations, most notably humpback, orca, fin and minke whales and the grizzly, black and spirit bears, as well as elk, mountain goat, and many others. Some of the largest and oldest forests in the world grow here.

Changes in the tourism industry also reflect new consumer preferences and tastes that are part of a global paradigm shift from an old mass production based to a more flexible, customized and responsible travel and tourism sector. Many of the new tourists visiting the B.C. coast are more experienced, better educated, independent, conservation-minded and quality conscious, but also harder to satisfy and much more adventurous in their activities.

These changes are also encouraging greater risk-taking in certain segments of the industry. Among the most significant changes is an increasing interest in remote getaway vacations, ecotours, cultural tourism (ethnotourism) and combining business trips with pleasure. There is also a shift in emphasis from passive enjoyment to active learning and quality. Authentic outdoor visitor experiences have become crucial for successful rural tourism. Concerned about impacts of large-scale tourism activities, many are seeking low impact tourism facilities consistent with environmental values. Further, these changes are occurring amidst shifting demographics in Europe and North America, where baby boomers (55 and older) have grown into a significant retirement population that is more affluent, more discriminating, more demanding, and able to spend more time travelling than previous generations, as well as invest in permanent and seasonal retirement and recreational marine properties.

British Columbia has been well-positioned to take advantage of these changes. A key goal is to draw visitors off the beaten path to some of British Columbia's most isolated, spectacular, and lesser known, wilderness and scenery. The coast is also rich in cultural heritage and resources associated with First Nations and non-aboriginal peoples. The establishment of federal and provincial parks and ecological reserves has increased awareness of the coast's offerings and resulted in a dramatic increase in the number of recreationists, tourists and commercial tourism operators visiting destinations all along the coast. They can also take advantage of a milder climate that expands the duration of the marine tourism season beyond that found elsewhere in rural Canada (Anderson and Gow, 2003).

Not surprising, new tourism is rich in diversity. Water based examples include: sea kayaking and canoeing; snorkeling and scuba diving; whale watching; wind and regular board surfing, and marine small and large vessel cruising. Cruise activity in B.C. now represents more than half of the total Canadian cruise traffic with more than 1.3 million passengers visiting B.C. ports and contributing an estimated \$1.6 billion to the B.C. economy in 2013. 470 cruise ship calls are expected to be completed in 2014, up from 455 calls in 2013 (Chamber of Shipping, 2014).

Even the more traditional forms of marine tourism such as sports fishing have been transitioning. B.C. has always offered some of the world's finest saltwater sport fishing for all five species of Pacific salmon and for bottom fish like halibut, ling cod, and an amazing array of rockfish. Today, with improved access by road, water, float plane or helicopter, almost every part of this vast coast is now available to anglers, often equipped with a fishing resort to serve them.

On the shoreside, new tourism examples include: remote backpacking, camping and coastal trail hiking; cave or karst exploring; rock climbing; beachcombing; storm watching; wildlife viewing; eco-trekking and natural history; photography; cultural/heritage viewing, special events, ceremonies and festivals.

Added to this, the region's unique geo-physical and ecological characteristics have also established it as one of the world's most valued destinations for seasonal and year-round marine and coastal land-based research. Key sectors include: ocean observation and science; marine transportation; offshore energy; defence and security; fisheries; marine recreation; aquaculture and education and training (NRC, 2009). A number of these activities are being carried out in collaboration with First Nations, enabling them to protect their aboriginal fisheries and establish collaborative management structures that integrate ecosystem/watershed management and planning processes with traditional heritage. Such collaboration is resulting in new approaches to jointly manage and sustain marine parks and reserves such as the Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve and Haida Heritage Site. Designated as a UNESCO World Heritage Site and accessible only by boat or plane, the terrestrial portion of Gwaii Haanas covers the southern portion of Moresby Island of Haida Gwaii and the marine portion extends 10 kilometres offshore from the coastline. Created in 2010, this is recognized as the first area in the world to be protected from mountain top to sea floor (Parks Canada, 2014, Haida Nation, 2014).

Mainstream economic activities are also morphing beyond their traditional basis of operation. Through the Asia-Pacific Gateway and Corridor Initiative, investment and policy measures are focusing on enhancing transportation networks facilitating global supply chains between North America and Asia. Container and bulk cargo loading and off-loading facilities are undergoing major expansions in many regions of the south and north coast, taking advantage of deep harbours and weather protected inlets and improved ground transportation.

In the energy sector, British Columbia has embarked upon an ambitious plan to broaden its natural gas export market as the demand for liquefied natural gas (LNG) is expected to increase by two-and-half times in the Asia Pacific region by 2040. Nearly a dozen project applications for facilities located along the northwest coast have been submitted and are at various stages in the

approval process, with the B.C. Government committed to having three LNG facilities in operation by 2020. Proposed export terminals include: Kitimat, Prince Rupert, Grassy Point and Kitsault. Other energy projects are in the works to increase terminal capacities to support oil, coal and other resource exports.

1.2 New Challenges for Tsunami Notification

The trends outlined above raise new challenges to ensuring effective tsunami event and warning notification along the B.C. coast, as more people reside in or traverse through more locations throughout all periods of the year. The areas of British Columbia most vulnerable to tsunamis are the exposed coastal and inlet systems along the west coasts of Vancouver Island and the Haida Gwaii Islands, and the mainland coast and small islands regions between the Haida Gwaii Islands and the northern tip of Vancouver Island. These regions also appear to correlate with many of the emerging and expanding socio-economic activities but have not yet been fully identified and documented.

Current tsunami notification arrangements¹ rely upon a series of inter-related systems, programs and jurisdictions that include:

- a detection subsystem to identify the presence of a tsunami hazard or the existence of hazardous conditions, tracking and monitoring of any generated waves, and the forecasting of wave arrival times and heights along the coast, coordinated by the U.S. National Tsunami Warning Center in Alaska;
- an emergency management subsystem to determine the extent and magnitude of the tsunami threat to B.C. (which includes assessment of public safety threat, property loss potential, environmental damage potential, and economic loss potential) coordinated by Emergency Management British Columbia in collaboration with the Canadian Hydrographic Services, and
- a public response subsystem to relay tsunami event notification information and warning for coastal populations, carried out by a consortia of international, federal, provincial and local authorities, volunteer agencies and other partners. It is important to note, however, that this subsystem is most effective in the case of far-field or telegenic tsunamis, where there is sufficient time to determine possible tsunami risk and effect a response along the coast. Locally generated tsunamis may pre-empt activation of this subsystem, as clearly indicated in the current BC Tsunami Notification Process.

Collectively, today, these authorities and partner agencies employ an array of methods to receive official tsunami event notifications and disseminate alerts and messages to populations-at-risk (including telephone, facsimile, email, radio, SMS, Twitter, WWW, sirens, personal contact). Their choices of methods are influenced by several factors, including: institutional and jurisdictional arrangements, budgets, available supporting infrastructures, the physical location and nature of the population (e.g. residents vs. non-residents), local customs and economic and social activities. In more rural and remote regions, communication with populations-at-risk can be challenged even further because of limited modes of transportation and widely dispersed populations that fluctuate according to seasonal variations and economic circumstances (tourism,

¹ These arrangements are described in more detail later in this report.

fishing, logging, aquaculture, etc.). Regardless of the method, additional critical considerations are consistency in application and messaging, timeliness, as well as ensuring widespread public knowledge of the nature of the risks, methods of notification and expected actions.

From a telecommunication perspective, particularly in rural areas, there are widely varying levels of access to services (especially basic fixed and cellular telephone, Internet and local broadcasting services) due to higher infrastructure costs, smaller supporting populations and greater distances from larger centres. Even where two-way radio (marine, commercial and public safety) and satellite communication systems are employed, access to and reliability of service can be influenced by line-of-sight coverage issues due to mountainous terrain. Consequently, current tsunami and other emergency notification arrangements must draw upon a broad combination of traditional and contemporary systems to support timely communication with all potentially affected populations (fixed and transient). Two of the most persistent challenges are:

1. how to get a disruptive/wake up alert to a diffuse population; and
2. how to get authorized, locally targeted and consistent messaging to mass populations through multiple popular modalities.

While many communications challenges persist, advances in information and communication technology (ICT) increasingly offer a range of options for integrating and standardizing notification arrangements. Among the potentially more useful ICTs are Internet Protocol-based fixed and mobile terrestrial and satellite systems. These systems are more addressable and becoming more affordable and widespread in use, including new data exchange schemes, such as the Common Alerting Protocol (CAP), that offer opportunities better to manage, integrate and target warning messages simultaneously across a wide variety of dissemination systems, with exponentially-growing communication capacity. Further, considerable experience is being gained in innovative community-based last-mile ICT projects in other locations, especially in the post-tsunami regions of South Asia and Japan, which could help to inform the development of new initiatives in the Canadian west coast region.

However, many of these technologies and strategies have not been designed or tested specifically for coordinated use in extreme emergency conditions, such as those posed along the B.C. Coast, or assessed for affordability and relevancy with local authorities and practices.

This project is intended to examine these changing coastal conditions, current tsunami notification methods, their underpinning institutional and infrastructure arrangements, and to contribute to studies and applied projects that support strengthening and sustaining B.C. coastal tsunami notification arrangements. It is hoped that successful implementation and integration of new techniques and strategies for B.C.'s rugged environments can also provide direct benefits to other regions of Canada that possess similar challenges.

1.3 Project Objectives

The principle objectives are to:

- bring practitioners and key stakeholder groups together with subject matter experts to share knowledge and build relationships to support long-term development of sustainable, reliable and integrated West Coast Canadian end-to-end public alerting and

emergency communication systems and to contribute to strengthening these types of systems elsewhere in Canada.

- improve application of these systems through selected pilot projects to support remote area tsunami alerting.
- provide clear and action-specific recommendations for a roadmap towards next-generation emergency communication systems to support emergency response activities throughout British Columbia.

1.4 Project Scope

The project is composed of two major phases:

- **Phase 1:** (April – December, 2014) Conducting a study to inventory and assess existing coastal warning and communication networks and last-mile segments.
- **Phase 2:** (January, 2015 – April, 2016) Piloting and evaluating new techniques and technologies that can support region-wide and localized needs. This phase will include revising and expanding the Simon Fraser University (SFU) “Tsunami Warning Methods Planning Tool Kit” planning guide originally published in 2006, and assist with community technology implementation and training.

1.5 Impact on Outcomes

It is anticipated that the improvement of tsunami warning can help build strong communities and enable connected practitioners, thus increasing resilience to disasters by:

- identifying most vulnerable populations, hazard zones, and community capacities;
- increasing community-level risk awareness and encouraging appropriate preparedness and mitigation activities;
- building social capital through facilitating connectedness and community building, and
- increasing community-level risk awareness and encourage appropriate preparedness and mitigation activities.

1.6 Excluded Work and Phase 1 Scope

This report summarizes the key activities of the Phase 1 study to inventory and assess existing coastal warning and communication networks and last-mile segments. The scope of the current work is limited to the coastal areas of British Columbia only.

It is important to note that much of the data collected and documented in this report is not intended to be analyzed in Phase 1. Rather, the primary purpose of this initial research and analysis is to serve as a baseline study to support carrying out pilot projects in a select number of communities in Phase 2 in order to validate existing preferred systems and to test and evaluate new warning techniques and supporting technologies. The research will also support the development of a Tsunami Warning Methods Planning Tool Kit Guide and an all-hazards alerting roadmap for British Columbia. As such, much of the data presentation and discussion presented in this report is intended to be more descriptive and should be viewed as a work-in-progress. We will also continue to collect, update and analyze data throughout Phase 2.

1.7 Building Upon Previous Tsunami Notification Projects and Initiatives

The current study builds upon a growing number of B.C. tsunami risk reduction studies and initiatives that have been carried out over the past decade, focused on improving tsunami notification, especially in the last mile segments. Many of the systemic and emerging coastal notification challenges described above, in fact, have already been identified during previous activities that produced a number of recommendations and strategies for further action. Those that are specifically relevant to this project, and which are yet to be fulfilled and/or updated, are briefly summarized below.

2004 B.C. Tsunami Warning Systems Review

In 2004, Simon Fraser University completed one of the first extensive reviews of the B.C. Tsunami Warning System and related risk reduction practices (Anderson and Gow, 2004). Key findings and recommendations included:

Monitoring and detection

While Canada's involvement in the Pacific Tsunami Warning System provides effective monitoring and alerting capability for distant tsunamis affecting the B.C. Coast, effective alerting for locally-generated tsunamis remains problematic.

Recommendations:

- Consider the deployment of new communications technology where it provides identifiable enhancements to the current monitoring and detection activities.
- B.C. PEP² should begin developing a warning and alerting strategy for local tsunamis along B.C. coastal region.

Education and public awareness

An essential element of tsunami mitigation is public awareness of the tsunami hazard and what actions are to be undertaken safely when a tsunami is expected.

Recommendations

- PSEPC³ should support a Canadian tsunami information clearinghouse to enable 'one-stop' access to tsunami information and planning resources.
- Federal and provincial agencies in conjunction with private sector partners should provide support for the creation and maintenance of targeted tsunami educational programs in place for industry sectors such as tourism, fisheries, aquaculture and forestry.

Further research

Recommendations

² BC PEP (BC Provincial Emergency Program) is now Emergency Management British Columbia

³ PSEPC (Public Safety and Emergency Preparedness Canada) is now known as Public Safety Canada

- An infrastructure audit should be undertaken to determine the communications capabilities of local populations along the B.C. Coast. Findings would provide important details for community planning and could make a valuable contribution to Industry Canada's Public Alerting initiative and to the future design of the B.C. Tsunami Warning System.
- Little is known about tsunami awareness within and the preparedness practices of coastal populations, particularly transient and marginal groups. A detailed assessment could provide an empirical basis for setting future targets, identifying priorities, and establishing quantitative measures for the effectiveness of mitigation and preparedness strategies.

Following the 2004 Indian Ocean Earthquake and Tsunami tragedy, a Western Canadian Tsunami Integrated Preparedness (TIP) group was formed by the B.C. Provincial Emergency Program in partnership with federal, other provincial and local governments, communities, private industry, First Nations, humanitarian organizations and the media to improve tsunami notification along the B.C. Coast. As a contribution to the initiative, SFU (Anderson, 2006) developed a "British Columbia Tsunami Warning Methods" community planning tool kit that incorporated a large compendium of information concerning the then current B.C. tsunami warning procedures, best practices and considerations for effective warning, and a guide to warning techniques and procedures tailored to B.C. needs. This guide has served as key resource for local notification planning but has not been updated since 2006 to reflect current best practices and new notification methods.

In July 2010, SFU, in partnership with Emergency Management British Columbia and the Cascadia Region Earthquake Workgroup, helped to organize and facilitate a special symposium on "Enhancing Tsunami Warning Along North America's Northwest Coast: Reaching the Last Mile" (Anderson, 2010). The symposium provided an opportunity to assess progress flowing from previous notification initiatives and to identify new challenges and opportunities. Recommendations relevant to this current project include:

- Carry out a comprehensive study to inventory and assess existing coastal warning and communication networks and last-mile segments, including service coverage, attributes and state of interoperability. The study should extend along the entire West Coast and include public and private sector resources.
- Develop a system to classify coastal communities and other key locations by level of vulnerability to guide prioritization of pilot projects and future risk reduction investment.
- Evaluate and pilot new techniques and technologies that can support region-wide and localized needs. Examples include satellite-based broadcast (e.g., XM and Sirius) and two-way radio (e.g., MSAT), GPS-based location reporting and CAP messaging systems, rural wireless and fixed-wire broadband systems, mobile social media, etc.
- Carry out workshops to:
 - inform emergency managers about the technical nature of new social media applications such as Twitter and Facebook and their implications for public warning.

- examine the use of social media in recent disasters and formulate lessons and best practices.
 - provide training in social media techniques.
- Revise and expand the SFU Tsunami Warning Methods Tool Kit Guide to include:
 - new innovations and best practices.
 - a workbook and set of templates for community self-assessment and communications planning.

1.8 Study Methodology and Scope

From the outset, this project set out to address many of the recommendations outlined above and to carry out new research by establishing a framework and study methodology that would enable its team to systematically capture and store study data concerning:

- tsunami hazard zones;
- populations-at-risk;
- coastal socio-economic activities;
- key notification processes and stakeholders;
- current and emerging notification methods and their underpinning communication infrastructures, including coverage;
- current notification methods usages, practices and capabilities, and
- other area communication methods and supporting technology not currently integrated into existing tsunami notification systems.

The principle methods of data gathering employed in this study include: semi-structured interviews, site visits and email correspondence with key agencies; Internet and online journal and data base searches for background data and information concerning warnings systems, lessons learned and recommended good practices, coastal populations, socio-economic activities, communications coverage and community tsunami hazard and public information programs; downloading special Twitter data sets to identify followers of @NWS_NTWC and @EmergencyInfoBC, the two key accounts used to disseminate official West Coast tsunami bulletins; participation in the Tsunami Notification Networking Group and EMBC planning meetings and activities; interviews with communication service providers and vendors. A number of additional specific requests were made to selected agencies for specialized data concerning notification processes, methods, supporting infrastructures and locations of facilities and service coverage.

Throughout the collection period, data was reviewed and organized into categories. Categories were then converted to data fields in a set of spreadsheets to establish a framework for systematically recording and organizing study data. Data fields initially included: community and other geographic locations and current tsunami notification zones identified in the British Columbia Tsunami Notification Process Plan; various other jurisdictional boundaries; types of methods used for receiving official external tsunami notifications, as well as methods used to disseminate messages to local populations. These fields were supplemented by adding geo-reference codes and other attribute data to each identified location. This process resulted in the creation of a large geo-coded community notification matrix that could be used not only for data

collection purposes, but also to support analysis and form the basis of a pilot project in Phase 2 that could use the matrix as community and regional notification planning tool.

Given the limited time frame for Phase 1 initial data collection (April - September 2014), it was uncertain as to how feasible it would be to collect detailed data for all locations along the B.C. coast, and it was decided that concentrating initially on a coastal sub-region would provide an opportunity to test and validate the matrix. Two northern Vancouver Island regional districts, Mount Waddington Regional District and Strathcona Regional District, agreed to participate by contacting their communities' emergency management authorities and assisting with filling in the appropriate data fields. As work progressed, it was soon realized that an on-line version could provide a means to quickly expand data collection across the entire coastal region. Coincidentally, the completion deadline for Phase 1 was extended to end of December, 2014, making this latest collection method feasible.

Consequently, an online questionnaire was created that imbedded the same data collection fields found in the spreadsheet, but was expanded to include additional questions concerning notification preferences and community capacities to receive and locally re-distribute tsunami notifications. With the assistance of EMBC's regional managers, invitations were sent out to local authority representatives within their regions. These included representatives from incorporated municipalities, regional districts and First Nations. A copy of the survey questionnaire accompanied the invitation to enable participants to view the questions and gather necessary information before going on-line. For those without Internet access, an option to fax the results was provided.

However, the initial response fell short of what was anticipated primarily because the on-line survey was launched towards the end of the summer season. The submission deadline was extended subsequently and reminders were sent out, followed by a round of personal follow-ups to encourage participation. This proved to be a successful strategy and produced 84 responses with a sampling of all coastal areas. The results were then incorporated into the community matrix spreadsheets.

Coinciding with the matrix data collection efforts were three other activities: 1) GIS data gathering and mapping, 2) social media analysis and 3) selected radio propagation mapping.

GIS Map Layering

Two types of data were used to support GIS mapping: Original and Derived data. Original data refers to the data that was downloaded from an external source. Derived data refers to data that was created from original data sets or collected through other means (e.g., surveys). A brief summary of techniques used follows. The GIS software used for this project is ESRI's ArcGIS 10.2.

Over 80 data sets were collected and/or derived from a number of sources. Principal Original data sources include: Data B.C. (GeoBC), Hectares BC, Geobase, Spectrum Direct and special requests from agencies and service providers. Derived data sources include: Census, email and SMS notifications, Twitter, NetworkBC and project surveys. These data sets are briefly listed below in Table 1. A detailed listing is contained in Appendix A.

Original Data	
Geography <ul style="list-style-type: none"> • CHS High Water Mark • Coastal BC Bathymetry • Elevation • BC Geographical Names • Geographical names v_2 • BC Fault Lines • Tectonic Plates (USGS) Political Boundaries and Census <ul style="list-style-type: none"> • Aboriginal Boundaries • Admin boundaries • BC Boundary • Baseline Thematic Mapping: Land use/cover • BC Census table [Refer to Derived data for details] • First nation land reserve • Land Cover • Landuse • Municipalities • Parks and Protected Areas Regional Boundaries • Parks and Protected Areas • Regional Districts Tourism <ul style="list-style-type: none"> • Coastal BC Marine and Fresh water Kayaking Routes • Coastal Rec and Pleasure Craft Routes • Coastal BC Campsites • Coastal BC Marinas • Coastal BC Diving Sites • Coastal BC Marine Kayaking destinations • BCTS Operating Areas • Recreational Points • Recreational Polygons • Recreational Feature Inventory • Guide Outfitter Areas • Recreational Lines • Ocean Paddle Areas 	Transportation <ul style="list-style-type: none"> • Cruise Ship Routes • MOT Rest Areas • Railway Networks • Road Networks Critical Infrastructure <ul style="list-style-type: none"> • BC Health Care Facilities Hospitals • BC Schools: Location of BC Schools • Coastal BC Moorages • Coastal BC Airports • Coastal BC Anchorages • Coastal BC Boat Launches • Coastal BC Ferry Terminals • Cruise Ship Routes • MOT Rest Areas • Railway Network • Road Networks Communication and Notification Networks <ul style="list-style-type: none"> • Cellular Mobile Coverage • Canadian Coast Guard VHF and NAVTEX radio coverage • Environment Canada Weatheradio Station Coverage • Tsunami Notification Zones • Pacific DART and Tide Stations • Broadcasting AM, FM and TV • CLC boundaries Economic <ul style="list-style-type: none"> • BC Off shore Oil and Gas Seismic Profiles (shows 5 lines) • Coastal BC Marine Industrial Sites • Fish Processor Tenures • Forest Tenure Harvesting Authority • Log Booming • Mineral, Placer and Coal Tenure • Forest Tenure Harvesting Authority • Salmon Hatcheries • Shellfish Aquaculture Plan Unit Boundaries • Saltwater Finfish • Shore unit Polygons Public Safety <ul style="list-style-type: none"> • BC Ambulance Services Stations • BC Police Jurisdiction Boundaries • EMBC Boundaries • Police, Fire and Ambulance (*Ambulance is the same as above) • Police

Derived Data	
<ul style="list-style-type: none"> • @NWS_NTWC Twitter Data Sets • @EmergencyInfoBC Twitter Data Sets • @NWS_NTWC Twitter SMS Data Sets • Special Regional District Sub-sets • MSAT EmergNet Coverage • MOTI VHF propagation 	<ul style="list-style-type: none"> • Community Notification Matrix • Local Authority Notification Methods survey • Network B.C. Broadband Coverage • Coastal Population Census

Table 1
Original and Derived GIS Data Sets

Two of the most significant sets of derived data come from the community notification matrix and local authority notification surveys described above. Once the data was placed into tables, spatial joins were administered to identify the latitude and longitude fields for each representative location. This technique worked for over half the locations; the rest were manually entered. The data was then imported into ArcGIS and converted into a Shape file. A spatial join was also processed between the survey data and the census data. Total population for the B.C. coastal region was then identified.

In addition to adding latitude and longitude fields to make table formatted data (ASCII, XLSX, CSV, TXT) viewable in ArcGIS, other data conversion techniques were employed to convert data back and forth between KML and ESRI Shape file formats. For example, in order to view and overlay KML file format data in ArcGIS, the data was converted to ESRI Shape files. In ArcGIS the tool “KML to layer” converts the file to a layer that retains the symbology but links to the original data set. The layer (lyr) format is then exported into a Shape file for processing purposes.

For ESRI Shape file to KML conversion, the tools used were either “Layer to Map” or “Map to KML”. First, the data is converted to a layer format then filtered into one of the tools. “Layer to Map” was used for exporting a small batch of layers and “Map to KML” was used for exporting multiple map layers into KML format.

Broadcast coverage data was collected from Industry Canada’s Broadcasting Database as MapInfo files. These files included data for: AM, FM and TV stations. QGIS was used to bridge the files from native TAB formats to ESRI shapefiles, allowing for layering and symbology configuration in ArcGIS.

A series of specialized maps can then be created based on data extracted from the community notification matrix as well as survey questions. Most of the maps presented in this report are intended to serve as examples of the diversity of maps that can be derived from this data.

Social media data collection

In our study, we undertook to identify B.C. followers of the U.S. National Tsunami Warning Center and Emergency Management British Columbia Twitter feeds through collecting a sample of 9,999 followers from each of the @NWS_NTWC and @EmergencyInfoBC Twitter sites and analyzing follower profile data. Once the samples were imported, the next step was to search for eligible users and ties located in the Pacific West Coast Region and check and hand-code each

follower for status, language, and location. Further details are described in Sections 4.3.1.5 and 4.3.2.3.

Radio Propagation

In order to identify and map radio coverage availability of existing Coastal RF-based notification systems, two methods were employed: 1) obtaining GIS coverage data directly from system providers and Industry Canada, the radio licensing authority and 2) generating our own maps based upon creating algorithms and program coding to automatically search and filter data from Industry Canada's Spectrum Direct licensing database and to streamline propagation mapping. Due to its vast diversity, taking into account Coastal terrain features is critical to plotting correct line-of-sight coverage to ensure that areas with poor or no service are noted, particularly for notification to transient populations.

The simplest form of coverage mapping to apply is the Longley-Rice Irregular Terrain Model (ITM). These models combine LoS information with terrain-based diffraction and scattering estimates to evaluate signal losses from a transmitter located in a complex landscape, given a digital elevation model (DEM) of the terrain and transmit power, climate, and soil property inputs. For the project, SFU uses *SPLAT!* – an open-source ITM tool. SFU has used this tool as a component of PolyLAB's long-existing *rd2splat* tool, which has been improved during the project. In particular, the tool has been improved for work in mountainous coastal areas and will serve as a component of work to be carried out in Phase 2.

This tool is especially useful for identifying hidden communication resources, such as other public agency and private sector radio systems that are not currently incorporated into community and regional notification systems, but could significantly improve reach to populations-at-risk. We have presented a few examples, as a proof-of-concept in Section 4.6.

1.9 Report Layout

This document is divided into five main sections. Section One begins with an overview of the British Columbia tsunami hazard, coastal characteristics and changing socio-economic conditions in order to establish a context for the study and then proceeds through a description of the project's objectives, scope and methodology. Section Two provides a more in-depth review of B.C.'s tsunami hazard and earthquake and tsunami threshold considerations that have been used to determine current coastal notification zone boundaries. Section Three explains the methodology used to identify and classify populations-at-risk within the tsunami notification zones, including both fixed and transient populations. Section Four provides a comprehensive review of end-to-end tsunami notification arrangements beginning with detection, and proceeding through the various stages of notification, concluding at the last mile/last person stage. Included in this section is an articulation of all key stakeholders notification procedures, processes and methods as well as an identification of other participating and potential notification partners and underpinning information and communication infrastructure. Section Five examines current local notification practices and presents preliminary results of an on-line survey undertaken with B.C. coastal local authorities. Section Six illustrates how derived map data can identify hidden vulnerabilities. A series of appendices are included to provide additional information about GIS data sources, tsunami messages, the on-line survey and participants.

2. British Columbia Tsunami Hazard Zones

As described in the Introduction, British Columbia is at risk from tsunamis generated from a number of sources, but especially from earthquakes occurring in various Pacific Ocean sub-regions. Some of these tsunamis are the result of distant great earthquakes. Sub-regions of note that have generated distant tsunamis sufficient to reach B.C. in recent history (1915-2012) include: Indonesia, Japan, Kuril Islands, Kamchatka, Aleutian Islands, South-central Alaska, Mexico, Peru and Chile. Two events had waves of over 1 metre recorded (Wigen, 1983; Clague et al, 2000) but only one of them, the 1964 Alaska earthquake, was sufficient to cause significant damage.

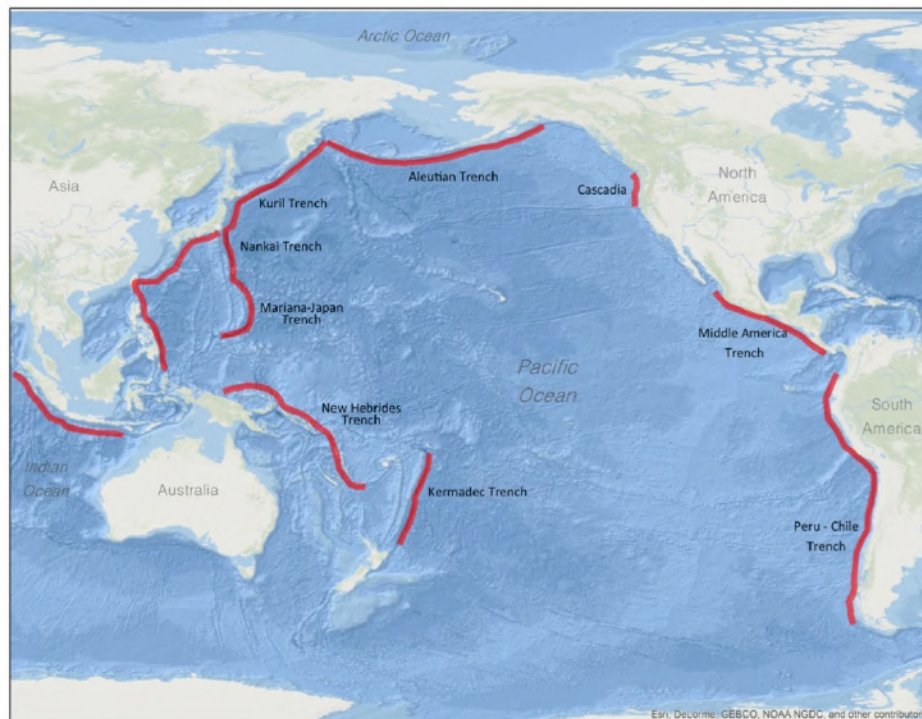


Figure 1
Sub-regions that have generated distant tsunamis sufficient to reach B.C.
Based on Clague (2001)

Despite these risks, the largest tsunamis have been found to be triggered locally by great earthquakes within the Cascadia Subduction Zone (CSZ) that extends along the Pacific Coast from Vancouver Island to northern California. Another B.C. Coastal tectonic zone of concern for local tsunamis is near the islands of Haida Gwaii. This region extends from the tip of the Explorer Plate and upwards into the Alaska Pan Handle.



Figure 2
BC Coastal Major Fault and Plate Boundaries

Yet another source of local tsunamis are those generated by landslides. Although common on a geological but not human time-scale (Mosher, 2009), large landslides have the potential to generate damaging transoceanic tsunami runups (Leonard et al, 2011). Such tsunamigenic landslides can be subaerial or submarine caused by natural events such as earthquakes, or anthropogenic events such as construction.

At a greater risk than anywhere else in Canada, B.C. is more susceptible to these events due to its steep-sloped topography and earthquake frequency (Mosher, 2009). Northern B.C. has more documented events of tsunamigenic landslides; however, risk in the more populated southern region of the province also exists (Rabinovich et al, 2003).

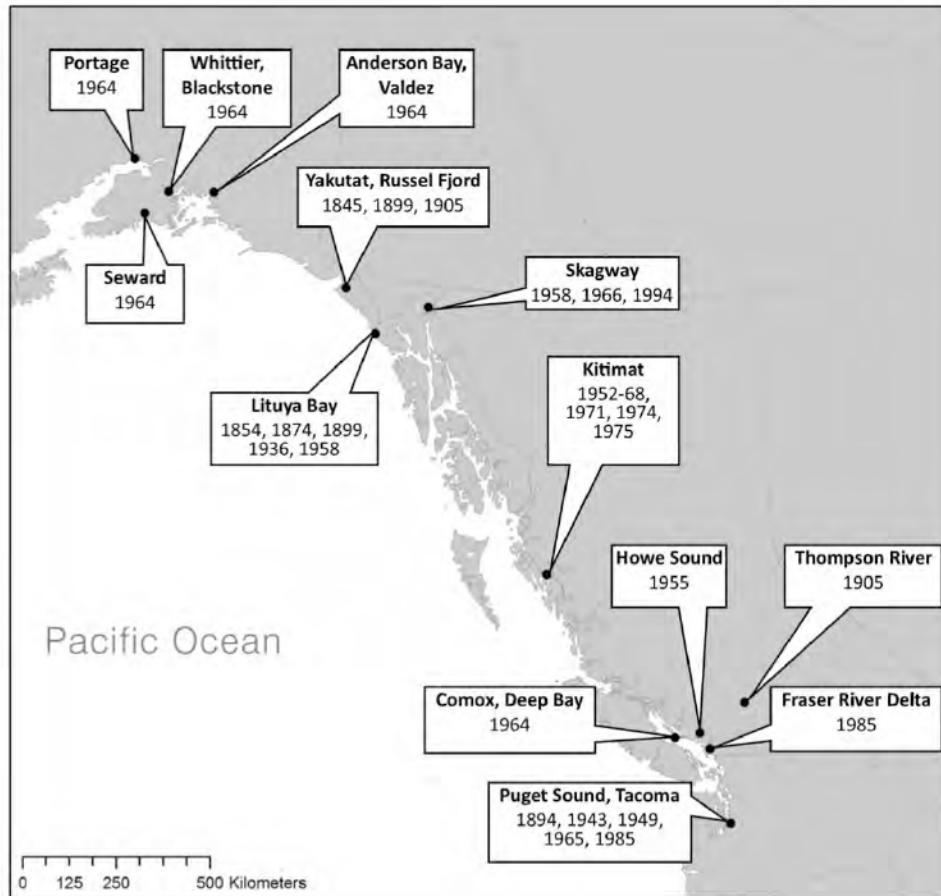


Figure 3
Pacific Northwest Identified Submarine and Land-side Landslide-generated Tsunamis
 Alexander B. Rabinovich et al. (2003)

Understanding historical impacts of great tsunamis in B.C. Coastal areas is difficult because of the infrequency of their occurrence and incompleteness of natural and human records of past events. Further, no large-scale local earthquakes have struck the B.C. Coast since the time of Euro-American settlement (early 1800s).

The largest B.C. West Coast tsunami event recorded in the past century occurred on 27 March 1964, following a magnitude 9.2 earthquake in Prince William Sound, Alaska, sending a series of tsunami waves down the west coast of North America. Along the outer coast of Vancouver Island, a number of communities were impacted. In particular, tsunami waves travelled up Alberni Inlet and struck Port Alberni, raising water levels four metres above high-tide level and causing extensive damage to the town. Residents received no official warnings about the incoming waves. Fortunately, there were no casualties as a result of the tsunami, but direct losses were estimated at upwards to \$40 million. (Anderson and Gow, 2003, Clague et al, 2000).

More recently, a localized magnitude 7.7 earthquake struck off the west-central coast of Moresby Island in the Haida Gwaii archipelago at 8:04PM PDT on 27 October 2012. Residents along the West Coast, from Alaska to southern B.C., also felt several aftershocks up to magnitude 6.3 (NRCAN, 2012). Tsunami warning messages were issued for coastal areas from Alaska to the

northern tip of Vancouver Island, along with advisories for other parts of the B.C. coast. Fortunately, no major damage or injuries were reported. This is the largest earthquake to strike Canada since 1949, when an 8.1 magnitude earthquake struck in the same area.

2.1 Evidence of past tsunamis

Sedimentary deposits from tsunamis have proven to be among of the most valuable sources for verification of previous tsunamis. Growing evidence that the CSZ produces large earthquakes has been found in the turbidite record off of the Cascadia Margin (Adams, 1990; Goldfinger et al., 2003) and on land more than 60 sites along the Cascadia margin containing potential or confirmed tsunami deposits have been identified and published (Clague et al, 2000; Peters et al, 2007). These include deposits found in tidal marshes and low-elevation coastal lakes on western Vancouver Island. There are many other locations where tsunamis may have also impacted, but local conditions (such as high cliffs) make it difficult for preservation and identification of deposits (Clague et al, 2000).

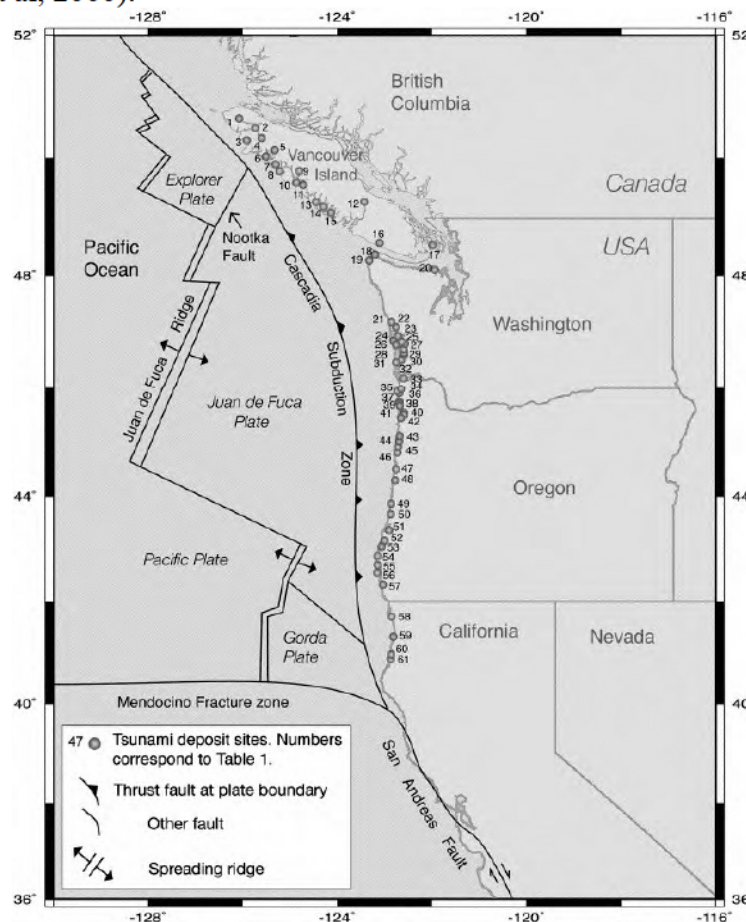


Figure 4
Locations of Tsunami Deposits Located in the Cascadia Region
Peters et al. (2007)

Multiple deposits unearthed at some particular sites signify that, over the last 7300 years, as many as 13 tsunamis have affected the coast along the Cascadia margin. Average recurrence

intervals of 500–600 are characteristic but the length of time between events can range from around 300 to over 1000 years (Clague et al, 2000).

Evidence of some of these events has been further corroborated and supplemented by other sources, including oral traditions of First Nations and archaeologists and ethnologists and anthropologists who are interested in understanding their effects on peoples and cultures (Losey, 2005). In fact, the relatively precise age estimate for the most recent earthquake, January 26, AD 1700, came about through correlation of evidence obtained by several disciplines including studied tsunami deposit layers, radiocarbon dating on terrestrial plant specimens and tree-ring analysis of Sitka spruce and western red cedar that appeared to have been killed or impacted by submergence in saltwater, and historical records from coastal areas of Japan impacted by the resultant tsunami [Atwater et al. (1991); Nelson et al. (1995); Jacoby et al. (1997); Yamaguchi et al. (1997); Satake et al. (1996)].

2.2 Wave travel time and run-up forecasting

Two important considerations that can be extrapolated and evaluated from the deposit evidence are tsunami run-up and inundation distance; key measures for assessing tsunami hazard and determining which coastal areas are at risk. Run-up is generally defined as the elevation of the tsunami relative to sea level at maximum inundation. Inundation distance is the inland extent of tsunami penetration (Clague et al, 2000). While tsunami deposit data can contribute to numerical hydrological modeling used to compute tsunami travel times and sea surface displacements for different coastal regions, deposits from previous events are absent for many areas of British Columbia.

For tsunami warning purposes, today, a model-based approach is employed utilizing a combination of scenario databases and real-time monitoring that uses available real time seismic information as well as sea level data. Whenever an earthquake occurs, the closest scenario to the event is extracted from the scenario database, based on magnitude and hypocenter location, to identify the regions at risk. Real time observations of sea level will be used to verify and this information is used to update the forecast.

2.3 Earthquakes and tsunami thresholds

Not all earthquakes generate tsunamis. Many factors contribute to the tsunami generating process, including the earthquake's magnitude and depth, whether or not there is concurrent slumping of sediments, and the efficiency with which energy is transferred from plate crustal thrusts to ocean water. Because of these complicating factors, there is no simple answer as to how large an earthquake needs to be in order to create a tsunami. Generally, it is thought that an earthquake needs to be a magnitude 7.5 or greater to produce a tsunami capable of creating damage at great distances from the source (Intergovernmental Oceanographic Commission, 2001; Dunbar, et al., 1989). Earthquakes of much lower magnitudes, however, are capable of generating local tsunamis by triggering coastal and/or submarine slumping or landslides where there is little time for notification.

2.4 B.C. Tsunami Zone Boundaries

Taking into account wave height, run-up, subsidence and adding a safety margin, and to ensure timeliness in notification, British Columbia has divided its West Coast into five tsunami inundation risk zones A, B, C, D and E. (PEP 2006; British Columbia, 2013b).

ZONE	WAVE HEIGHT (m)	RUN-UP (x2.0) (m)	SAFETY (X1.5) (m)	SUBSID-ENCE (m)	PLANNING LEVEL (m)
Zone A (North Coast)	2.0	4.0	6.0		6
Zone B (Central Coast)	2.0	4.0	6.0		6
Zone C (W. Vancouver Island)	3.0	6.0	9.0	1.0	10
Zone D (Juan De Fuca Strait)	1.3	2.7	4.1		4
Zone E (Strait of Georgia)	0.5	1.0	1.5		2

Table 2
Recommended Tsunami Run-up Planning Levels
(PEP 2006)

Each of the five designated zones includes all islands and inlets within the location description (British Columbia, 2013a).

Zone A: The North Coast and Haida Gwaii

Beginning on the Alaska/B.C. border near Stewart, B.C. and moving in a southward direction along the coast to the southern tip of Banks Island, including the Queen Charlotte Islands.

Zone B: The Central Coast and Northeast Vancouver Island Coast including Kitimat, Bella Coola and Port Hardy

Beginning on the southern tip of Banks Island to the northern tip of Vancouver Island (the western limit of the eastern boundary of Cape Scott Provincial Park.) This zone has a southern limit of a line running from the convergence of the Tsitika River and Johnstone Strait (in Robson Bight Provincial Park) on Vancouver Island in the south to the most eastern point of Broughton Island in the north.

Zone C: The Outer West Coast of Vancouver Island from Cape Scott to Port Renfrew

Beginning on the eastern boundary of Cape Scott Provincial Park on the northern tip of Vancouver Island and running in a south-easterly direction along the outer coast of Vancouver Island to Sombrio Point southeast of Port Renfrew.

Zone D: The Juan de Fuca Strait from Jordan River to Greater Victoria including the Saanich Peninsula

Beginning at Sombrio Point southeast of Port Renfrew and running in a easterly direction to the most northerly point of the Saanich Peninsula.

Zone E: The Strait of Georgia including the Gulf Islands, Greater Vancouver and Johnstone Strait

Beginning at the most northerly point of the Saanich Peninsula, including Brentwood Bay and all

the Gulf Islands within the Georgia Basin to one of two points at the northern limit. The northern limit is a line running from the convergence of the Tsitika River and Johnstone Strait (in Robson Bight Provincial Park) on Vancouver Island in the south to the most eastern point of Broughton Island in the north.

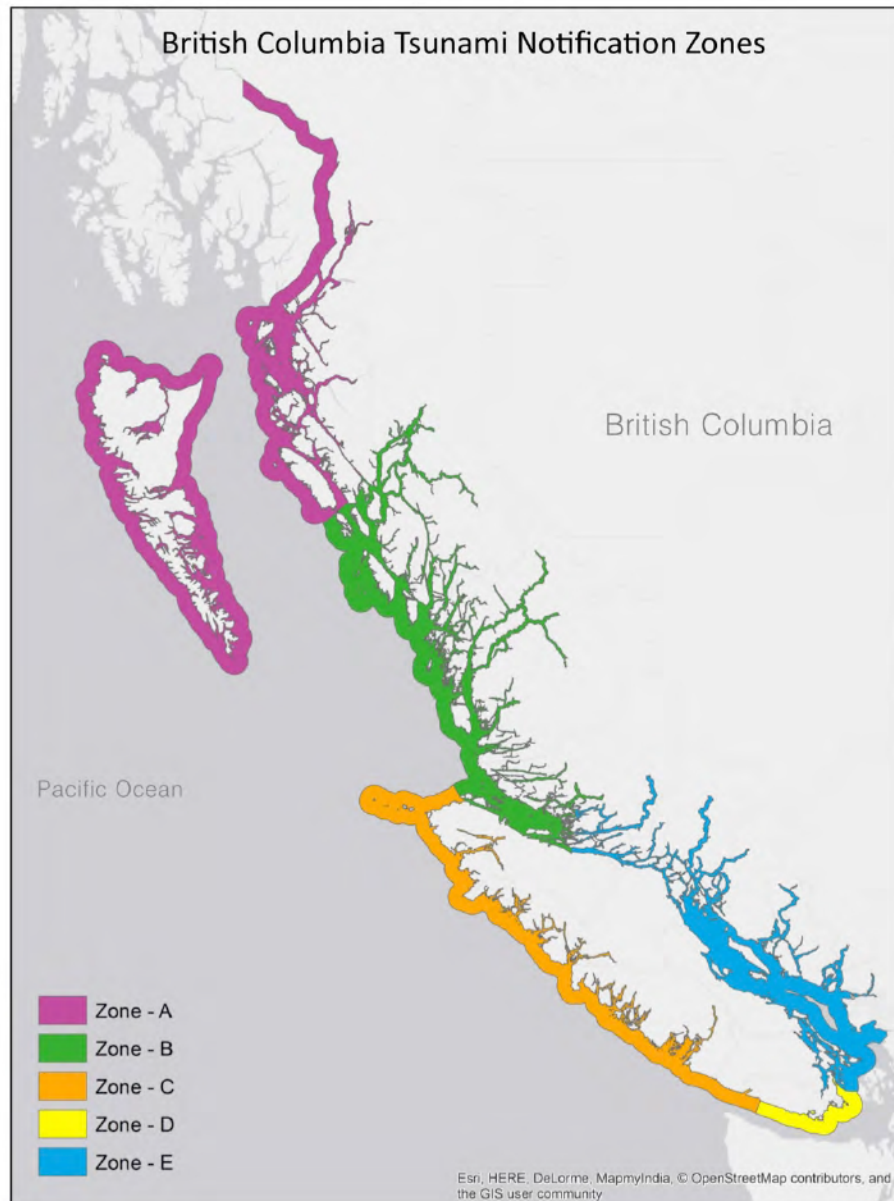


Figure 5
British Columbia Tsunami Notification Zones

3. Populations-At-Risk Within The Tsunami Notification Zones

Using the Tsunami Notification Zones as a geographical guide, we have attempted to identify various populations-at-risk along the Coast within and adjacent to these zones. Estimating actual population numbers, however, is very challenging. Current notification arrangements focus mostly on settled locations and, despite an extensive search, we have not been able to uncover any significant data on numbers of transient/mobile populations. Further, while we have been able to extract data from 2011 Census Canada for settled locations, the population counts do not fully account for seasonal variations. For example, many locations have summer cottages that today may or may not be permanently occupied by retirees or others. Consequently, the results we present below should only be treated as rough estimates.

3.1 Fixed Population Locations and Densities

We used GIS to estimate coastal population susceptible to tsunami risk. We joined the 2011 (most recent) census data from Statistics Canada with corresponding Dissemination Areas (DA) shapefile. The data was filtered to display the “COL 6” field, the population and dwelling counts. Next, the Tsunami Notification Zone was given a radial buffer to expand its coverage inland for 1 horizontal kilometre. At this stage, attaining detailed vertical elevation for all of BC was not possible. For this reason a 1 kilometer buffer was assigned to account for vertical variability. Last, the expanded buffer was spatially joined to the census data; all DAs within the kilometre buffer were extracted.

DAs were used in this analysis because they represent the smallest geographical unit used to inform population counts. They account for 400 to 700 persons per block. In rural places within B.C., the DAs are very large in opposition to urban locations. With this reasoning, one rural block may cover hundreds of kilometres in land and it may be thought that, for this reason, the analysis of our data could be grossly inaccurate. However, this method was used owing to the fact that, on average, most people within these large DAs tend to live by water. This can be seen through yet another form of census mapping.

LandScan, developed by Department of Energy’s Oak Ridge National Laboratory, is a database for users to download global population data of a 30 by 30 arc seconds resolution, disregarding any census units. The premise of the tool is to utilize nighttime lighting, slope, transportation networks, land cover and available census data, to provide insight of population clusters (Dobson et al, 2000).

Figure 7 further demonstrates LandScan’s population plotting for B.C. Despite greater resolution in rural areas, this form of mapping provides alternative challenges and errors that will not be discussed here. Regardless, the purpose of this map is to provide a visual representation of population clusters and, therefore, reasoning as to why DAs were deemed appropriate to use for census counts.

Some 280 settled location place names have been identified in the tsunami notification zone maps. Of these, 88 are incorporated municipalities, 61 are First Nations territories and the

remaining 131 are rural unincorporated places that fall within the jurisdiction of one of the 14 coastal regional district authorities.

Tsunami Notification Zone	Population 2011
Zone A	19,804
Zone B	13,407
Zone C	18,075
Zone D	192,511
Zone E	727,128
TOTAL	970,925

Table 3
Estimates of Fixed Location Populations Residing Within B.C. Tsunami Zones

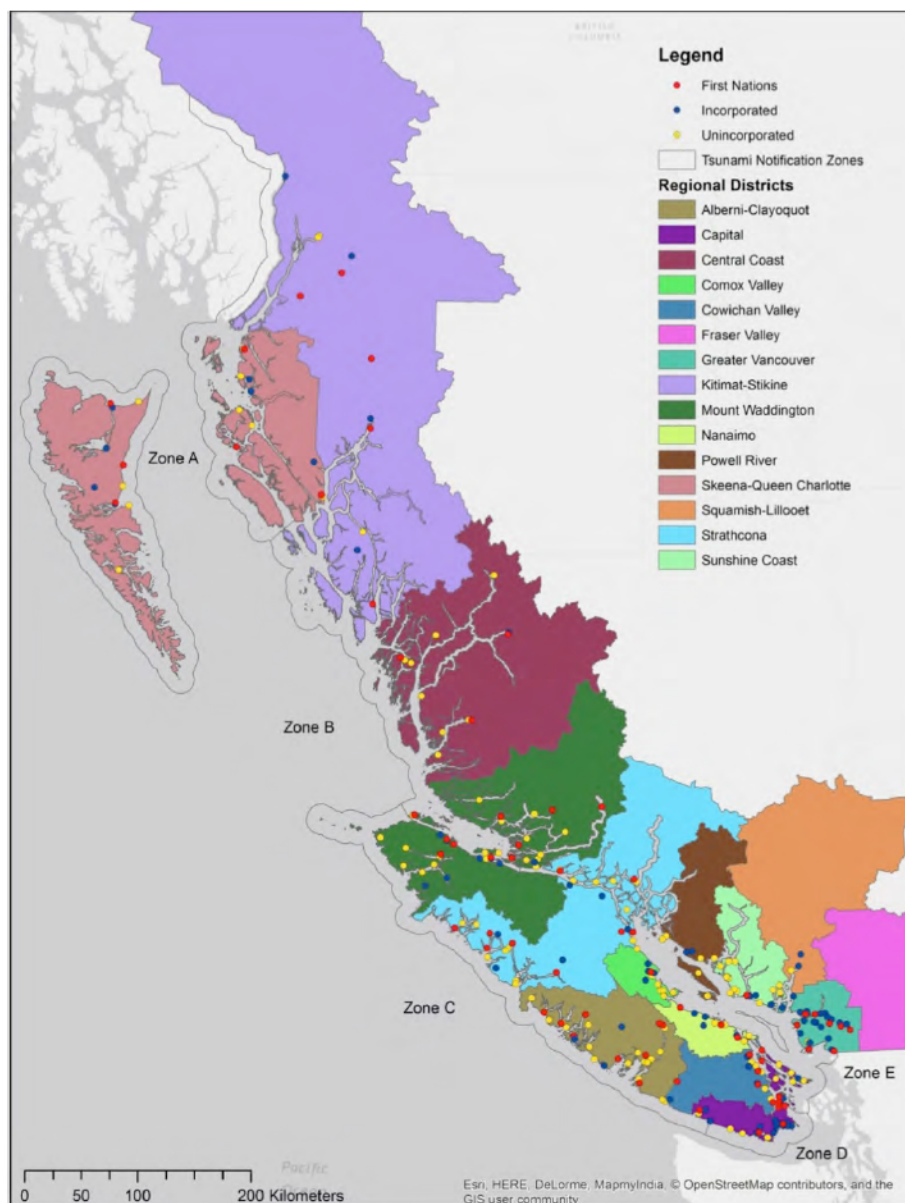


Figure 6
Fixed Population Locations within B.C. Tsunami Notification Zones

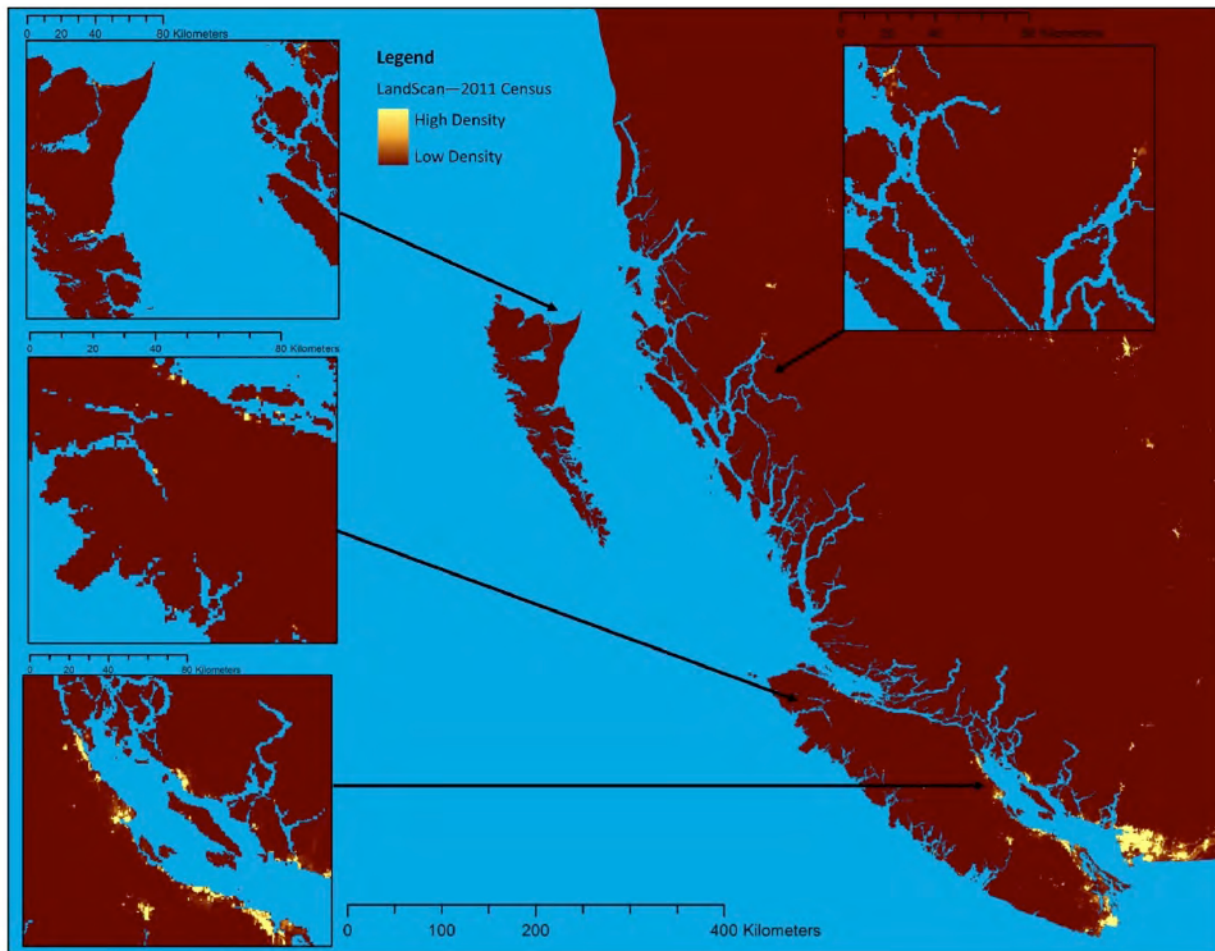


Figure 7
B.C. Coastal Population Densities

3.2 Transient populations

While there are a variety of different transient Coastal population groups potentially at-risk from tsunamis, the scope of this project phase did not permit a full investigation to identify all classes and potential locations. Nevertheless, we have been successful in identifying several classes and a representative selection is presented below. Further, those types and activity locations that we have been able to identify have been captured and recorded in the project notification matrix to support additional analysis for community notification planning in Phase 2 of this project. We also use this data to support observations about notification coverage in Section 4.

3.2.1 Coastal Resource Industry Examples

Coastal Logging

Figure 8 illustrates active logging tenures along the western, southwestern and northeastern coast of Vancouver Island and within adjacent mainland areas. While not all tenures are active in any given area, the map shows the extent to which transient logging populations work within tsunami risk areas.

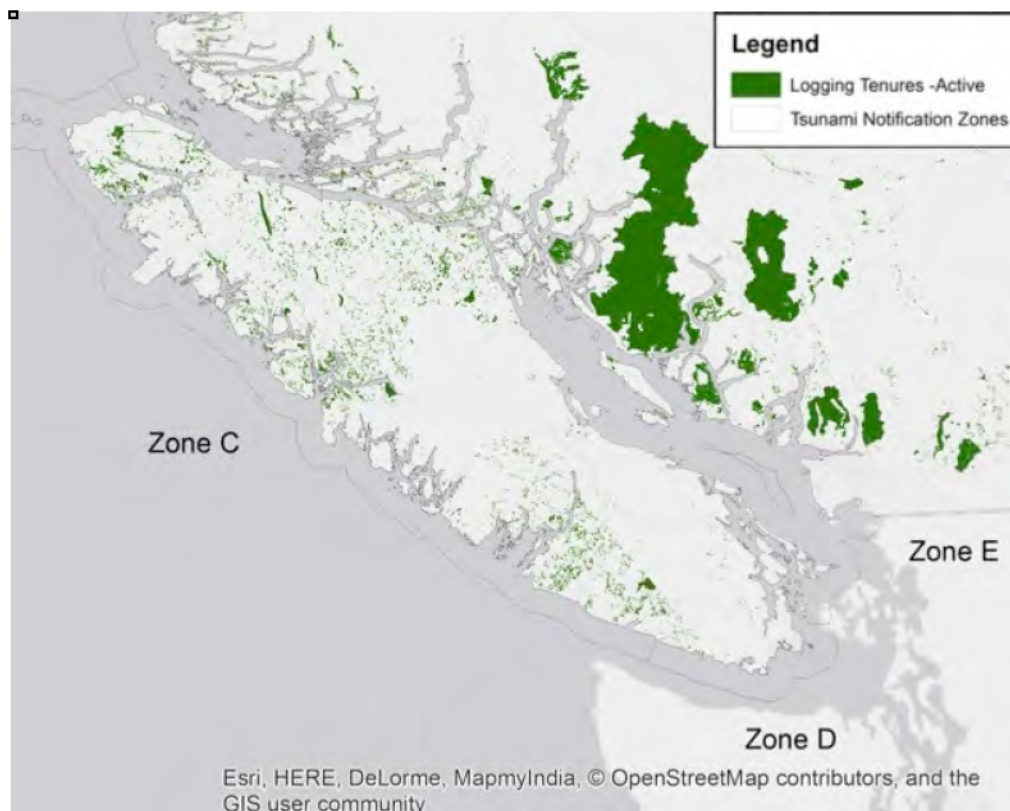


Figure 8
Coastal Logging Tenures

Aquaculture – Fish Farms

Marine finfish (almost exclusively Atlantic salmon) farms are licensed primarily in the Campbell River, Port Hardy and Tofino areas. Fish farm sites are located close to shore, mostly in remote areas and accessed via crew boat. Most farm site aquaculture jobs are camp based, with staff living in float houses during shifts. Shift lengths are usually 8 days on/6 days off, or 4 days on/3 days off. (Marine Harvest, 2014)

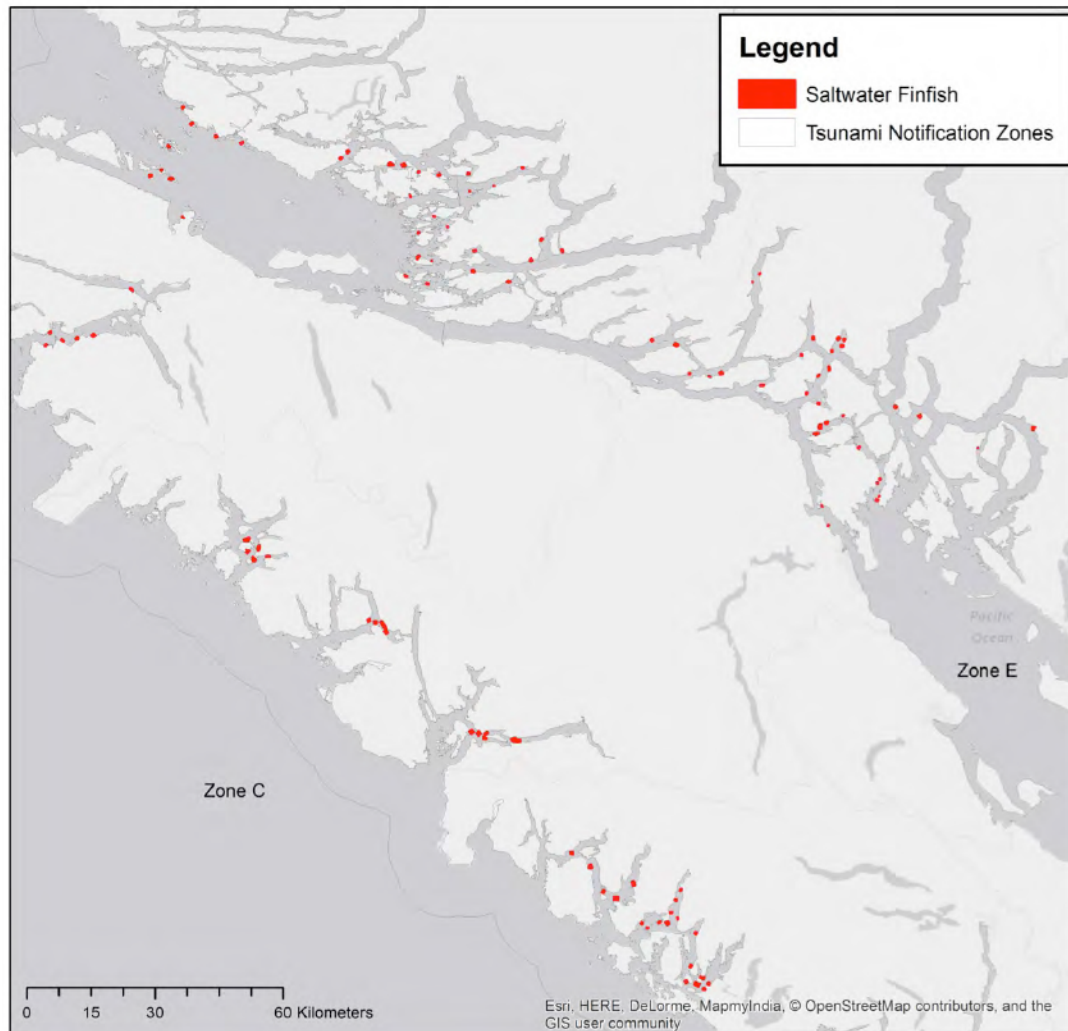


Figure 9
B.C. Saltwater Finfish Farms

Recreation and Tourism

As discussed on Section 1, tourism has grown steadily all along the coast coinciding with much improved personal and commercial transportation, global economic ties, environmental awareness and protection concerns, new tourism social trends and demographic shifts.

For illustrative purposes, we present below a series of profiles for camping, diving, recreational cruising and cruise ship routes.

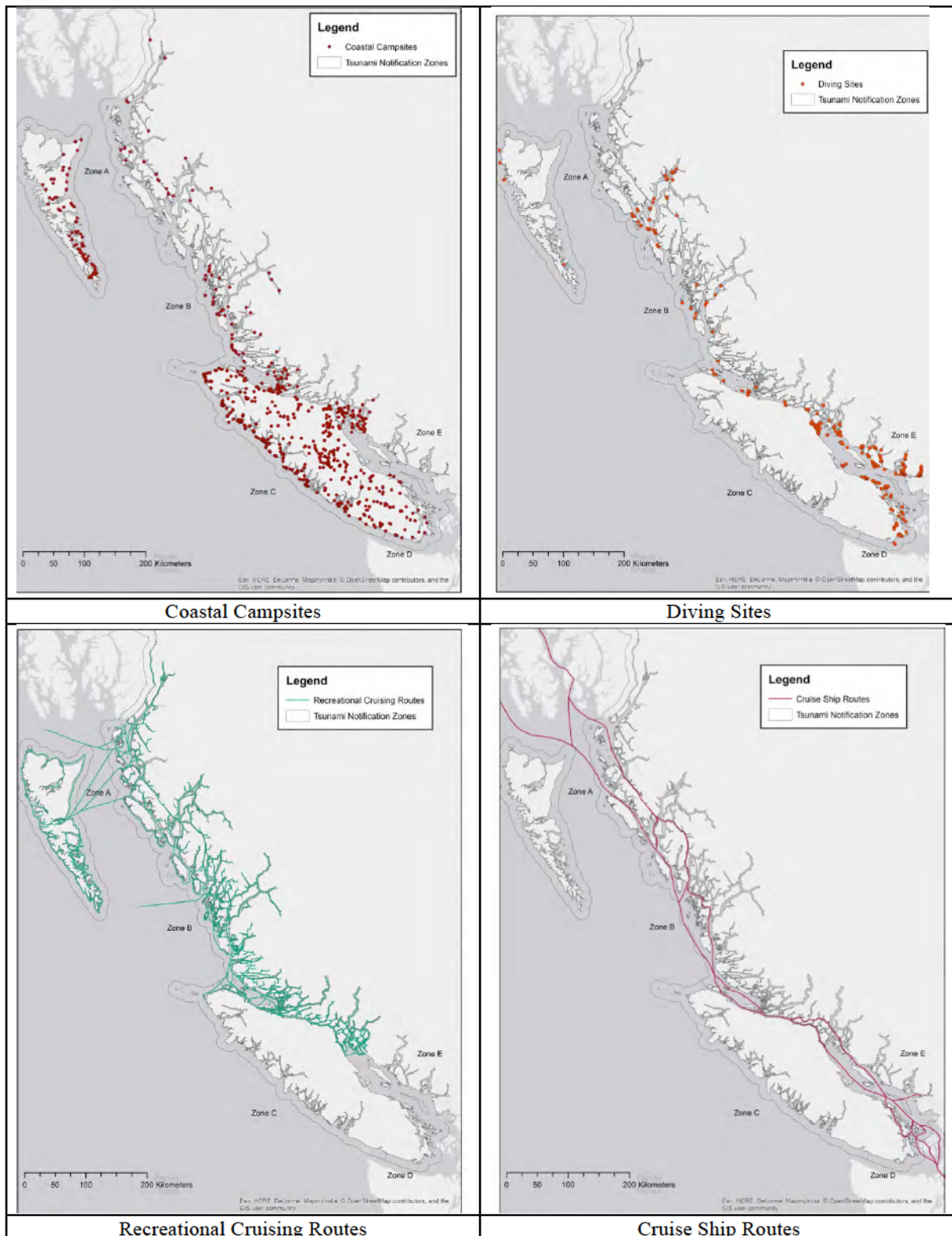


Figure 10
Camping, Diving, Recreational Cruising and Cruise Ship Travel Routes

4. Tsunami Notification Arrangements

4.1 Traditional Notification Arrangements

British Columbia's Tsunami Notification System comprises three sub-systems (Anderson, 2006):

1. Detection and initial notification subsystem
2. Emergency management subsystem
3. Public response subsystem

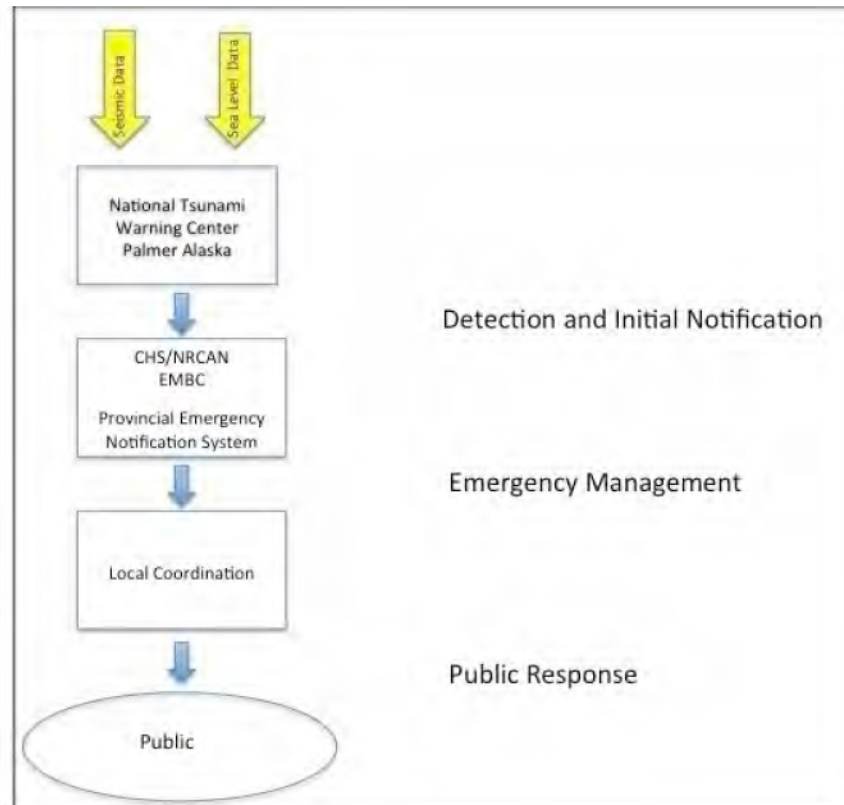


Figure 11
Traditional Flow of Tsunami Notifications

Traditionally, tsunami notifications flowed from one subsystem to the next proceeding in a linear, cascading manner as briefly described below.

4.1.1 Detection and Initial Notification Subsystem

The Detection and Initial Notification Subsystem's function is to identify and issue alerts about the presence of a hazard or existence of hazardous conditions. In the case of a tsunami hazard, this involves: the monitoring and detection of certain seismic events, the anticipation and detection of tsunami generation, the tracking and monitoring of any generated waves, and the forecasting of wave arrival times and estimated heights along the coast. The U.S. National Tsunami Warning Center (NTWC), located in Palmer, Alaska, is responsible for operating this subsystem in support of British Columbia.

4.1.2 Emergency Management Subsystem

Emergency Management British Columbia is the receiving authority for NTWC bulletins and the provincial lead for tsunami notification within the B.C. Emergency Management Sub-system. Upon receipt of a NTWC bulletin indicating a threat to British Columbia, EMBC consults with the Canadian Hydrographic Service (CHS) of Fisheries and Oceans Canada. CHS scientists assess the local tsunami threat based on ocean and tidal conditions at the time bulletins were issued and assist EMBC in the preparation of tailored notifications for B.C. sub-regions or zones. Seismologists at Natural Resources Canada's Pacific Geoscience also provide input. EMBC tsunami messages are issued through the Provincial Emergency Notification System (PENS). PENS relies on multiple methods and partner agencies to facilitate timely and accurate tsunami messaging. These arrangements will be described in more detail later in this report.

It is important to note, however, that this subsystem is most effective in the case of distant tsunamis, where there is sufficient time to determine possible tsunami risk and affect an appropriate response along the B.C. Coast. Tsunamis generated locally (1000 kms or less) within a B.C. Coast sub-region, may forestall activation of this subsystem for nearby locations.

Tsunami messages issued by NTWC and EMBC use the same alert levels. From the highest to the lowest threat, the alert levels are: Warning, Advisory, Watch, Information Statement and Cancellation (NTWC, 2014a; NTWC, 2014b; British Columbia, 2013b). Each has a distinct meaning relating to recommended local emergency response activities. The following table outlines the meaning of each alert level and recommended action. It is important to note that during a tsunami, updated information may result in a change in the alert levels.





 Warning	Inundating wave possible	Full evacuation
 Advisory	Strong currents likely	Stay away from the shore
 Watch	Danger level not known yet	Stay alert for more information
 Information Statement	Minor waves at most	No action required
Cancellation	Tide gauges show no wave activity	Confirm safety of local areas

Table 4
NTWC and EMBC Tsunami Alert Levels

Warning

A "Warning" is the highest level of tsunami alert. Warnings are issued due to the imminent threat of a tsunami from a large undersea earthquake, or following confirmation that a potentially destructive tsunami is underway. They may be based initially only on seismic information as a means of providing the earliest possible alert. Warnings indicate that flooding up to the maximum expected limit is possible and residents should follow their local emergency management instructions, including evacuation of coastal areas within the area. Warnings are issued when the earthquake information or tsunami forecasts indicate that a wave over 1 metre in amplitude is expected, possible, or ongoing.

Advisory

An “Advisory” is the second highest level of tsunami alert. Advisories are issued when a tsunami with the potential to generate strong currents or waves dangerous to those in or very near the water is imminent, expected, or occurring. The threat may continue for several hours after initial arrival, but significant inundation is not expected for areas under an advisory. Appropriate actions by local emergency management personnel may include closing beaches and evacuating harbours and marinas. Advisories are issued when the tsunami forecast is in the range of 0.3 to 1 meter, or an observed tsunami is in the range of 0.5 to 1.0 metres.

Watch

A “Watch” is the third highest level of tsunami alert. A tsunami watch is an early alert issued to areas that may later be impacted by a tsunami. Watches are normally issued based on seismic information without confirmation that a destructive tsunami is underway. Tsunami impact is normally at least three hours away for regions within a tsunami watch. When watches are issued, emergency management officials and the public should prepare to take action and communities have time to prepare to take action in case the Watch is upgraded to an Advisory or Warning.

Information Statement

An “Information” statement is issued to inform emergency management officials and the public that an earthquake has occurred, or that a tsunami warning, watch or advisory has been issued for another section of the ocean. In most cases, information statements are issued to indicate there is no threat of a destructive tsunami and to prevent unnecessary concern when an earthquake has occurred but there is no tsunami threat.

Cancellation

A “Cancellation” cancels any previously issued tsunami messages. It is issued when there is no longer observed evidence of tsunami waves at tide gauge stations. Local conditions may differ from those at tide gauge stations and local authorities need to determine the safety of their coastlines. Cancellations are the final tsunami messages issued by NTCW and EMBC.

4.1.3 Public Response Notification Subsystem

Once local government (local authorities and First Nations) emergency managers and program staff receive EMBC tsunami messages and are made aware of a tsunami risk to their community, they will begin notifying response agencies, the public and media in their jurisdiction according to their emergency plans. Others who share local responsibilities for notification include provincial and federal parks authorities.

4.2 Recent changes and revised notification processes

As mentioned above, the B.C. subsystems are most effective in the case of distant tsunamis, where there is sufficient time to more accurately determine possible tsunami risk and affect an orderly response along the Coast. Until recently, the practice was not to automatically redistribute NTCW bulletins to B.C. populations, but rather to wait until a refined version could be issued by B.C. Provincial authorities who would take into account unique coastal characteristics, so that messages could be geographically tailored and targeted according to level of risk. However, depending upon time of day and staff availability, this procedure has often

resulted in delays of up to one hour or more, but has not been particularly problematic when several hours of margin exist.

For local tsunamis, because wave travel time is so short, these procedures are not adequate to provide effective warnings for the closest affected coastal areas. In such cases, residents have been instructed to assume that a tsunami has been generated if they feel strong shaking from an earthquake and to move immediately to high ground (British Columbia, 2013b).

Nevertheless, there are occasions when a local earthquake occurs and, although little time is available to alert immediate populations-at-risk, with appropriate systems in place, it is possible to provide timely notification to others who are further away within the same sub-region. Such was the case when a Magnitude 7.7 earthquake occurred on October 27, 2012 at 8:04 PM PDT approximately 40 kms south of Sandspit off the coast of Haida Gwaii.

At 8:07 PM, NTWC issued its first Tsunami Warning bulletin for regions of B.C. and Alaska from the North Tip of Vancouver Island to Cape Decision, Alaska. At 8:34 PM, it issued its second warning for the same area. At 9:05 PM, EMBC issued its first email based warning to emergency authorities for Tsunami Notification Zones A and B (B.C. North and Central Coast regions). By this time the first wave had already passed through the warning zones and at 9:04 PM had reached Winter Harbour, south of the North Tip of Vancouver Island.⁴

Following this event, the Province of B.C. revised and issued a new Tsunami Notification Process Plan to give NTWC bulletins the initial highest message priority and to affirm that receipt of a NTWC tsunami message from EMBC's PENS or directly from NTWC, should be considered a PENS message and observed until such time as EMBC bulletins are issued (British Columbia, 2013b).

While the original tsunami notification arrangements were tailored to ensure a coordinated and consistent message flow from NTWC to EMBC and from EMBC to local emergency management stakeholders and the public, advances in information and communication technology were already partially bypassing them and enabling both emergency managers and the public to obtain NTWC messages directly via NTWC email, SMS and WWW services. Also appearing on the digital landscape were new social media applications, in particular, Twitter, that enabled rapid duplication and public redistribution of tsunami messages. Details of these changes are discussed further in Section 4.3 below.

The combined effects of these changes have been such that emergency managers, critical service providers and the public now all possess a wide array of methods for receiving and distributing tsunami notifications, both directly and indirectly through multiple dissemination routes.

⁴ Based on data extracted from NTWC October 27, 2012 and EMBC Tsunami Bulletins, October 27, 2012.

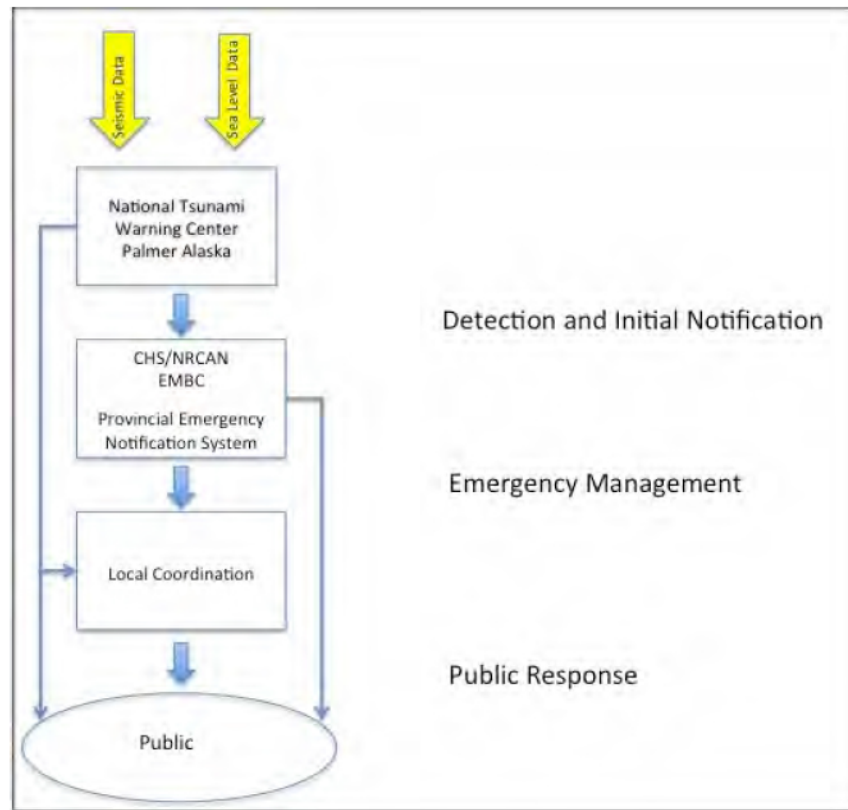


Figure 12
Present Flow of Tsunami Notifications

4.3 Individual Stakeholder Notification Procedures and Processes

This section describes the roles and responsibilities of the key notification stakeholders and methods employed.

4.3.1 NWS-NTWC⁵

The U.S. National Tsunami Warning Center (NTWC) is operated by the Alaska Region of the National Weather Service and is located in Palmer, Alaska. The Center collaborates with the Pacific Tsunami Warning Center to provide tsunami warning service, and mutual backup, to United States coastal regions and many other countries throughout the world. Its area-of-responsibility (AOR) is Puerto Rico, the Virgin Islands, Canada, and the ocean coasts of all U.S. states except Hawaii. More specifically for the Pacific Coast, it includes the U.S. states of Alaska, Washington, Oregon, California and the Province of British Columbia. The Pacific Tsunami Warning Center (PTWC) in Hawaii serves as a backup to NTWC and is responsible for notification to the remaining areas of the Pacific.

To accomplish its mission of providing accurate and timely tsunami bulletins to its AOR, the NTWC detects, locates, sizes, and analyzes earthquakes throughout the world. Earthquakes that activate the center's alarm system initiate an earthquake and tsunami investigation which

⁵ Based on excerpts from NTWC, 2014a and personal interviews.

includes the following four basic steps: 1) automatic locating and characterizing the earthquake; 2) earthquake analysis and review; 3) sea level data analysis and tsunami forecasting, and 4) disseminating information to the appropriate emergency management officials.

NTWC's goal is to issue tsunami warnings within five minutes of an earthquake. Since the Center has implemented 24x7 on-site operations, average response time has dropped to approximately three minutes for events within its AOR.

To accomplish this, the first tsunami bulletins issued are based solely on seismic data. Approximately 600 seismic stations are recorded at NTWC. Seismic networks that provide the data are operated and funded by many different agencies, including the United States Geological Survey (USGS), the Global Seismic Network, NOAA, various universities throughout the country, and foreign governments. Access to data is provided through dedicated circuits, private satellite networks, and the Internet. The Center's initial response must be issued very quickly and is based on seismic analysis and well-defined, preset criteria. Whether a Tsunami Warning, Watch, Advisory, or Information Statement is issued, it is based on these pre-set criteria and the initial seismic analysis.

Once a significant event has occurred, the nearest tide gauges and deep ocean tsunami detectors (DARTs) are monitored to confirm the existence or nonexistence of a tsunami, and its degree of severity. NTWC has access to approximately 600 tide sites and 50 DARTs. Many of these sites are maintained by NOAA's National Ocean Survey (NOS). For the Pacific Northwest coastal sub-region, in addition to the NOS sites, sea level information is provided by the Canadian Hydrographic Service and Ocean Networks Canada to the Center.

If a tsunami has been generated, the sea level data is critical for use in calibrating forecast models. Following the first message, the tsunami is analyzed using observed sea level data, forecast models, historic data, and further seismic processing. Based on this analysis, supplemental messages are issued if a Warning, Watch, or Advisory was originally issued. Areas with forecasts of 1m or greater in zero-to-peak amplitude are generally put in a tsunami Warning; those with forecasts 0.3m to 1m in an Advisory, and for those less than 0.3m Warning, Watch, and/or Advisory are cancelled. Historical information has shown that tsunamis can cause damage due to strong currents when amplitudes reach 0.5m or greater.

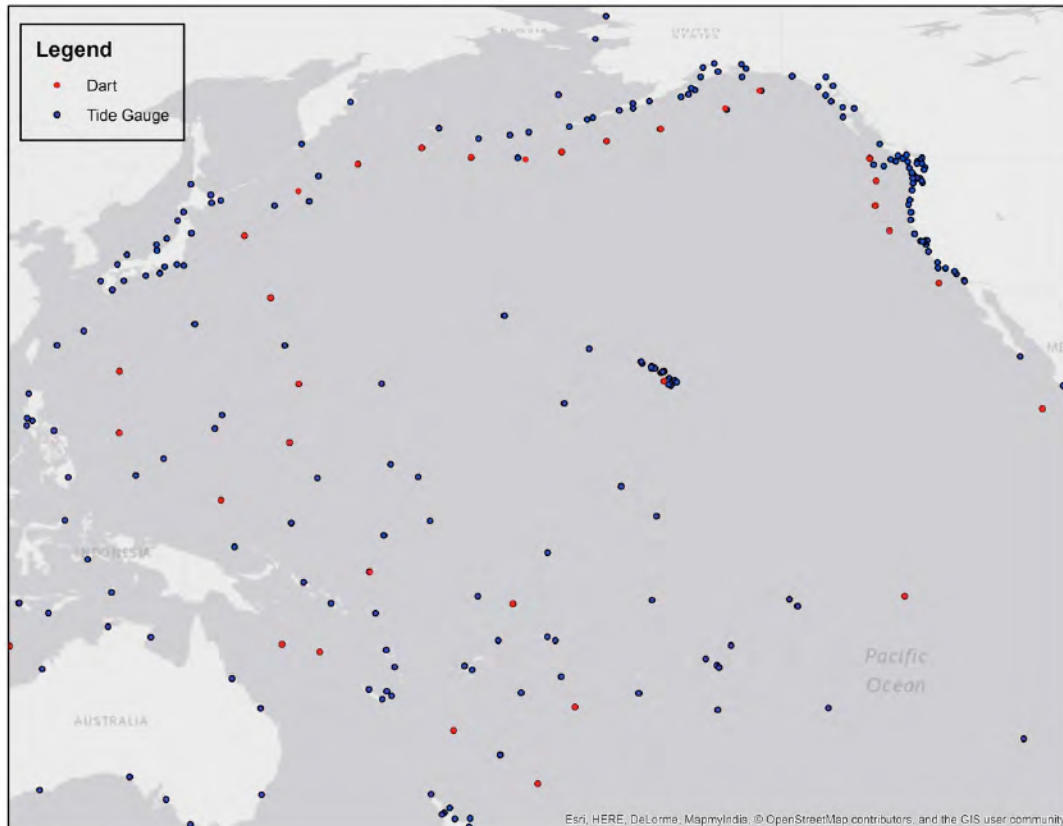


Figure 13
Pacific Ocean DART and Tide Gauge Stations

Supplemental Warning, Watch or Advisory bulletins for events within the AOR are issued every 30 minutes in the early parts of an event, and less often in the latter parts of an event. Occasionally a follow-up message may be necessary for a Tsunami Information Statement (e.g., when a small tsunami has been recorded or where the statement must be upgraded to a Warning). This would be considered Tsunami Information Statement #2 or, if upgraded to a Warning, Tsunami Warning #2.

4.3.1.1 Geographical Message Targeting: Use of Breakpoints

Warning, Watch, and Advisory extents are based on distance from epicentre, tsunami travel time, or pre-computed threat estimates, and are listed in the messages as extending from a geographical point X to a point Y.

Estimated tsunami arrival times are provided for up to 30 cities along the Pacific U.S. and Canadian coasts in the official messages and 250 sites on the web site. The present Pacific AOR breakpoints for British Columbia are:

- B.C. - Alaska Border
- Northern Tip of Vancouver Island
- Washington – B.C. Border

It is understood that additional breakpoints will be added soon that will correlate closely with the

B.C. Tsunami Notification Zone boundaries.

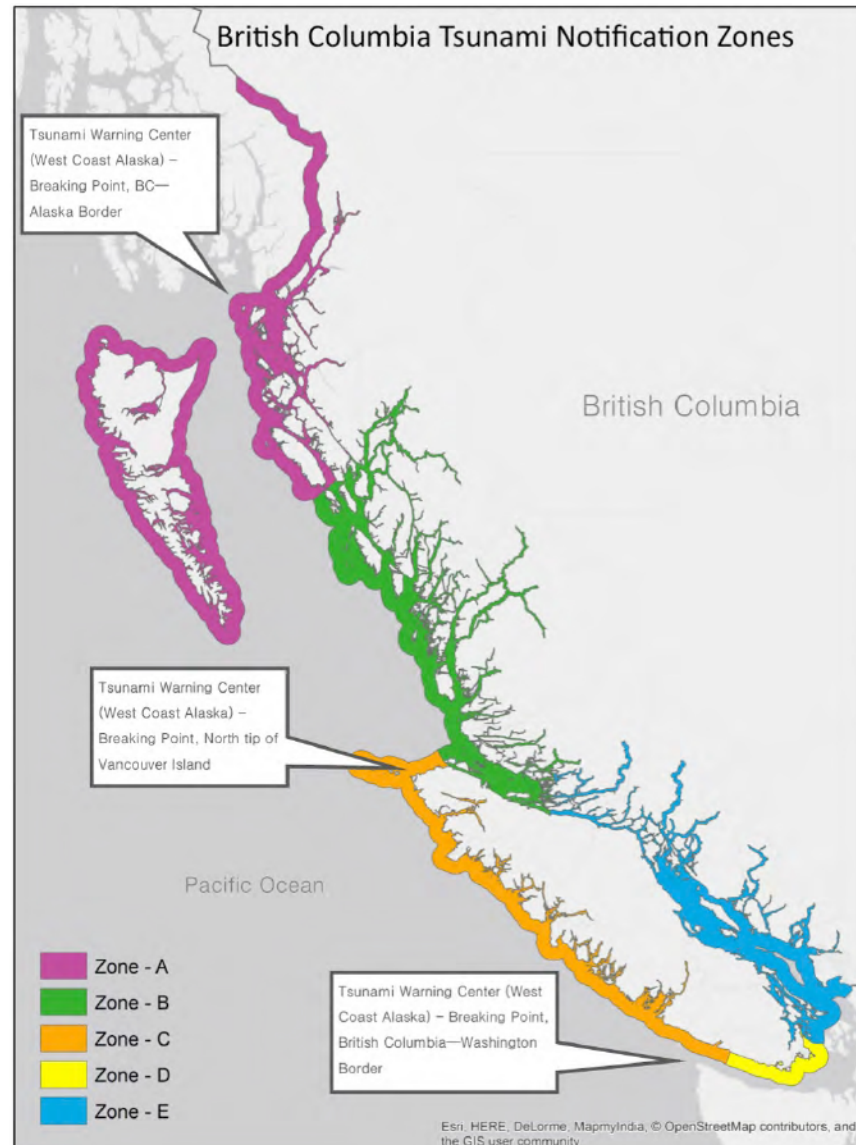


Figure 14
NTWC Notification Breakpoints

4.3.1.2 Message Identifiers

The NTWC tsunami messages are based on NOAA National Weather Service (NWS) products. NWS products are described by both a World Meteorological Organization (WMO) Header and a NWS Advanced Weather Interactive Processing System (AWIPS) ID.

For tsunami Warning, Advisory, and Watch messages, the Center issues three messages types. One type, WEPA41, is segmented messages that are designed for automated systems. This type of message includes NWS universal generic codes (UGC) and valid time event codes (VTEC). The second, WEAK51 is Warning, Advisory, and Watch messages intended for public

consumption with forecast/observation tables. The third, WEAK61, is Spanish equivalents of the WEAK51 message. WEAK53 is Information Statements indicating that a strong earthquake has occurred within the Pacific Ocean Region but a tsunami is not expected along the California, Oregon, Washington, British Columbia or Alaska Coasts. SEUS71 is Tsunami Seismic Information Statements indicating that an earthquake has occurred but there is no tsunami danger.

WMO Header	NWS AWIPS ID	Explanation
WEPA41 PAAQ	TSUWCA	Segmented Tsunami Warnings, Watches, and Advisories AK, BC, and US West Coast
WEAK51 PAAQ	TSUAK1	Public Tsunami Warnings, Watches, and Advisories AK, BC, and US West Coast
WEAK61 PAAQ	TSUSPN	Spanish Tsunami Warnings, Watches, and Advisories AK, BC, and US West Coast
WEAK53 PAAQ	TIBAK1	Tsunami Information Statements AK, BC, and US West Coast
SEUS71 PAAQ	EQIWOC	Tsunami Seismic Information Statements BC and US West Coast

Table 5
NTWC Message Identifiers and Intended Recipients

4.3.1.3 Intended Recipients

The primary recipients of tsunami messages are coastal state/provincial departments of emergency services, the Federal Emergency Management Agency, National Weather Service offices, Coast Guards, and military offices. While these agencies are considered primary, the bulletins are also available through a variety of means to local emergency managers and the general public.

4.3.1.4 Message Content

As indicated earlier, initial Warning, Advisory and Watch messages are generated based solely on seismic event data and will contain the following information:

- Areas between breakpoints covered by the message
- Recommended actions
- Preliminary earthquake parameters
- Estimated tsunami arrival times

Updated messages will include tsunami impact forecasts and measurements of tsunami activity from DART and tide stations and/or other reports of activity. Samples of NTWC messages are attached in Appendix B.

4.3.1.5 Message Dissemination Methods

NTWC messages are disseminated through a multitude of systems to emergency management agencies and the public. The table below summarizes message output devices used at the Center. An asterisk (*) in the table indicates messages are transmitted directly from the operational software.

Service	Owner or Operating Agency	Primary User Audience
Lines 276/277 *	NWS	NWS Offices via AWIPS, NWS Telecommunications Gateway to EMWIN, Family of Services, Global telecommunications system, and other NWS communication systems
NOAA Weather Wire *	NWS	National Weather Service forecast subscribers and U.S./state – Canada/province emergency management agencies
NAWAS	FEMA	U.S./state – Canada/province emergency management agencies
EIDS *	USGS	Emergency management officials
INTERNET * (web site, email, RSS, and cell phone text messaging)	Public Telecommunications	International and domestic government agencies, academic institutions and the public in general

Table 6
Message Dissemination Methods at the National Tsunami Warning Center

Lines 276/277 are circuits connecting the NWS Telecommunication Gateway in Silver Spring, MD to the NTWC. The NTWC transmits and receives messages to and from these lines via a socket connection to a server at the Gateway. From there, the messages are sent to a multitude of NWS communication services such as the Emergency Managers Weather Information Network (EMWIN), Family of Services, and the Global telecommunications system.

NOAA Weather Wire - The NOAA Weather Wire is a satellite broadcast service maintained by the NWS to disseminate weather products domestically. Both the NTWC and PTWC have uplink and downlink capability on the NWW system. Users of the NWW system consist of Weather Service Offices, state and provincial emergency management agencies, and the U.S. Coast Guard. Receiver sites can program their selector box to receive any number of selected NWS products (or messages).

NAWAS - The National Warning System is a nationwide dedicated voice telephone system connecting selected defense, National Weather Service, emergency management, and Coast Guard agencies. The circuit is supported by the Federal Emergency Management Agency (FEMA). Control over transmissions on the circuit is maintained by the FEMA Operations Center or the FEMA Alternate Operations Center.

EIDS – Earthquake Information Distribution System is an earthquake information dissemination tool operated by the United States Geological Survey. The Internet is used to transmit earthquake information to USGS servers where it is disseminated to various web sites and agencies.

Internet

NTWC maintains a set of group email lists for emergency managers. Watch/Warning/Advisory messages and Tsunami Information Statements (WExxxx products) are sent to the full set, whereas messages regarding lesser events (SExxxx) are sent to a smaller subset. Shortened cell phone text (SMS) messages are also transmitted via Internet to emergency managers.

A NTWC public web site is maintained at <http://ntwc.arh.noaa.gov/> where current event messages and maps are posted. The web site also provides a large amount of educational, safety, and scientific information. Beyond the web site, NTWC also provides direct Internet distribution of messages to the public via RSS maintained at <http://ntwc.arh.noaa.gov/events/xml/PAAQAtom.xml> and an XML/CAP format product maintained at <http://ntwc.arh.noaa.gov/events/xml/PAAQCAP.xml>.

Presently, NTWC does not provide email or SMS service directly to the public, but does enable access via third party providers. In the case of email, the Intergovernmental Oceanographic Commission provides a public mailing list tsunami-information-ioc@lists.unesco.org and redistributes bulletins from Pacific Tsunami Warning Centre and National Tsunami Warning Center and North West Pacific Tsunami Advisory Center in Japan. Third party public SMS distribution is explained below.

Social Media

NTWC sends out automated shortened Warning, Advisory, Watch and Information messages on its Twitter account, @NWS_NTWC. Users can also sign up for a SMS version, simply by entering “Send Follow [username]” to the appropriate mobile carriers’ supported Twitter shortcode and users will start receiving Tweets from that user on their devices. In Canada, 21212 is the shortcode supported by Bell Mobility, Rogers Communications, and Telus Mobility. Further, users do not have to have a Twitter account to use this service.

@NWS_NTWC's followers are among the Twitter users to see B.C. related tsunami bulletins from an official source in real-time. Because of this, in our study, we undertook to try to identify British Columbia followers of @NWS_NTWC through collecting a sample of 9,999 followers from the Twitter site and analyzing follower profile data. A similar analysis was undertaken for the Government of B.C. @EmergencyInfoBC and will be discussed later in this report. Similar data was not available for SMS users, so it is not known at this time how many additional non-Twitter account users are using Twitter generated message content.

At the time of sampling, (February, 2014) @NWS_NTWC had 11,657 followers. The study sample thus comprised 86%, the vast majority, of the total follower network at that time. Once the sample was imported, the next step was to sift out all eligible users and ties located in the Pacific West Coast Region. Between March 1 and June 30, 2014, each @NWS_NTWC follower was checked and hand-coded for status, language, and location. The canon methods for recording location in Twitter are self-reporting, via the location field, and automatic, via geolocation

services. Given that 64% of the @NWS_NTWC sample used self-reported location while only 2.1% had metadata coordinates respectively, self-reported location was used.

@NWS_NTWC had 1,849 accounts that self-reported locations in Alaska, Washington, Oregon, California or B.C. Of these, 1,070 (58%) were in B.C. specifically. Each municipality was assigned coordinates. Follower distributions were then mapped using ArcGIS to make concentrations easier to see. Municipalities were also grouped by rural or urban status to assess the proportion of follower accounts in at-risk communities. Those with less than 150 persons per square kilometre (Statistics Canada, 2009), or less than 5,000 residents, were designated “rural”. All others were marked “urban”. The results are shown in Figure 15 below.

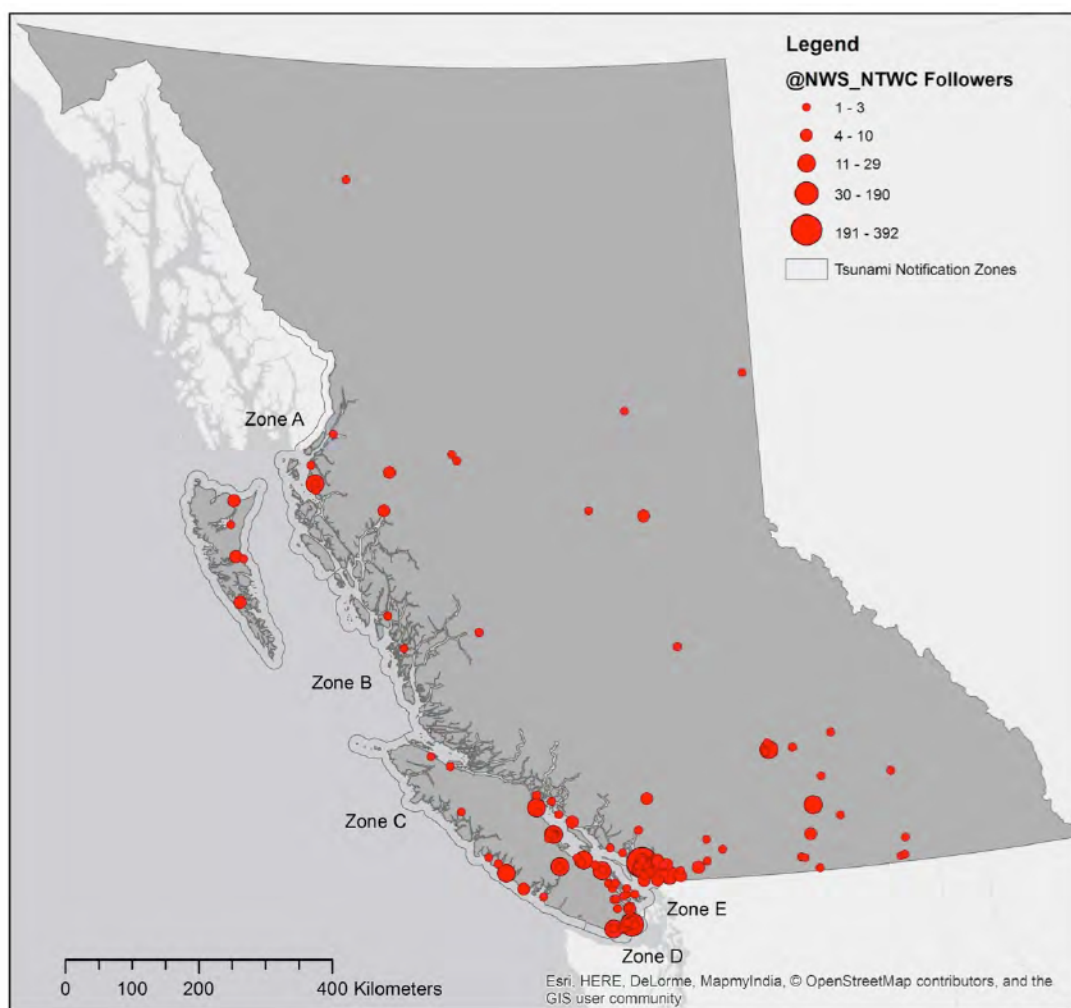


Figure 15
Locations of Sampled @NWS_NTWC Twitter Followers

As could be expected, these results correlate with population densities and communication infrastructure availability. The vast majority of followers are located in the larger centres, most of which are also located in lower tsunami risk zones. The lack of larger numbers of followers in the higher risk and more remote coastal sub-regions also appear to correlate with lack of mobile phone and/or broadband Internet service; the latter will be discussed in more detail later.

4.3.2 British Columbia Provincial Emergency Notification System⁶

NTWC tsunami messages are received by the 24/7 Emergency Coordination Centre (ECC) located at EMBC Headquarters in Saanichton (Victoria) via NTWC email and the NOAA Weatherwire, and may be followed by a NAWAS conference call between NTWC and EMBC for situational updates during a tsunami event. Upon receiving a NTWC Watch, Advisory or Warning for B.C., the ECC will initiate steps to notify key partners and the public through its enhanced Provincial Emergency Notification System and activate EMBC's management structure as described further below.

4.3.2.1 EMBC PENS Activation Process

British Columbia's Tsunami Notification Process Plan (British Columbia, 2013b) identifies and briefly describes the roles, responsibilities and general procedures used by international, federal, provincial and key stakeholder agencies in the dissemination of tsunami messages within B.C. Beyond the general roles and responsibilities outlined in the Plan, each identified stakeholder has its own internal standard operating procedures that detail its activities during a tsunami.

EMBC's notification criteria are as follows: (British Columbia, 2012)

- If NTWC issues a tsunami Watch, Advisory or Warning, EMBC's enhanced notification process will be immediately initiated.
- If NTWC issues an earthquake notification that does not result in any tsunami threat, EMBC will not, as a matter of protocol, issue a notification to its greater audience or via social media.
- The ECC forwards the NTWC notification, via email, to its pre-established tsunami alert distribution list and telephones the Provincial Duty Manager (PDM). Concurrently, the EMBC Social Media Unit (SMU) is notified directly by NTWC via email, SMS and Twitter and is to communicate the tsunami message via its Twitter account, @EmergencyInfoBC. Once the SMU tweet has occurred, the SMU will call the PDM. If the PDM has not heard from the SMU after being notified by the ECC, the PDM is to call the SMU so the tweet can be sent.
- Concurrently, the ECC phones EMBC's provincial duty manager and then EMBC's social media unit directly, who will communicate the tsunami notification via Twitter, on @EmergencyInfoBC.
- EMBC activates the emergency management structure, both provincially and regionally. This may involve activation of its Provincial Emergency Coordination Centre (PECC) at EMBC HQ and those EMBC Provincial Regional Emergency Operations Centres (PREOCs) that have populations and communities at risk within their zones. The four coastal B.C. EMBC zones are Northwest, Central Vancouver Island, and Southwest.
- The affected PREOCs contact, via phone call, the necessary local authorities, placing priority on those communities at highest risk.
- Notification is also sent out through B.C.'s provincial emergency notification system (PENS) to reach local authorities, public safety agencies and key media via landline, fax or e-mail. Additional NTWC notifications will also be sent out through PENS.

⁶ Based in part upon descriptions extracted from British Columbia, 2013b

- As new updates arrive, EMBC's social media unit posts the latest verified information to the www.EmergencyInfoBC.gov.bc.ca site. Links to these posts will be tweeted.
- Activation of the provincial and regional emergency management structure will continue until the cancellation of all tsunami alerts is communicated via PENS. This will also be conveyed via social media.
- Local authorities have overall responsibility for notifying their residents of any risk or evacuation plans, which may employ a variety of methods, including community sirens or loudspeakers, local radio, e-mail distribution, social media, phone trees, door-to-door, community sirens or loudspeakers. These are described in more detail in Section 5.

4.3.2.2 PENS Message Targeting and Content

To ensure all coastal communities receive appropriate tsunami messages, EMBC uses the five tsunami notification zones discussed earlier. If known, the PENS tsunami message will contain the following information:

- A brief description of the event including location and earthquake magnitude;
- Whether or not it is known that a tsunami has been generated;
- The B.C. tsunami zone(s) placed in Warning, Advisory, Watch, Information Only or Cancellation; and
- Recommended actions.

4.3.2.3 Technical Components of PENS

Although EMBC is the Provincial lead for tsunami notification to emergency management stakeholders in BC, as briefly outlined above, many organizations collaborate both formally and informally to disseminate tsunami messages to as many people as possible in as short a time as possible. Formally, the Provincial Emergency Notification System consists of a set of core EMBC methods, supplemented by partner agency methods to ensure timely and accurate tsunami messaging. These methods include:

- EMBC direct telephone calls;
- EMBC email;
- EMBC interactive voice telephone;
- EMBC fax;
- EMBC social media twitter feed and EmergencyInfoBC blog;
- Provincial Emergency Radio Communications Service (PERCS);
- Environment Canada Weatheradio and Weather website, and
- Marine Communication and Traffic Services/Canadian Coast Guard - Channel 16 marine radio transmissions.

EMBC Email:

EMBC uses email messaging to contact emergency managers and key agencies, health authorities, media, and critical service and infrastructure providers. Emails are relayed through three different methods:

1. The Emergency Coordination Centre (ECC) comprehensive and pre-established tsunami alert distribution list. This list includes provincial ministries, Crown corporations, federal

- agencies, local authorities, key media and first responders.
- 2. Provincial Regional Emergency Operations Centres (PREOCs) email lists that serve specific coastal regions.
- 3. The Provincial Emergency Notification System automated email distribution list

Figure 16 illustrates the coverage of the PENS automated email system as of May, 2014.

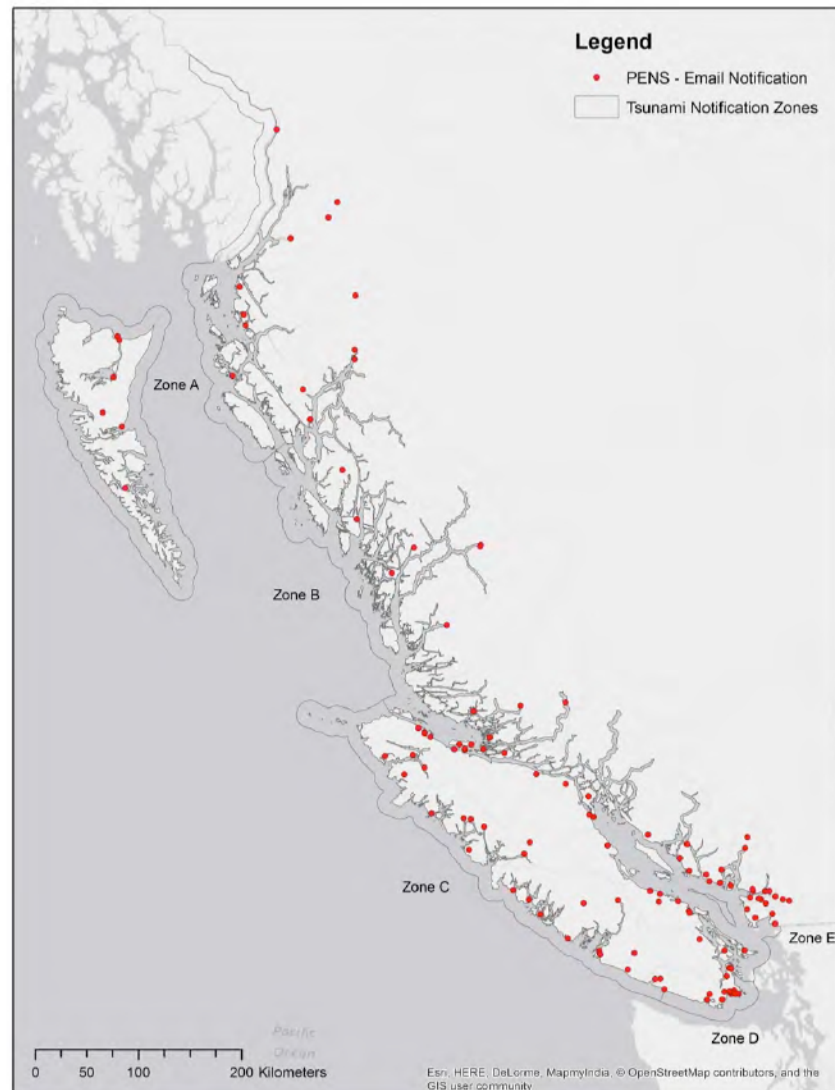


Figure 16
Provincial Emergency Notification System Automated Email Recipient Locations

Interactive Voice Response Telephone Auto-dialer system:

EMBC disseminates BC-specific tsunami messages through an automated phone system to predetermined emergency management stakeholders. This web-based system can be accessed remotely and can dial many phone numbers in a short period of time. Although it may be slower to be activated and received than email methods, it is the most intrusive alert method and allows for modification of the messages to provide customized information specific to B.C. At time of writing this report, several upgrades and modifications are being undertaken and details will be

provided in the Phase 2 project documents. Figure 17 illustrates the current reach of the auto-dialer system as of May, 2014.

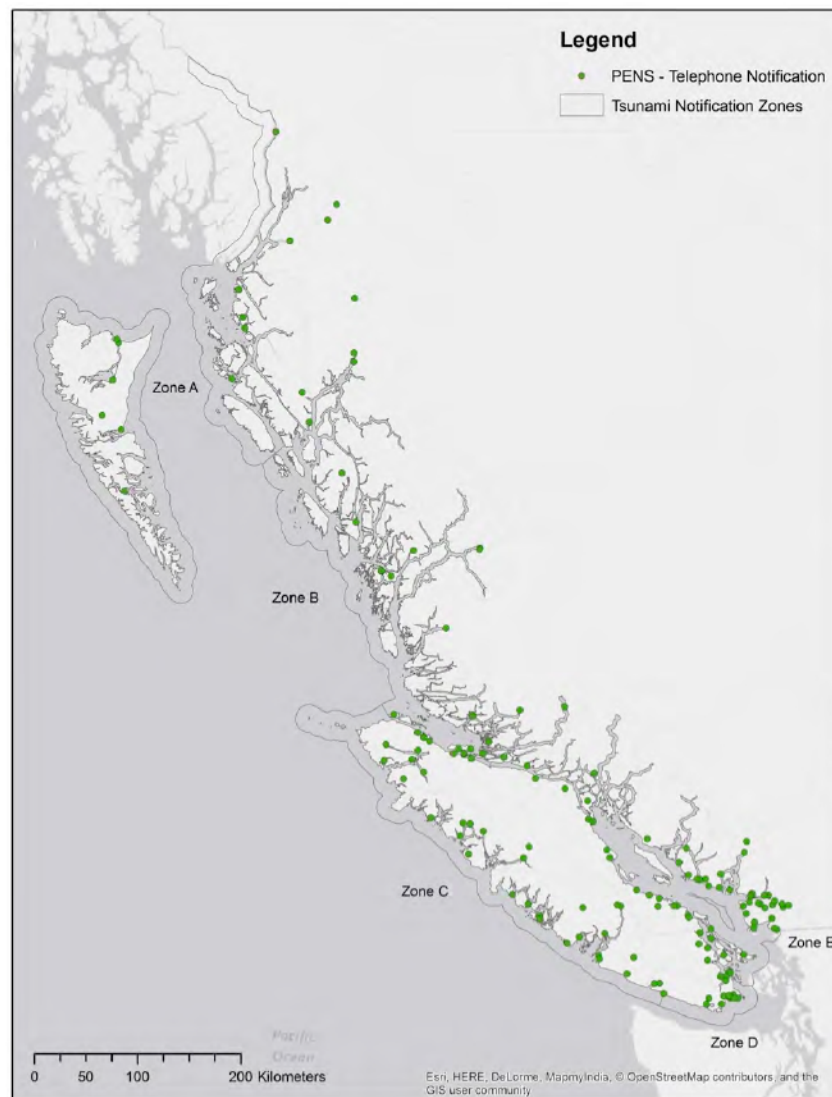


Figure 17
Provincial Emergency Notification System Automated Telephone Recipient Locations

Fax:

While advances in ICT, such as email, have superseded the general use of facsimile (fax), for many rural communities, where cellular and Internet is unreliable or unavailable, fax remains a valuable form of communication. In some cases, fax also complements other forms of alerting. For example, many rural fire departments are paged when a tsunami event occurs and are then instructed to check their fax machines for full message details. Figure 18 illustrates the current reach of the PENS fax system as of May, 2014.

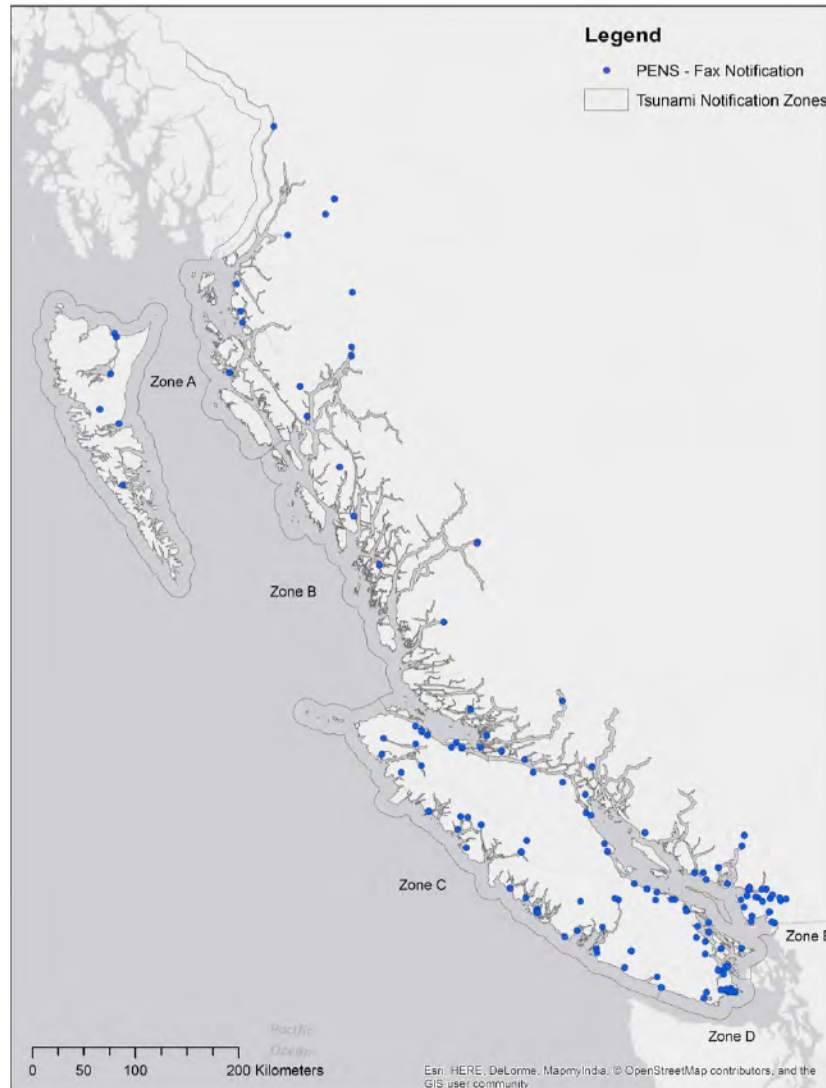


Figure 18

Provincial Emergency Notification System Automated Facsimile Recipient Locations

PREOC Direct Phone Calls:

EMBC Regional offices have established contact lists with emergency management personnel in B.C. coastal communities. Phone calls are prioritized based on the arrival time of the tsunami and historical tsunami impacts. This is a reliable person-to-person system that allows for confirmation that the tsunami message is received and reporting about actions taken. PREOCs also facilitate conference calls to enable regional coordination.

Social Media:

EMBC utilizes social media to alert British Columbians to a tsunami threat by amplifying messages and verified information from NTWC and EMBC officials. The primary channels used are the @EmergencInfoBC Twitter account, the Emergency Info BC blog maintained at <http://www.emergencyinfobc.gov.bc.ca> and an RSS feed maintained at <http://www.emergencyinfobc.gov.bc.ca/atom.xml>. A second account, @EmergencyPrepBC, provides preparedness & recovery information. Two features that differentiate

@EmergencyInfoBC from @NWS_NTWC messages are that messages are not generated automatically and are not always tsunami specific. @EmergencyInfoBC is used to disseminate all provincial hazard alerts. However, due to the near real-time nature of Twitter, tsunami messages and updates can often be received via @EmergencyInfoBC before the other PENS notification methods.

Similar to our analysis of @NWS_NTWC followers, we undertook to try to identify who are the BC Coastal @EmergencyInfoBC followers. Again, using a sample of 9,999 followers, @EmergencyInfoBC had 3,708 accounts that self-reported location in Alaska, Washington, Oregon, California or B.C. (37 % of the total network). Of these, 3,668 (99%) were in B.C. specifically.

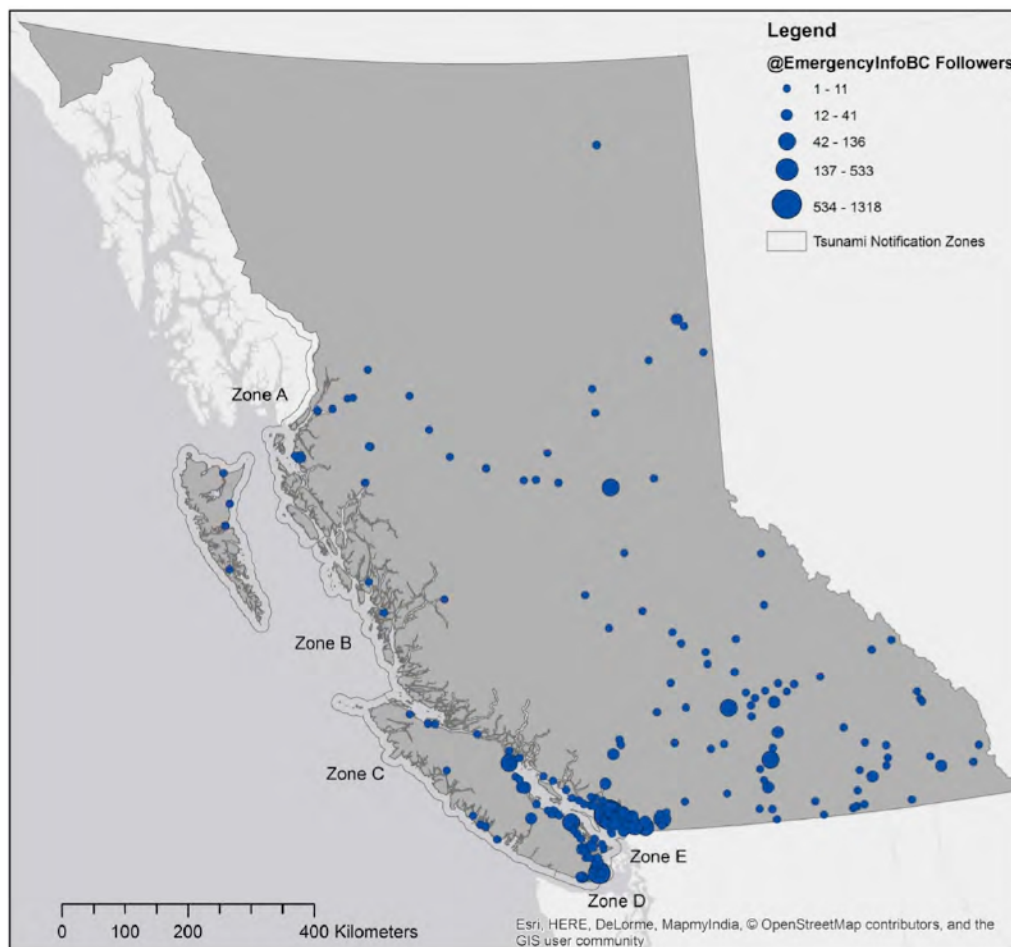


Figure 19
Locations of Sampled @EmergencyInfoBC Twitter Followers

Provincial Emergency Radio Communications Service (PERCS):

Within British Columbia, the Provincial Emergency Radio Communications Service (PERCS) operates in support of the British Columbia Provincial Emergency Program and communities in B.C. During a tsunami event, EMBC may also broadcast tsunami Watch, Advisory and Warning messages by amateur radio, providing additional redundant delivery of tsunami information.

4.3.3 Key PENS Partners

4.3.2.1 Environment Canada

Environment Canada (EC) utilizes its infrastructure and expertise in national weather alerting to further disseminate tsunami messages in B.C. On behalf of EMBC, it issues B.C. specific tsunami messages through a number of key channels, including WWW, Weatheradio and subscription media and emergency management web platforms. EC receives NTWC notifications through NTWC's National Weather Service network connections and EMBC notifications via ECC email and PENS automated systems.

World Wide Web

EC uses a web based dashboard at http://weather.gc.ca/mainmenu/alert_menu_e.html to post alerts for weather and tsunami related events for each of its forecast regions. RSS feed versions are also available for individual forecast locations.

Weatheradio⁷

Utilizing the same technology as NOAA's Weather Radio service in the U.S., Environment Canada (EC) operates its own "Weatheradio Canada" nationwide network of radio stations broadcasting weather and environmental information 24 hours a day in both official languages on 7 dedicated frequencies within the VHF public service band.

The enhanced Specific Area Message Encoding (SAME) capable Weatheradio receivers use digital SAME codes as the trigger that activates the alarm features ahead of a warning message and alert users to an incoming important message (EC 2014c). Users who use a SAME-capable Weatheradio will be able to receive the full suite of weather and non-weather related emergency messages that include Watches, Warnings and Advisories. In addition, they will be able to access the full functionality of the warning device unit, with features like the ability to pre-select which warnings to receive, and for which region(s).

All Weatheradios with the SAME decode feature can be preset to activate only in a local geographic area by programming the appropriate Canadian Location Code (CLC) code. CLCs correspond to EC's weather forecast regions. There are also options that permit the receiving of alerts for more than one location in the broadcast area and, with some models, an additional option to disable the alerting feature for certain types of warning messages. This enables the receivers to be used as distinct tsunami alerting devices if desired. Also, because these codes are standard across Canada and the U.S., receivers can work in either country; a useful feature for maritime travelers.

Older Weatheradios do not have the SAME decode feature. These units will continue to receive the full range of watches, advisories and warnings as in the past. However, they will not be able to take advantage of the enhanced options offered by a Weatheradio with SAME decoding capability.

⁷ Based, in part, upon descriptions extracted from EC, 2014c

For coastal British Columbia, 10 transmitters provide Weatheradio service. The average range for reception of the broadcast signal is approximately 60 km from the transmitter site, but this can vary considerably depending on the terrain. At one location (Port Hardy) a low power broadcast without the alert tone or SAME code is transmitted on the regular FM and can be heard using an ordinary radio. Figure 20 illustrates current radio coverage.

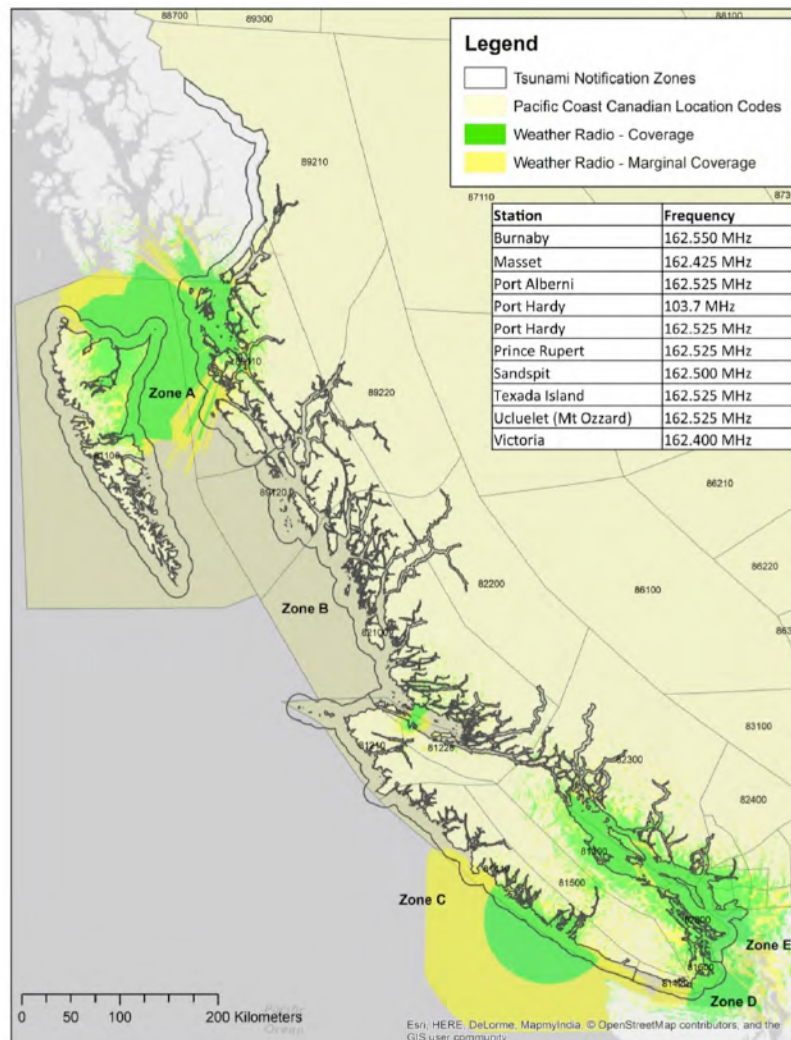


Figure 20
Environment Canada Weatherradio Coverage

EC Alert Me

EC Alert Me is a new experimental notification service that allows emergency management subscribers to custom-define their alert areas, types and conduit options. The client management interface is a web application that serves as the primary gateway for creating and managing customized weather and tsunami alerts. Alerts can be viewed on-line or as email messages. Through the client web interface, registered subscribers can create a new alert when they wish to be informed of certain conditions/events occurring in a designated area. They can create as many alerts as they want. The types of messages for which they might want to be alerted include warnings, advisories, watches and statements for a full range of weather events, as well as

NTWC and EMBC tsunami warning, advisory and watch events. Once alert types are selected, subscribers are allowed to select the area (s) for which they wish to be alerted during specific conditions. Desired sub-regions can be selected by using an on-line interactive map, entering the name(s) or specific CLC tab(s). For tsunami alerts, CLCs have been grouped to correspond with the B.C. Tsunami Notification Zones (EC, 2014a).

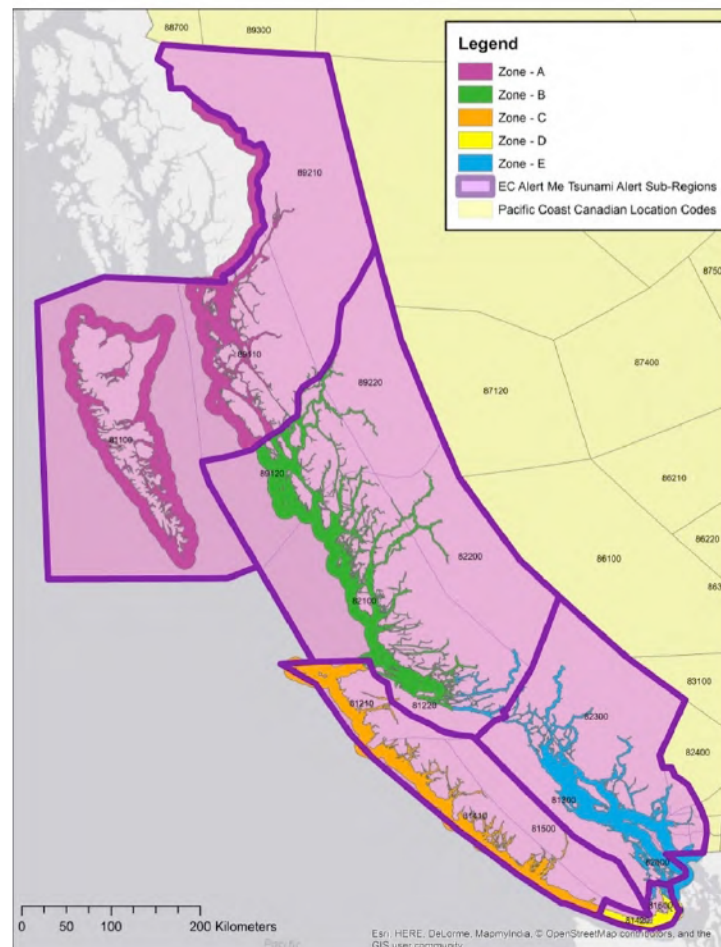


Figure 21
EC Alert Me Tsunami Alert Sub-Regions
EC, 2014a

- Zone A - the North Coast and Haida Gwaii, B.C. (081100-089110-089210)
- Zone C - the Outer West Coast of Vancouver Island from Cape Scott to Port Renfrew, B.C. (081210-081410-081500)
- Zone B - the Central Coast and Northeast Vancouver Island coast including Kitimat Bella Coola and Port Hardy, B.C. (081220-082100-082200-089120-089220)
- Zone D - the Juan de Fuca Strait from Jordan River to Greater Victoria including the Saanich Peninsula, B.C. (081420-081600)
- Zone E - the Strait of Georgia including the Gulf Islands Greater Vancouver and Johnstone Strait, B.C. (081300-082300-082500-082600-082800)

4.3.2.2 Canadian Coast Guard – Marine Communication and Traffic Services⁸

The Canadian Coast Guard (CCG) Program serves a broad stakeholder group ranging from the general public, to commercial shippers, ferry operators, fishers, recreational boaters, coastal communities, other government departments, other levels of government and international organizations. Its primary objective is to ensure safe, efficient and accessible waterways as well as protecting our marine areas from environmental damage

CCG Programs plays a key role in achieving the first three of five DFO Mandate objectives:

- Protecting marine and freshwater environment;
- Maintaining maritime safety;
- facilitation of maritime commerce and ocean development;

Within the Western Region, CCG Programs is responsible for:

1. Aids to Navigation;
2. Waterways Management;
3. Search and Rescue;
4. Marine Communications and Traffic Services and
5. Environmental Response.

For tsunami warning purposes, the MCTS is particularly crucial in providing aid in the warning and recovery stages.

The Canadian Coast Guard's extensive communications network offers one of the most practical mass notification methods to alert marine and some land (especially remote) populations along most of the B.C. Coast.

MCTS provides marine safety communications co-ordination with rescue resources and the Joint Rescue Co-ordination Centre Victoria (JRCC) - one of three JRCCs in Canada operated by the Canadian Armed Forces in conjunction with CCG. MCTS also supports vessel traffic services and broadcasts marine safety information such as weather bulletins, Tsunami Messages and notices to shipping.

In the Western region, there are 5 centres located at Vancouver, Victoria, Prince Rupert, Comox and Tofino.

These centres are connected to an extensive network of remote communications sites located to provide continuous coverage of almost all of the BC coastal region in VHF, HF and MF frequencies. Two systems used to broadcast safety, navigational and marine weather are:

1. Continuous Marine Broadcast (CMB) is an automated recorder used to disseminate marine weather information provided by Environment Canada and is updated several times a day (MF and VHF);
2. Navigational Telex (NavTex) is an international automated medium frequency direct-printing service for delivery of navigational and meteorological warnings and forecasts,

⁸ Based, in part, on excerpts from CCG, 2014a and CCG, 2014b

as well as urgent marine safety information to ships and is effective 40 to 300 nautical miles offshore (518Khz)

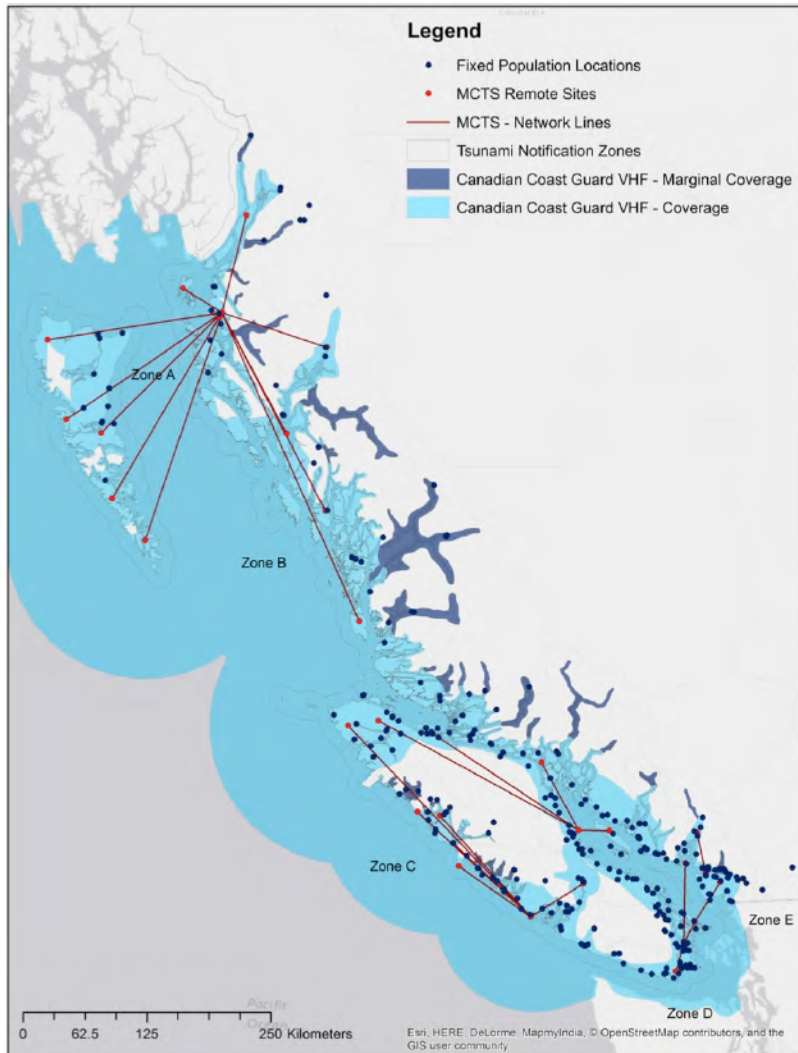


Figure 22
Canadian Coast Guard Pacific Coast VHF Coverage

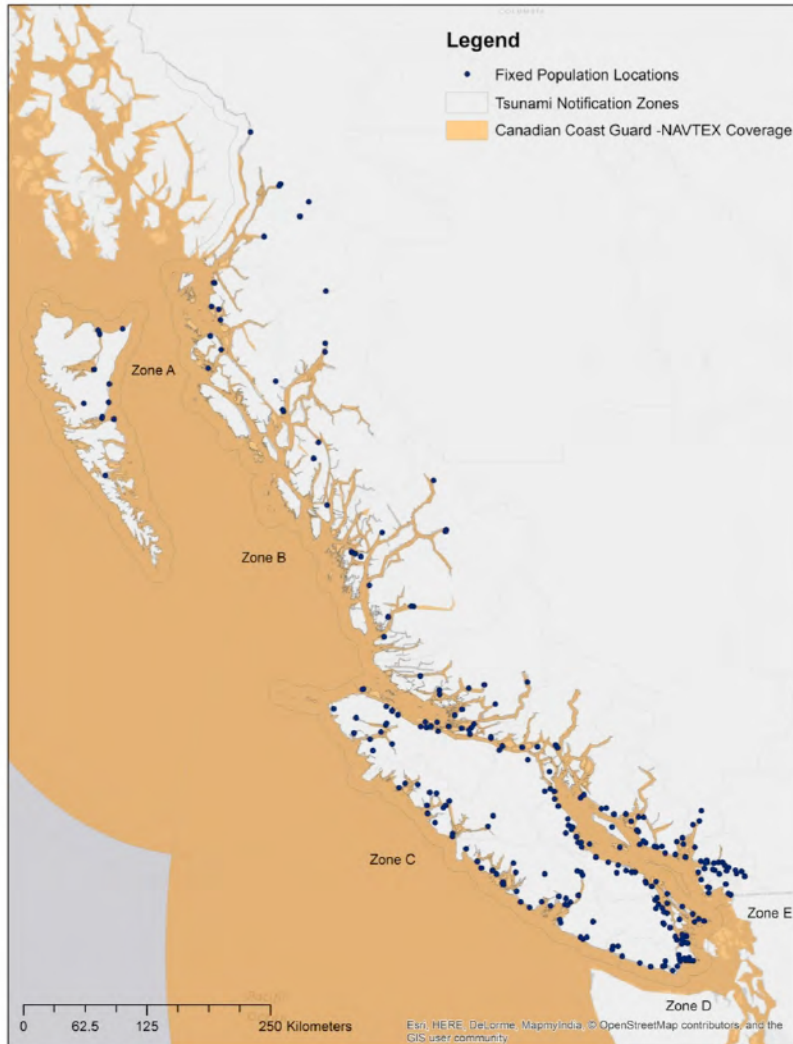


Figure 23
Canadian Coast Guard Pacific Coast NAVTEX Coverage

Digital Selective Calling

As part of a Global Maritime Distress and Safety System (GMDSS) initiative, newer marine VHF and MF radio models are equipped with a Digital Selective Calling (DSC) feature that allows selective calling on VHF Marine Channel 70 and MF 2187.5 kHz. Normally, after establishing contact on the DSC channel, both parties will change to an agreed voice channel to communicate. To make a digital call each radio must have an identity, a 9-digit Maritime Mobile Service Identity (MMSI) number that can be obtained free of charge, by Industry Canada. An important safety feature of a DSC radio is that it can initiate a special Distress Alert which will tell the Coast Guard and other boaters in the area that the caller requires immediate assistance and, if equipped with a Geographical Positioning Satellite (GPS) device, will automatically let rescuers know the radio's exact location. Although a DSC receiver will normally only respond to its individual Maritime Mobile Service Identity number call, all DSC receivers in a given area can be mass alerted by an "All Ships" DSC call. Some VHF models have a DSC watch function that monitors Channel 70 while receiving another channel. Upon receiving a distress call it will

automatically switch to the International Calling and Distress Channel 16 to receive follow-on voice communication.

Coast Guard MCTS Western Tsunami Notification Procedures

MCTS is responsible for broadcasting NTWC and EMBC Warnings, Advisories and Watches to ships at sea. MCTS will begin broadcasting WEPA41 PAAQ messages received from NTWC but stop broadcasting and replace them with EMBC PECC PENS messages once they are received. Presently Comox MCTS functions as the primary Coast Guard liaison between the NTWC, Coast Guard operational sites, the Canadian Hydrographic Service (CHS) of Fisheries and Oceans Canada and the EMBC Provincial Emergency Coordination Centre. In the event that Comox is unable to perform this function, Victoria MCTS is the liaison alternate.

Broadcast Priority

- Tsunami Watch and Advisory messages for general marine traffic are designated as URGENT.
- Tsunami Watch messages are designated as SAFETY.

Centres will use the highest broadcast priority based on the tsunami activity within the notification zone for the centre's AOR. Further, although warning, advisory, or watch tsunami messages will specify the geographical area of concern, all MCTS centres will broadcast the complete tsunami message to ensure the widest possible coverage. Broadcasts will be made via DSC, 2054 KHz, 4125 KHz, the CMB and NAVTEX.

Once MCTS initiates a tsunami broadcast, centres can expect calls from ships at sea, anchored or alongside, and from other agencies (e.g., police, shipping agents, etc.). Centres may also establish local community fan-out lists where necessary.

4.3.4 Additional PENS Public Safety and Security Partners

NTWC and PENS messages are redistributed and amplified further by other organizations through their own networks in order to ensure widespread notification of their members and/or the public according to their own established plans. In our investigation we were able to identify a number of public safety organizations that contribute additional critical methods of tsunami event notification, especially in rural coastal sub-regions.

4.3.4.1 Royal Canadian Mounted Police

The Royal Canadian Mounted Police (RCMP) "E" Division which serves British Columbia is the largest Division in the RCMP, with approximately one-third of the entire force located in British Columbia (RCMP, 2014). 51 of its detachment offices are located along the Coast within the five B.C. tsunami notification zones.

NTWC and EMBC tsunami messages are received by the Royal Canadian Mounted Police (RCMP) and relayed to affected detachments through its extensive network of District and E Division Headquarters Operational Communications Centres. NTWC messages are received directly via email. EMBC messages may originate from the ECC and automated PENS. District

OCCs and local detachments may also receive them directly via PREOCs in the affected areas. Messages relayed by OCCs are normally redistributed via the Canadian Police Information Centre (CPIC) system, radio, email and telephone.

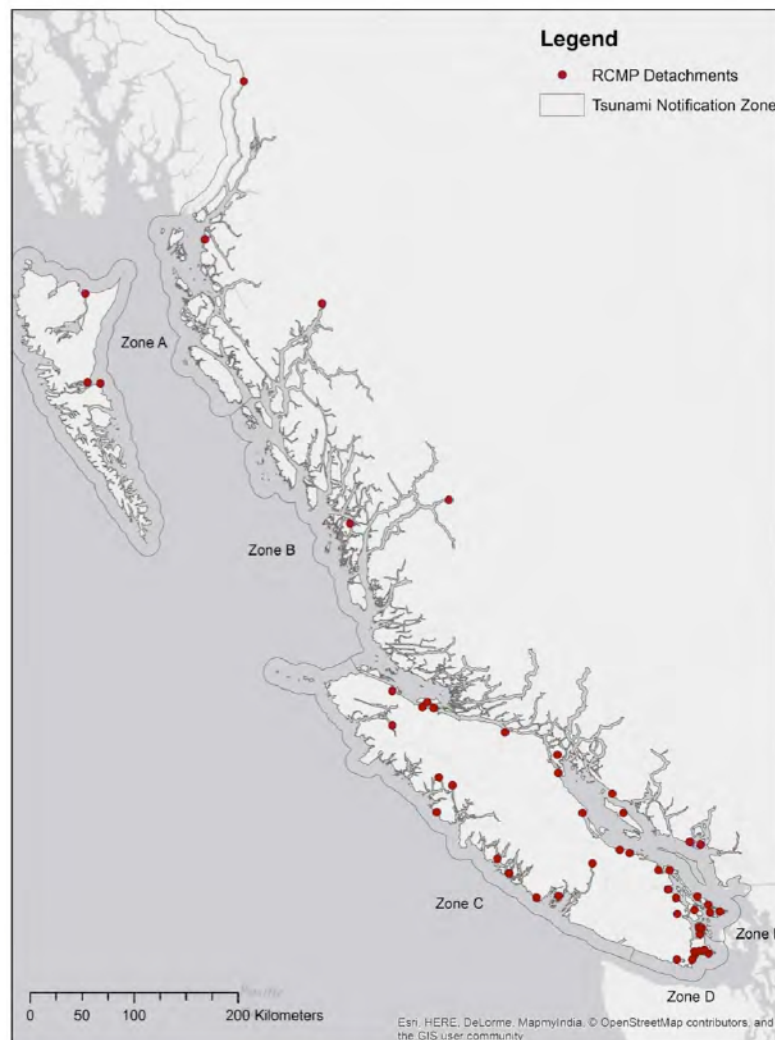


Figure 24
RCMP Coastal Detachment Tsunami Message Reception Locations

4.3.4.2 BC Ambulance Service

BC Ambulance Service (BCAS) operates as an agency under BC Emergency Health Services (BCEHS). BCAS provides emergency medical services 24 hours a day, seven days a week to more than 4.4 million British Columbia residents and millions of visitors. BCAS responds to calls from 184 ambulance stations and five aircraft bases located throughout the province. 57 of the ambulance stations are located along the Coast within the five B.C. tsunami notification zones.

BCAS receives NTWC messages directly via email. Messages received from EMBC may originate from the ECC and automated PENS, or PREOCs. When BCAS receives a NTWC or

EMBC Tsunami Advisory, Warning or Watch notification it activates its Major Incident Notification Matrix using E-Team and Emergency Response Management System (ERMS) automated notification system tools to notify operational directors, the BCAS Communications Branch, impacted area managers and unit chiefs at ambulance stations. Notification is carried out by automated telephone and email messages, with an option to follow up by teleconference.

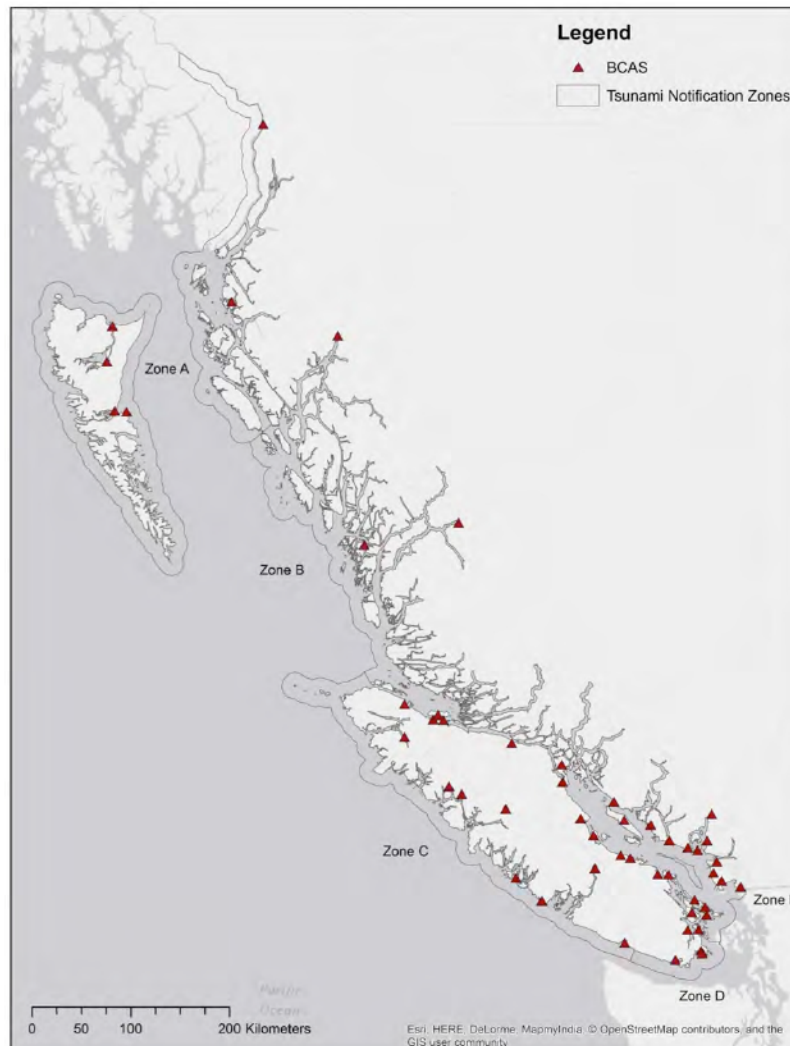


Figure 25
B.C. Ambulance Service Tsunami Message Reception Locations

4.3.4.3 Fire Department Dispatch

In many of the coastal sub-regions, fire department dispatch centres may also receive NTWC and EMBC PENS tsunami Warnings, Advisories and Watches and alert fire departments in affected areas via pager and/or radio. Within the limited time frame of Phase 1, we were not able to fully identify notification practices for all Coastal fire department dispatch centres but include, in Figure 26, locations within the mid and northern Vancouver Island areas that exemplify these practices.

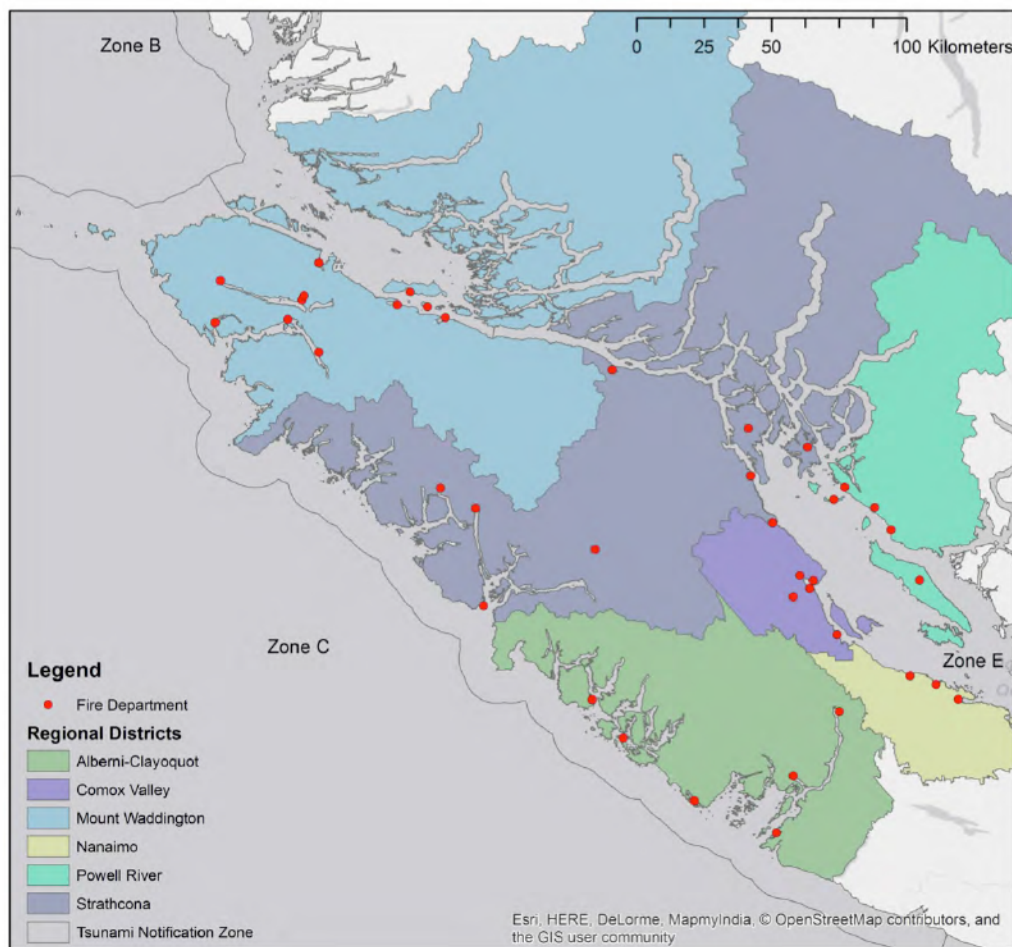


Figure 26
Mid and Northern Vancouver Island Fire Dispatched Tsunami Notification Locations

4.3.4.4 Joint Task Force Pacific

Joint Task Force Pacific (JTFF) is located at Esquimalt and is responsible for all Canadian Armed Forces (CAF) operations in the Province of British Columbia and its western air and maritime approaches (NDAFC, 2014). Commander JTFF is also the Commander Maritime Forces Pacific (MARPAF) which provides maritime security in the North Pacific Region (RCN, 2014). JTFF operates a 24/7 Regional Joint Operations Centre (RJOC) that is responsible for informing Canadian Armed Forces in B.C. of tsunami threats and subsequent actions or measures to mitigate/reduce the threat (NDAFC, 2014).

The RJOC receives notifications through a variety of means: NTWC direct to RJOC via NOAA Weather Wire, Government of Canada Operations Centre (GOC), and from the PECC via PENS.

4.3.5 Media

Presently, there is no formal media association within B.C. that serves as a focal point or coordination body for public alerting. However, many of the mainstream media (newspapers,

radio and television stations) are linked to PENS and other EMBC email lists and are active @NTWC and @EmergencyInfoBC Twitter followers.

4.3.5.1 National Public Alerting System Initiative

At the time of writing this report, national efforts are underway to improve public alerting system interoperability and increase targeted mass notification across all channels of public communication. These efforts build on the work of Canadian Federal, Provincial and Territorial (FPT) governments and the Canadian Radio-television and Telecommunications Commission (CRTC) to establish a National Public Alerting System (NPAS). NPAS embodies an all channel communications approach to enable alerting authorities to transfer a single alerting electronic information file to a central collection point for public distribution through a variety of established communications media. These digital alert messages may also be redistributed through multiple methods by other Last Mile Distributors (LMDs) and the public. In some cases, alerting authorities may maintain their own specialized distribution systems (such as PENS), through which they can distribute the alert messages of other alerting authorities (CanOps, 2014).

Five key functions within NPAS are to:

1. Create an alert;
2. Aggregate all alerts;
3. Share alerts through efficient communication channels;
4. Distribute alerts to the public through a variety of media, and
5. Receive alerts through a variety of communication tools and applications.

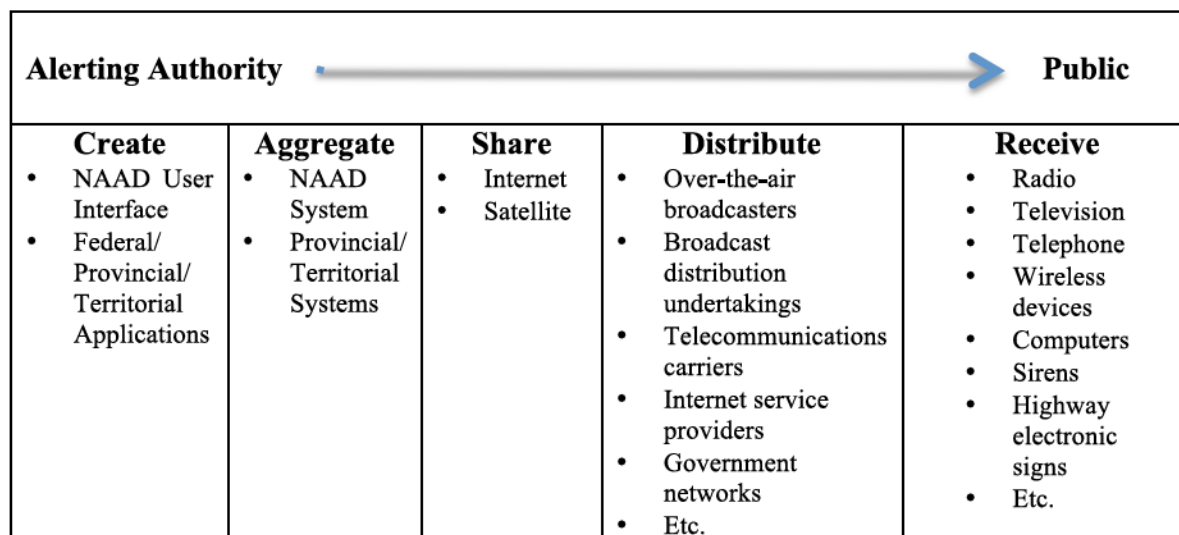


Figure 27
NPAS Communications Model
(CanOps, 2014).

4.3.5.2 National Alert Aggregation and Dissemination System

In 2007, the CRTC issued a public notice (CRTC, 2007) that aimed to remove regulatory barriers to alert services and enable a voluntary approach toward distribution of public alerts. In June

2009, the Pelmorex Communications Inc. received CRTC approval (CRTC, 2009) for its application to launch a National Alert Aggregation and Dissemination (NAAD) System. The application also included a commitment to broadcast emergency alerts at no cost to subscribers. FPT governments worked with Pelmorex and broadcasters to address the actions required to make the system operational, and on June 9, 2010, the NAAD System was officially launched.

The NAAD System is one of the critical components of the larger NPAS. It authenticates alerts issued by public officials and allows them to be aired immediately over selected radio and over-the-air (OTA) television transmitters, video-on-demand (VOD) and broadcasting distribution undertaking (BDU) systems as well as through systems operated by other parties for distribution to the public and emergency management/public safety organizations.

The NAAD System processes messages based on the Common Alerting Protocol (CAP), an international standard for exchanging public warning and emergency messages between alerting technologies. CAP defines a single alert message file that includes a collection of one or more audience alert messages (and referenced content) to be presented to the public. Additionally, sufficient information, along with some supplemental guidance, is present for the last mile distributors to determine if the message(s) is relevant for distribution through their media. CAP is intended to provide an alternative to the use of email, fax and phone calls between alerting authorities and LMDs, because it supports the automated processing and distribution of alert messages by LMDs, and more efficient and complete distribution to the multitude of LMDs (CanOps, 2014).

Since the NAAD System became available in 2010, Environment Canada and all 13 provinces/territories have completed user agreements to issue or accept emergency alerts via their Emergency Management Organizations (EMOs) through the NAAD System.

In August, 2014, following a period of consultation with the broadcast industry and interested parties, the CRTC announced (CRTC, 2014a) that it had made amendments to the *Radio Regulations, 1986* (the Radio Regulations), the *Television Broadcasting Regulations, 1987* (the TV Regulations) and the *Broadcasting Distribution Regulations* (the BDU Regulations). The amendments make participation in the National Public Alerting System (NPAS) mandatory for broadcasting distribution undertakings (BDUs), radio broadcasters and over-the-air (OTA) television broadcasters by 31 March 2015, and for campus, community and Native radio and television broadcasters and radiocommunication distribution undertakings (RDUs) by 31 March 2016.

For OTA licensees, there are both primary, or local, service contours (the 3 mV/m contour for FM radio stations / the 15 mV/m contour for AM radio stations / the Grade A contour for analog television / the digital urban contour) and secondary, or regional, service contours (the 0.5 mV/m contour for FM radio stations / the 5 mV/m contour for AM radio stations / the Grade B contour for analog television / the noise-limited bounding contour for digital television / the digital service area for digital radio). For purposes of areas to be covered by the alert, the Commission has mandated the distribution of emergency alert messages relevant to areas within a station's regional service contour (that is, the larger coverage area).

The Commission further announced (CRTC, 2014a) that it had similarly amended the exemption order for terrestrial BDUs serving fewer than 20,000 subscribers, low-power tourist information related radio programming undertakings, and certain Native radio undertakings in order to incorporate provisions relating to the broadcast of emergency alert messages. Finally, the Commission announced that it has revised the standard requirements for video-on-demand (VOD) undertakings to include a provision relating to their mandatory participation in the NPAS.

4.3.5.3 NPAS and Tsunami Notification

While these changes hold promise for dramatically expanding the reach of public emergency message dissemination across Canada, a number of additional steps will need to be taken to integrate these arrangements with existing tsunami notification methods and ensure adoption by the emergency management organizations and the public. For example, at the macro level, the Common Alerting Profile has not yet been fully implemented. NTWC has an automated CAP process for its bulletins, but there is no process in place to vet and pass these messages through NPAS, although they are being distributed through Canada's new Multi-agency Situational Awareness System (MASAS). At the provincial notification level, upgrades currently being applied to EMBC's PENS may be capable of feeding CAP messages to NAAD, but the challenge remains at the LMD level where much is yet to be understood about which methods and forms of NAAD message distribution will be available and most relevant to B.C. Coastal populations.

In this regard, we believe that this project's community notification matrix will serve as a useful and key knowledge base for informing NPAS developers and implementers. As an initial step and contribution to this process, for broadcasting services, we have been able to identify licensees and their over-the-air (OTA) signal coverage and have incorporated it into the notification matrix for further analysis in Phase 2. We are also seeking additional information to identify which locations have licensed terrestrial Broadcast Distribution Undertakings (BDUs), especially cable television outlets.

We present below, in Figure 27 and 28, composite views for B.C. radio and television over-the-air coverage respectively. We will be exploring further in Phase 2 where the programming originates from and the extent to which local programming is available since these services may support both NTWC and EMBC and locally tailored notification.

It is especially important to note that OTA coverage is limited to urban and larger rural populated areas. In the unserved rural areas, satellite-based BDU services are the only means of providing service.

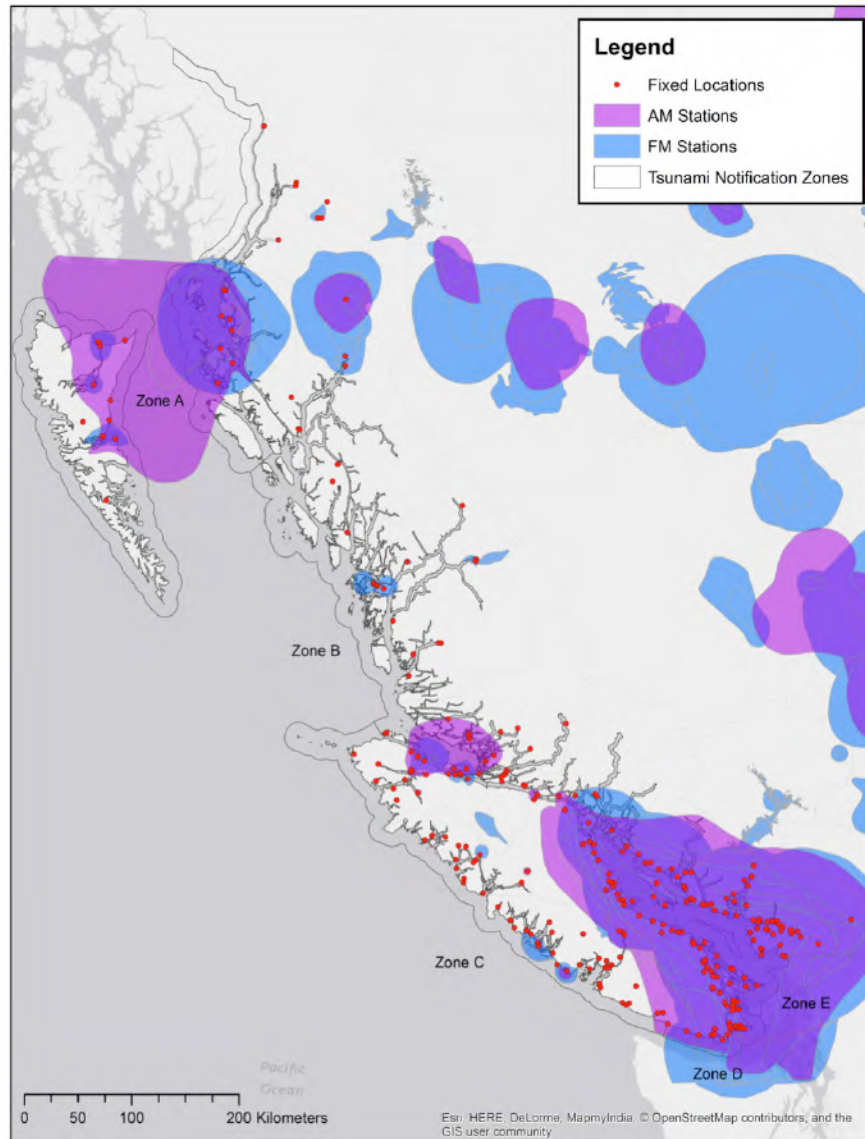


Figure 28
B.C. Over-the-air AM and FM Radio Coverage

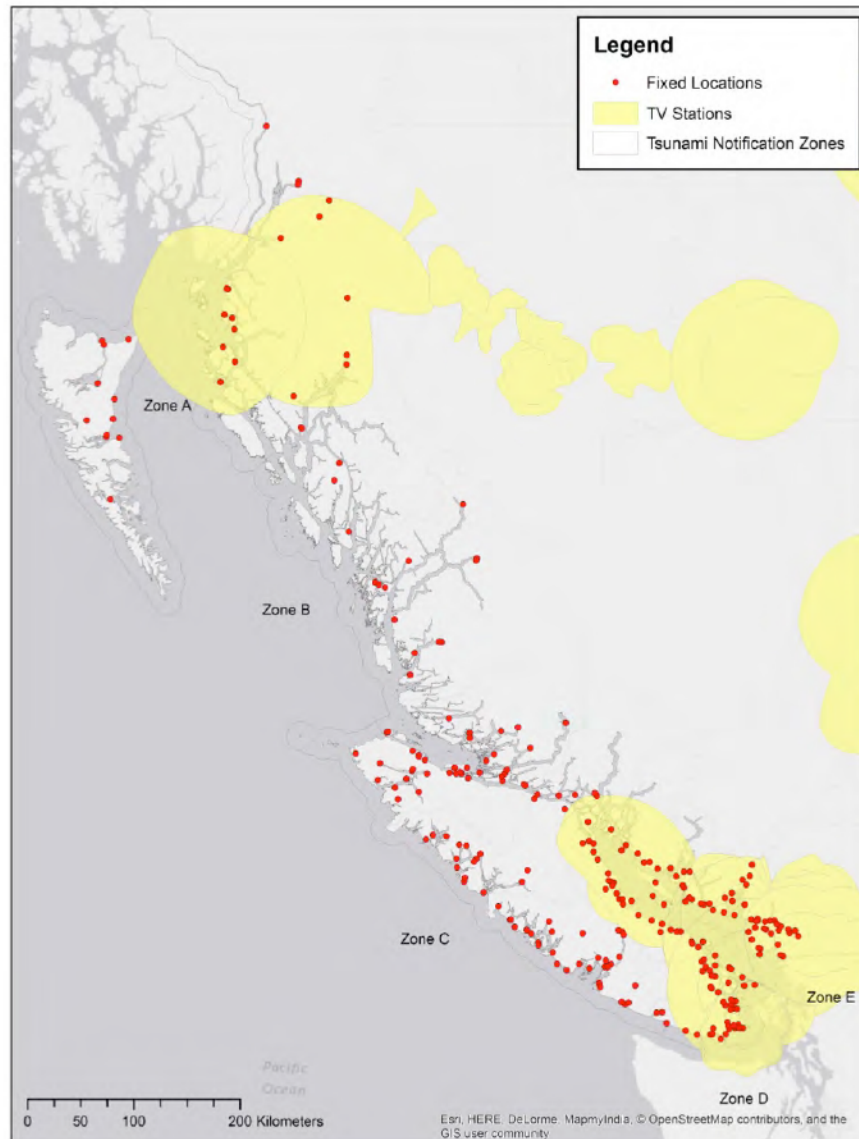


Figure 29
B.C. Over-the-air Television Coverage

4.4 Underpinning Information and Communication Infrastructure for Tsunami Notification and NPAS

While many agencies, as described in the preceding sections, operate their own radio systems and may have in-place dedicated infrastructure such as microwave and satellite services to connect to their sites, many others, including the public-at-large, rely heavily upon public commercial telecommunications infrastructure to establish and maintain communication within and outside their locations. Due to rapid changes in information and communication technology (ICT) development and differing adoption rates, we found that it is difficult to systematically identify and document all of the applications used in public tsunami notification within the B.C. coastal sub-regions. It is possible, however, to identify a number of the key underpinning infrastructures that support local notification and to verify usage and specific applications

through surveys with local authorities.

It is also very important to take into account wider industry ICT trends that reflect shifts in consumer habits and preferences, especially for maintaining existing notification arrangements or planning new ones. For example, total mobile cell phone usage, whether used exclusively or in combination with other types of phone service, continues to grow in popularity in Canada and is replacing traditional residential and commercial wireline service. Statistics Canada (2013) reported in its 2013 Residential Telephone Service Survey that within B.C., while 85% of households use mobile phones, only 57% now use traditional wireline and 14% receive service via cable TV providers. Telephone service from Internet providers (Voice over Internet Protocol), although still relatively small (with 3% of households nationally reporting its use in 2013), may now provide a potential alternative method for voice-based notification even in remote Coastal regions that have no traditional phone service or terrestrial Internet service, but have Internet access via satellite service.

Two key factors that influence ICT selection and adoption are affordability and service offerings whose determinants are often linked to market size and proximity to urban infrastructures. Given the significant variations in B.C. Coastal population densities and distribution, and that the sub-regions most at risk are rural, these factors are especially important because they can also regulate which underpinning technology is available to support tsunami notification. Such influences are highlighted in the recent CRTC Communications Monitoring Report 2014 (CRTC, 2014b), in which it is reported that, based on a sampling of 54 rural communities:

- Canadians living in rural communities generally spent up to \$25 more per month for communications services than those in urban centres;
- Basic home telephone and basic broadcast distribution undertaking (BDU) services generally cost up to \$9 more per month in rural communities, and
- The prices B.C. subscribers paid in rural communities ranged between \$35 and \$38 per month for home telephone service, whereas subscribers living in B.C. urban centres paid between \$30 and \$31 per month.

In addition to price variations, service offerings also vary between rural and urban centres across the country. According to the Report (CRTC 2014b):

- Almost all Canadians have access to basic (i.e., 1.5 Mbps) broadband Internet service. Since 2011, the availability of 5 Mbps broadband service has increased from 87% to 95%;
- In general, Canadians living in large population centres have access to broadband speeds in the 50 Mbps to 99 Mbps range, whereas only 25% of Canadians in rural areas can access these higher speeds;
- Canadians living in urban centres have access to three types of BDU service providers: cable, Direct-to-home satellite (DTH), and Internet Protocol television (IPTV). Those in rural areas generally have access to a DTH service provider and, to a lesser extent, a cable service provider.
- Approximately 49% of households in rural areas had access to a cable service provider and a DTH provider. The remaining 51% were generally dependent on DTH service.

Within the limited time scope of this project, we sought to identify broadband coverage for the

fixed locations within the B.C. TNZs. Through the addition of data to our community notification matrix provided by Network BC, Telus Mobility and Rogers Wireless, we have been able to broadly map both fixed and mobile service types. This data collection will be refined further in Phase 2 of the project to support local and sub-regional notification planning and pilot projects. Presented below is a ‘high level’ snap-shot of supporting broadband infrastructures. As is shown, the availability and type of broadband service closely correlates with the CRTC’s findings above.

4.4.1 Broadband Coverage

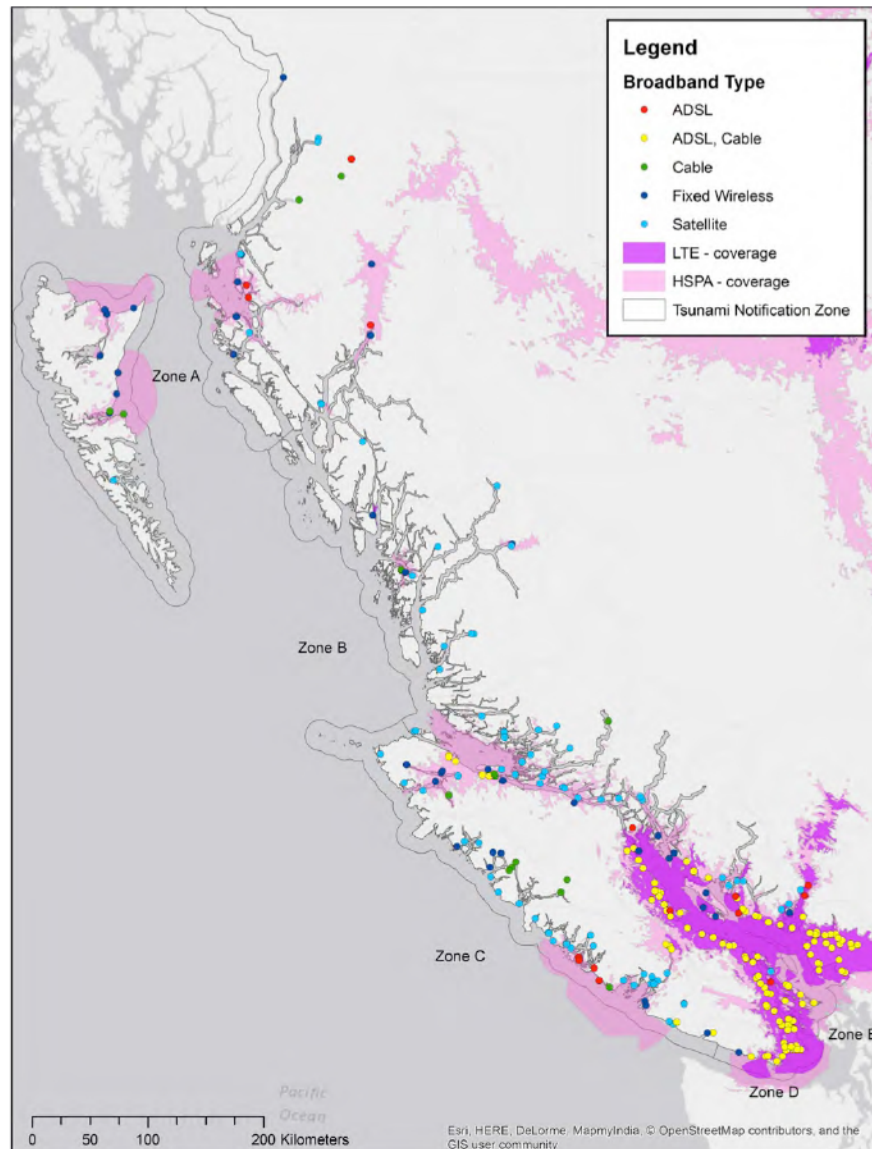


Figure 30
B.C. Coastal Fixed and Cellular Broadband Service Locations

Figure 29 illustrates that all fixed locations have potential access to Internet based services. However, only the more urbanized regions or locations within proximity to them have multiple choices of provider and infrastructure type (e.g. ADSL, Cable, Cellular). Those in the most

remote regions must rely primarily on service from a satellite based provider, which generally is more expensive, may have data usage caps and may not have the necessary quality of service to support the same two way voice and video services associated with urban wireline broadband services. Service connections are also affected by mountainous topography influencing the ability to achieve line-of-sight visibility with the satellite. Conversely, other than power, DTH satellite service does not depend upon other local or regional technical infrastructure to operate.

Mobile cellular service tends to follow a similar pattern, with coverage and level of service determined by population density and/or higher volume highway transportation routes. While, High Speed Packet Access (HSPA) has become the standard service offering, higher capacity Long Term Evolution (LTE) service remains tied to more urban centres or rural corridors that have higher capacity backhaul provisions.

4.5 Coastal Last Mile/Last Person Tsunami Notification

A key function of the Last Mile/Last Person part of the public response subsystem is to enable local populations to be alerted and informed of a potential or imminent threat to the area so they can initiate and coordinate protective actions, including evacuation. It is important to note that communities are primarily responsible for local warning and evacuation arrangements. However, to be effective, local warning activities must be undertaken and coordinated by a range of organizations and agencies, depending on the plan established within each community. Designated emergency program members will be responsible for issuing warnings and evacuation orders to members of the public within their jurisdictions. They may be aided by RCMP, search and rescue groups, fire departments and others in accordance with their plans. Where there is a large employer in the area, warnings may be issued at the worksite.

The type of methods that each area uses will be shaped by several factors, including: the physical location and nature of the population (e.g. residents vs. non-residents), time of day, budget, geographic location, local transportation, available supporting infrastructure, local customs, economic and social activities, etc. This part of the end-to-end notification system is the least formally documented. For purposes of the study, we found the most informative means of collecting local notification data was through administration of a brief questionnaire. The results of the survey are recorded in the community notification matrix and discussed in more detail in our Section 5 review of current local notification practices. Based on the survey and other local interviews, we were able to confirm that the following types of local notification methods are used:

- Siren
- Local telephone - landline and mobile cell
- Automated mass notification system
- Local broadcast radio
- Local broadcast television
- Local cable television community channel
- Pager
- Marine radio
- Mobile notification (e.g., vehicle or boat with PA system)
- Door-to-door

- Agency two way radio
- Amateur radio
- FRS/GMRS two-way radio
- Email
- Twitter
- Facebook
- WWW

4.6 Other Potential Resources

In addition to those already identified in the report, we have also attempted to identify other methods that currently are not formally employed in tsunami notification processes but could extend both the reach and effectiveness of notification. While conducting our research, we came across a number of potential existing and emerging candidates for consideration. Below we present some examples.

4.6.1 MSAT EmergNet

MSAT is the longest running geostationary mobile satellite service in North America. Among the mobile satellite telephone systems available to Canadians, it is also the only system that currently offers both a telephone and a two-way voice-radio capability (called dispatch radio). The two-way radio functions much like a terrestrial trunking radio system and offers talk-groups that can be pre-configured for different groups of agencies. Because the system is satellite-based, there are no traditional terrestrial constraints other than any line-of-sight issues, and the system can be used over very wide geographic areas.

In B.C., a special service package aimed specifically at emergency preparedness and response agencies has been developed called “EmergNet”. This service package includes two radio talk-groups as well as voice telephone capability. The two radio talk-groups are designated as the private-mode talk-group and the interoperability talk-group. The private-mode lets callers enter a four-digit number to access any other MSAT user enrolled in EmergNet and then have a private one-on-one conversation. Using the inter-operability talk-group, an MSAT user can listen and participate in a conversation similar to any other open-radio system channel. This makes a useful briefing tool for a group of participants or a combined-events channel for site management or for wide-area coastal tsunami notification and follow-on communication throughout the event period. As Figure 31 illustrates, a number of Coastal emergency management, health and public safety agencies are now using EmergNet, including local authorities. EMBC also has EmergNet terminals installed at the ECC and at all of the PREOCs. An important feature is that any group of EmergNet users can establish its own private talk-group and layer it on top of the original two, creating its own private channel network, such as a special B.C. Coastal network for tsunami and other hazard response.

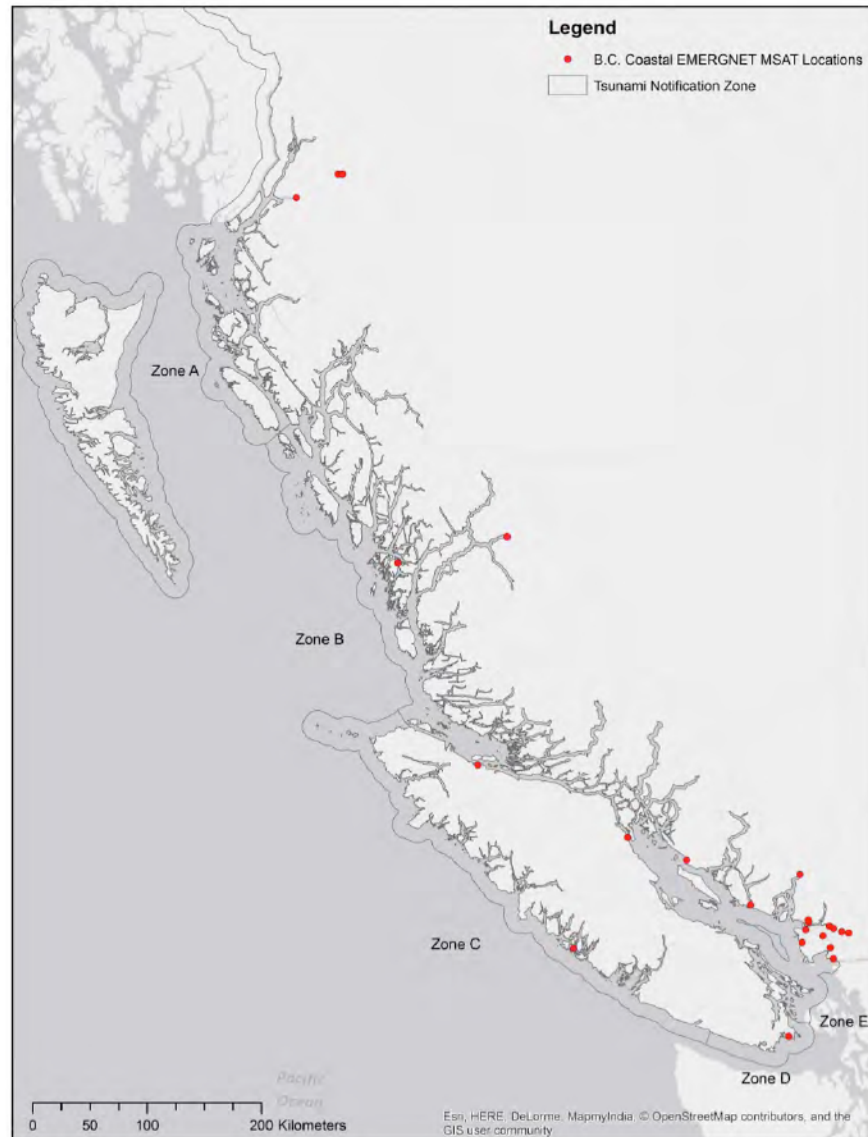


Figure 31
B.C. Coastal EMERGNET MSAT Locations

4.6.2 Other Public and Private Agency Networks

In addition to the VHF and other radio networks used to support tsunami notification discussed earlier in this report, we undertook a search of the Industry Canada Spectrum Direct radio licensing data base to identify other “hidden” radio systems that may extend coverage into Coastal areas not provided by existing formally recognized tsunami notification systems, such as Coast Guard and Weatheradio, or may add other means to receive notifications within the same coverage areas. We managed to uncover hundreds of licensed transmitters operated by federal, provincial and local government and public safety agencies, private and public sector industries, including utilities, logging, aquaculture, marine, helicopter and tour operators, etc.

The extent to which the owners and operators wish to participate may be due to a combination of policy, legal obligation, good will or other considerations. For private networks, while there is no obligation to broadcast tsunami notifications to others, under Workers Compensation and safety regulations, there is an obligation for all employers to notify their workers of hazardous conditions, especially those who are working alone. Thus, any work site and its underpinning communication infrastructure could be considered a critical resource for extending and/or amplifying tsunami notifications, although formal arrangements are not yet in place to assist with their integration.

As an example, we present below two maps. The first, Figure 32 illustrates locations in the northwestern sub-region of Vancouver Island that are outside Weatheradio and mobile cellular coverage and, at best, are in a marginal coverage area of Canadian Coast Guard VHF.

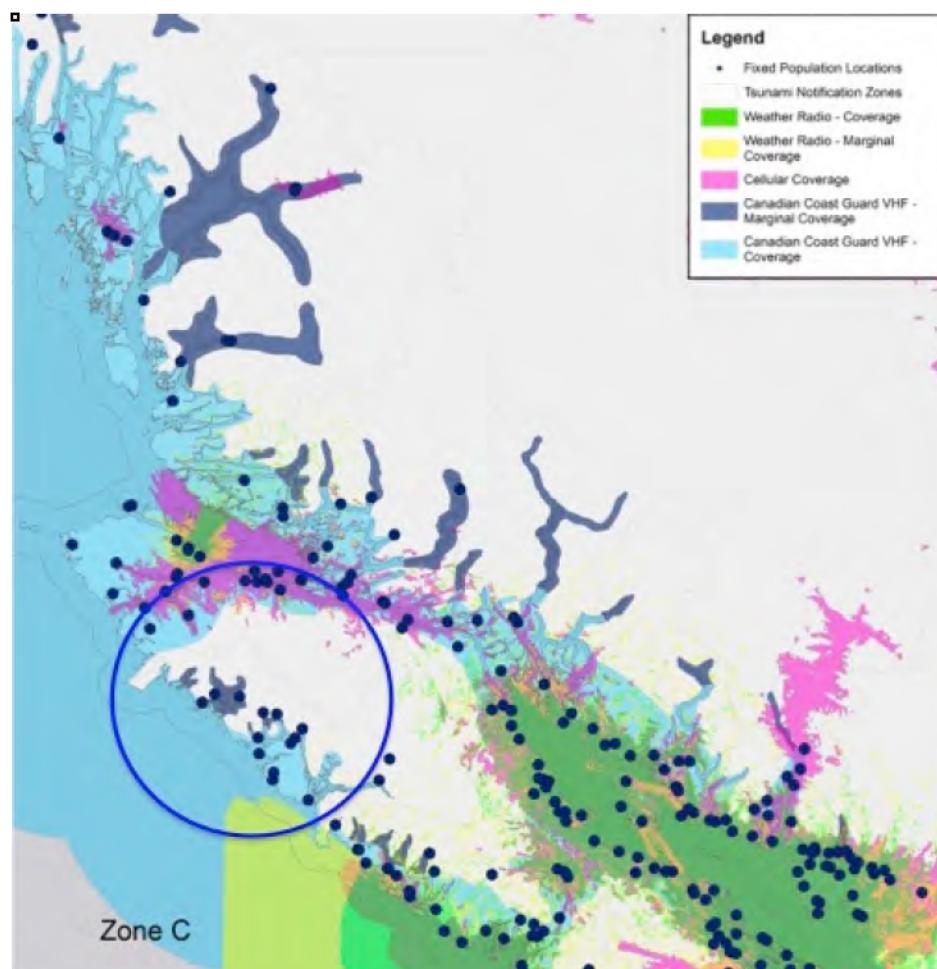


Figure 32
Northwestern Vancouver Island Weatheradio, CCG and Cellular Coverage

Figure 33 illustrates the same locations, but with additional VHF radio coverage of B.C. Ministry of Transportation and Infrastructure.

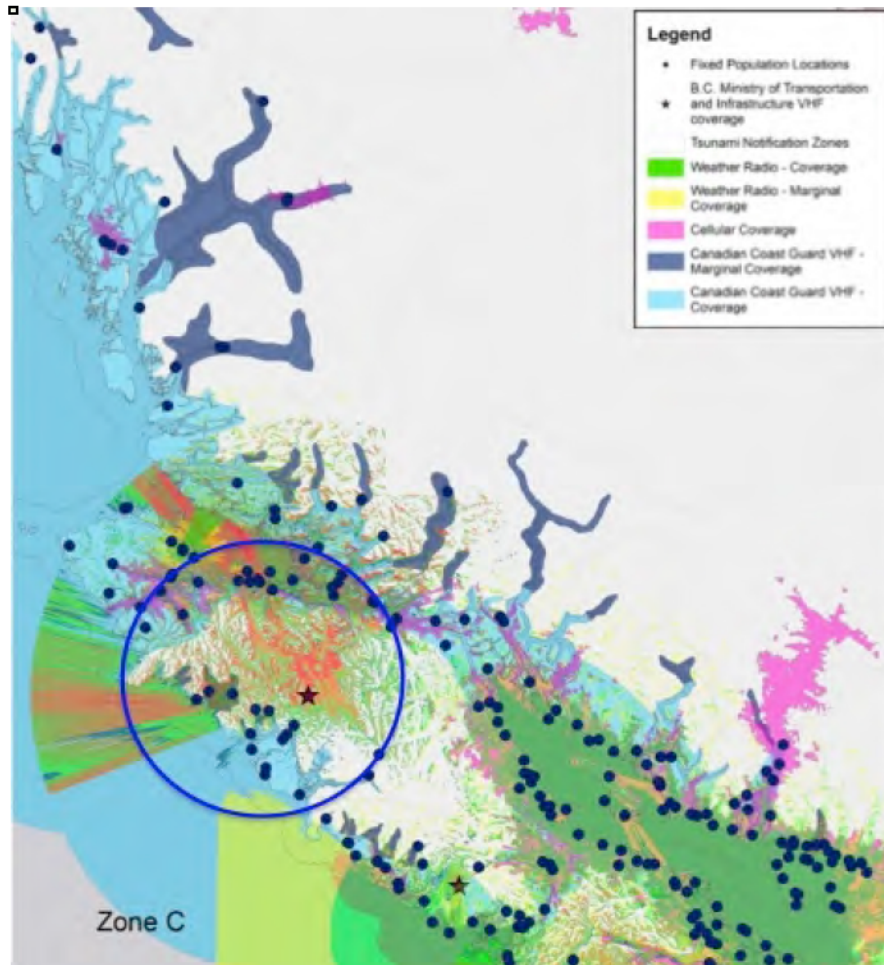


Figure 33
Northwestern Vancouver Island Weatherradio, CCG and Cellular Coverage
with MOTI Coverage Added

4.7 Emerging Systems

4.7.1 Satellite Emergency Notification Devices

A standard has recently emerged for use of satellite technologies in safety applications. This is the Radio Technical Commission for Maritime Services (RTCM) Special Committee 128 (SC-128) Satellite Emergency Notification Device (SEND) standard that can be used for life-critical communications, alert, and response. SENDs are small portable devices that use the Global Positioning System (GPS) and a satellite communication network, such as Iridium, to relay tracking and alert messages back to a server which may send the data to a designated contact person (DCP). A range of SEND compliant systems are now available and being used in public and occupational safety, as well as outdoor recreation. SEND devices can have many functions, including the following:

- Emergency Button / Emergency Call: a button can be pressed to send a radio signal designating an alert. May also provide a loud audio signal from the radio for aiding searchers;

- Location Transmission: the device has a GPS or other location technology to determine user position, and may be able to make that information available on-demand or in an emergency to the DCP;
- Location Tracking: SEND unit locations can easily be shared via GPS location imbedded emails, SMS messages, Twitter and other social media or via a web page; and
- Two way messaging: Free-form, 160-character text messages can be sent and received as SMS messages outside of cell phone range. Many devices allow for pairing of mobile phones.

Recently, EMBC, in partnership with the National Search and Rescue Secretariat, provided SEND devices to all registered land search and rescue organizations in B.C. to enable them to carry out real time tracking of their teams during searches. SEND devices are also being used more widely for work alone and remote safety check-ins.

SEND devices could be especially useful for alerting remote fixed and transient Coastal populations, and could easily interface with existing NTWC and EmergencyInfoBC Twitter/SMS feeds. They also enable tracking of populations during response to tsunami events, especially evacuations.

4.7.2 Public Safety Broadband Network

The development of the proposed Canadian Public Safety Broadband Network (PSBN), providing public safety cellular/mobile communications in the 700 MHz band via the Long-Term Evolution (LTE) standard is expected to have a significant impact on emergency preparedness, notification, and response operations across B.C. A future PSBN will be able to provide an always-on in-place robust communications path to communities, with the added capability to be extended in times of emergencies via portable deployed systems. The network will be able to support communications to mobile resources such as vehicles, aircraft, and personnel on foot, and also provide connectivity to fixed assets such as cameras or sensors, or even responder agency incident command posts and emergency operations centres. Most importantly, a PSBN will provide a common, shared network architecture to support all emergency agencies, enabling interoperability across jurisdictions and disciplines.

For emergency preparedness and monitoring, a PSBN will enable agencies to be continuously informed of the status of assets, including detection and notification systems. This would include knowing the present operating state of the PSBN itself. This is critical for a rapid-onset emergency in which it is important not to have a wait time to establish the status of response assets after the incident has started; it is also important to know which assets have been lost due to the event, rather than simply having been down previously. Additionally, by using the same communications technology on a day-to-day basis, emergency personnel will be better prepared for using it during an actual event. This user experience is further enhanced by the fact that the technology will closely resemble commonly used commercial mobile technology, such as smartphone mobile tablet devices.

For hazard alerting purposes, a PSBN would allow high-speed access to sensor and forecast data, and rapid delivery of detailed hazard event and warning information to communities and

responders; enhancing existing notification methods that rely on text-based data by providing mapping and image data. The PSBN could provide backhaul to feed local public notification infrastructure, such as sirens, electronic signs, and mobile alerting devices, and ensure that these local systems benefit from the robustness requirements of the PSBN itself.

However, the scale of PSBN capacity that would be in place for a community can be expected to be influenced by community cost and may not be sufficient for major emergencies. In such cases, PSBN deployments will be required to provide extra capacity in impacted communities. Further, B.C.'s complex coastal terrains and many areas of low population density make ubiquitous extension of emerging fixed PSBN systems impractical. In these areas, PSBN systems will need to be deployed on an as-needed basis. In this regard, marine based deployments may also be very effective for tsunami alerting and response operations where Canadian Coast Guard, RCMP, Canadian Forces and other public safety and security vessels and other marine assets are operating.

At time of writing this report, another CSSP-supported project⁹ is underway in B.C. to establish a detailed in-field testing capability to validate the systems required to meet the operational requirements of deployable PSBN systems necessary to support disaster response situations where conventional communication infrastructure is damaged or non-existent (especially in rural and remote regions). The field-based PSBN facility is testing different backhaul techniques related to emerging broadband systems and contributing to the development of new protocols and strategies to overcome connectivity and interoperability problems. The major field tests are being conducted in the B.C. Interior and Yukon, but are expected to inform requirements for rural and remote Coastal deployments and could serve as a very important test bed for a marine based PSBN component. We will be exploring such opportunities further in Phase 2 of this project.

⁹ Field Operational Test Facility For Next-Generation Interoperable Mission- Critical Communications (CSSP-2013-CP-1021)

5. Current Local Notification Practices

In order to assess the on-the-ground situation along the B.C. Coast, we conducted an on-line survey designed to garner a better understanding of:

- 1) the means by which B.C. Coastal communities receive tsunami event notifications from outside agencies;
- 2) the means by which their local authorities communicate such information to their populations at risk, and
- 3) what are the local capacities to receive and take action on tsunami notifications.

A copy of the survey questionnaire is attached in Appendix C.

A total of 84 local authorities completed the survey between September 18th and November 26th, 2014, providing valuable insight into infrastructure availability and use across regional districts and tsunami notification zones. The survey was roughly broken down into four sections: tsunami notification sources, preferences, local dissemination media and community notification capacity. This structure enabled our researchers to assess which media local authorities had access to, found valuable, and actually used various notification methods across regional districts and tsunami notification zones. This data, in turn, has been integrated into the community notification matrix and will allow for comparisons to be made in Phase 2 between self-reported media use and infrastructure availability as assessed by the geo-located services reported in the preceding sections of this report.

The following sections detail the survey sample and sampling procedure, as well as the overall response rate and limitations imposed by the design. Some preliminary findings are presented below, bearing in mind that more detailed analysis will be carried out in Phase 2.

5.1 Survey Population and Response Rate

A total of 281 fixed locations have been identified within the 5 TNZs and represent the total locations where fixed population may reside for survey sampling purposes. Included in this count are 25 regional district locations that fall within one or more TNZs. Of these 281 fixed locations, 84 are incorporated municipality, 74 are First Nations and 123 are unincorporated locations.

Of the 84 survey responses received, 41 were from authorities representing incorporated municipalities and regional districts, representing a 49% response rate; 29 were from First Nations, representing a 39% response rate, and 14 were from unincorporated locations, representing a response rate of 11%. A much lower participation rate for unincorporated locations was anticipated since they generally come under the jurisdiction of regional districts for notification purposes and their local notification authorities are largely volunteers. Further, a number of the unincorporated locations are occupied only by seasonal residents (e.g., summer homes, campsites, etc.) and, as such, it is difficult to fully identify and assess local notification arrangements. Many of the unincorporated location respondents are located in the more remote and higher risk sub-regions of TNZs B and C where there are few, if any, incorporated municipalities nearby. As such, their survey results provide important insights into remote local notification reception and dissemination practices.

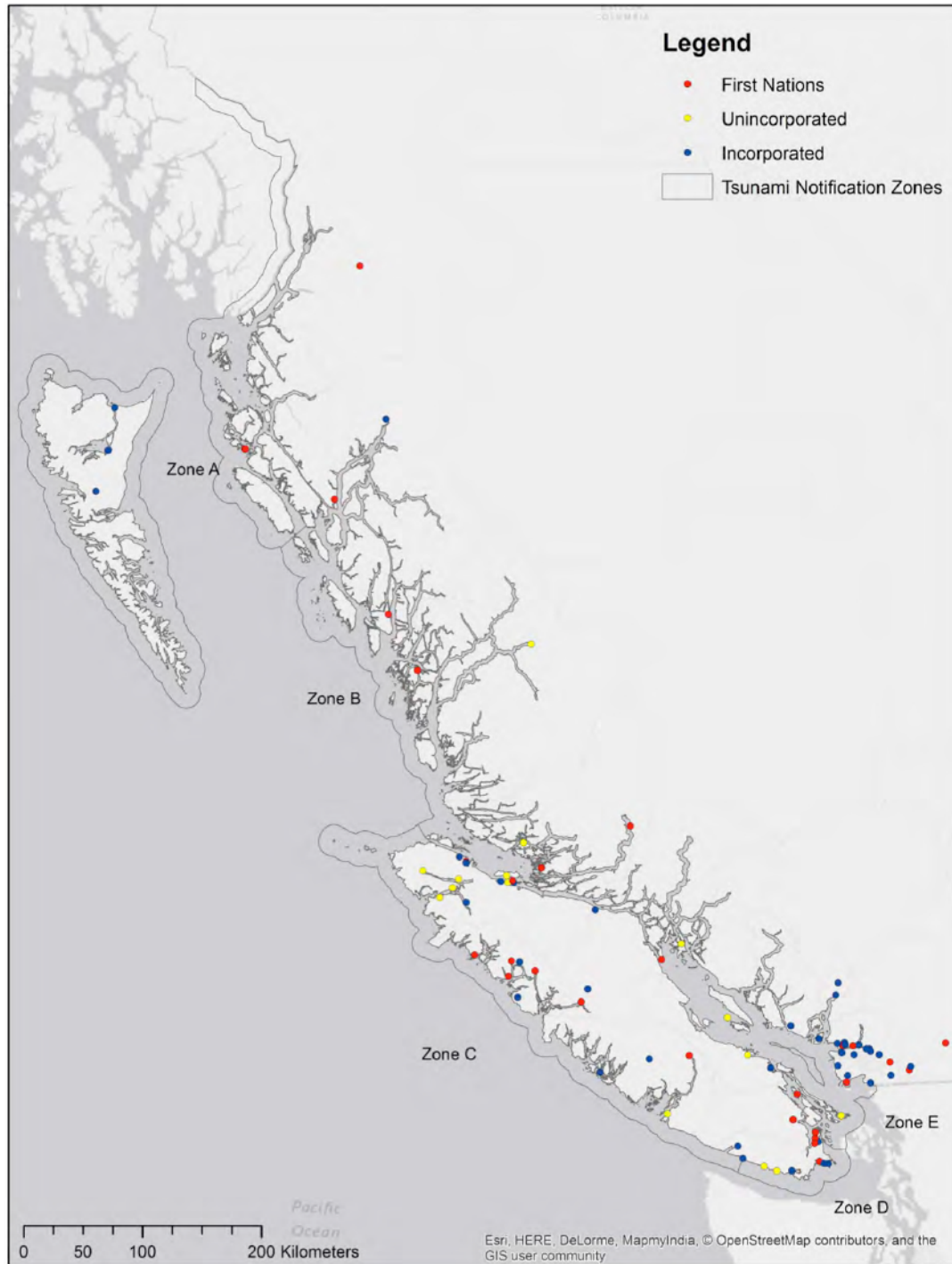


Figure 34
Survey Respondents

5.2 Geography

Of the 84 local authorities surveyed, 43% reside within the more densely populated Zone E, the Greater Vancouver Area and Lower Mainland. Zone A had the lowest number of entries, which reflects the more remote populations. Although fairly populated, Zone D also had a low submission, but out of all 5 zones, it is the smallest in area.

Table 7 provides the breakdown of entries for each zone for the different local authorities.

<i>Zone</i>	First Nation	Incorporated	Unincorporated	Total Sum
<i>A</i>	2	3	0	5
<i>B</i>	7	5	4	16
<i>C</i>	6	7	6	19
<i>D</i>	1	5	2	8
<i>E</i>	13	21	2	36

Table 7
Entries by Zones and Local Authority

5.3 External Notification Sources

Participants were asked to select which source media they had access to for receiving external tsunami notifications from a predetermined list. The options were, as follows:

- EMBC's PENS System:
 - Telephone
 - Fax
 - Email
- EMBC PREOC email
- EMBC ECC email
- EmergencyBCInfo website, @EmergencyBCInfo Twitter or SMS feeds or RSS subscription
- Regional District (RD) telephone, email, or other media
- RCMP
- Fire Department Dispatch (FDD)
- BC Ambulance Service (BCAS)
- Canadian Coast Guard radio - Channel 16 (CCG16)
- NAVCAN aeronautical radio
- Environment Canada ECAAlert email or Weather radio;
- Natural Resource Canada (@CanadaQuakes) Twitter or SMS subscriptions;
- NOAA's National Tsunami Warning Center website, (@NWS_NTWC) Twitter or SMS feeds, or RSS subscription
- USGS (@USGSted) Twitter or SMS subscriptions
- UNESCO tsunami-information-ioc@lists.unesco.org email

The response results for all local authority external media sources are displayed in Table 8.

Notification Sources		
<i>Media</i>	Sum	% Total
<i>EMBC PREOC - Email</i>	38	8%
<i>EMBC ECC - Email</i>	30	7%
<i>EMBC PENS - Telephone</i>	45	10%
<i>EMBC PENS - Fax</i>	27	6%
<i>EMBC PENS - Email</i>	38	8%
<i>Regional District - Telephone</i>	9	2%
<i>Regional District - Email</i>	20	4%
<i>Regional District - Other</i>	5	1%
<i>RCMP</i>	10	2%
<i>FD Dispatch</i>	19	4%
<i>CCG Radio Ch16</i>	11	2%
<i>BC Ambulance Service</i>	3	1%
<i>NAVCAN Aeronautical Radio</i>	0	0%
<i>Env. Can. ECAAlert email</i>	29	6%
<i>Env. Can. Weather radio</i>	9	2%
<i>Twitter - EMBC</i>	21	5%
<i>Twitter - NOAA NTWC</i>	15	3%
<i>Twitter - NR CAN</i>	9	2%
<i>Twitter - USGS</i>	10	2%
<i>SMS - EMBC</i>	8	2%
<i>SMS - NOAA NTWC</i>	12	3%
<i>SMS - NR CAN</i>	5	1%
<i>SMS - USGS</i>	7	2%
<i>RSS - EMBC</i>	5	1%
<i>RSS - NOAA</i>	5	1%
<i>WWW - EMBC</i>	18	4%
<i>WWW - NOAA</i>	17	4%
<i>Email - UNESCO</i>	20	4%
<i>Other</i>	13	3%
Total	458	100%

Table 8
External Notification Sources

To provide further detail on the methods used to receive external tsunami notification, Figure 35 displays each media method for First Nations, Incorporated and Unincorporated local authorities. The data represents the sum of method used and not the total percentage.

□

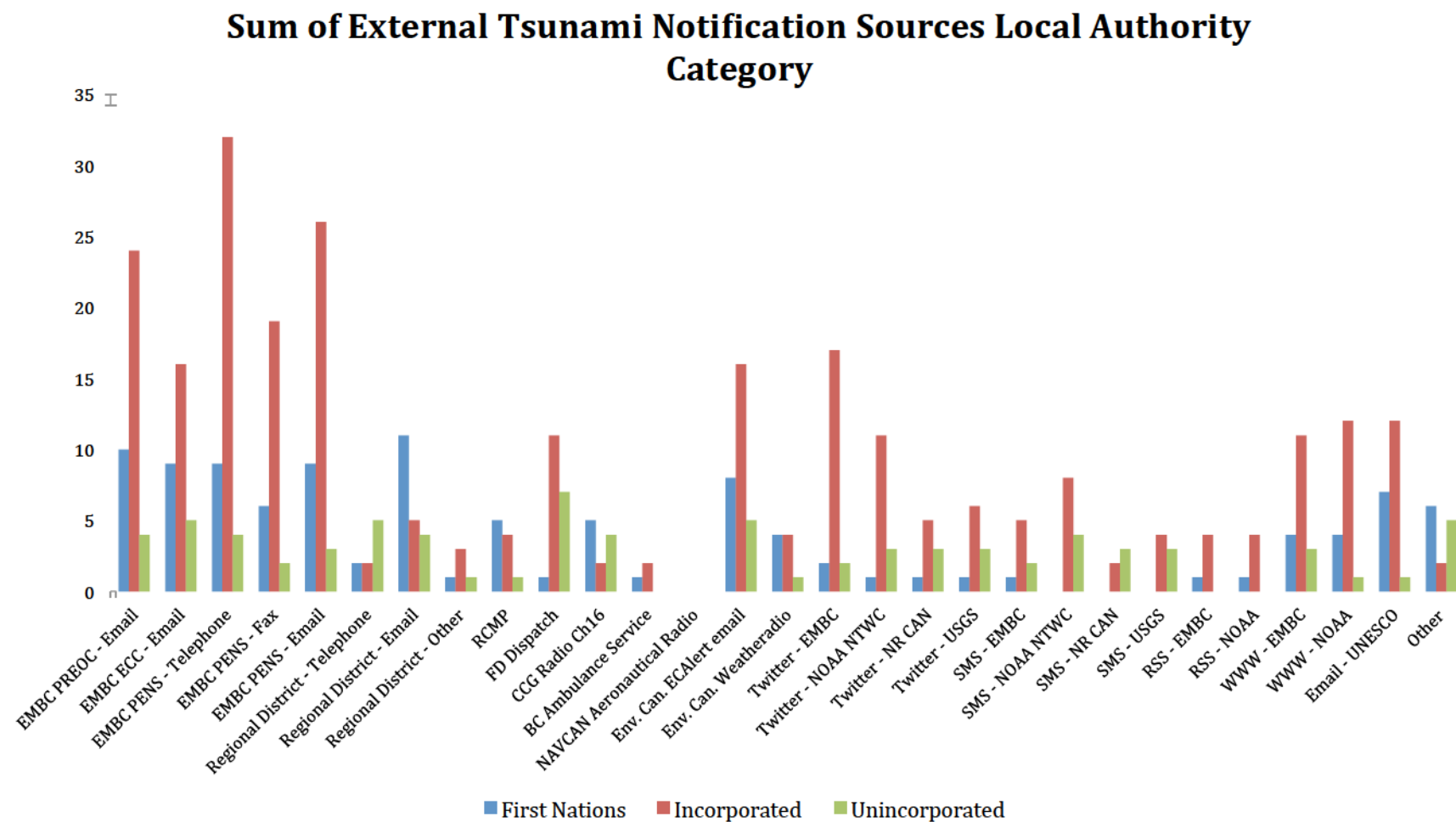


Figure 35
External Tsunami Notification Sources by Local Authority Category

Source media were also grouped by owner and by type in order to look at prevalence of organizations and means of communication in aggregate across the sample (Tables 9 and 10).

In Table 9, all EMBC media were placed in the “EMBC” group. Regional District media were grouped under “Regional Districts”. Any other Federal Canadian Government media were placed in the “Government Group”. All NOAA media were grouped under “NOAA”. RCMP, FDD, CCG, and BCAS were grouped under “First Response”, all USGS media were grouped under “USGS”, and all remaining options were placed in the “Other Org” category.

Based on this data, it is apparent that EMBC (50%) is the organization with the most utilized means of external tsunami notifications. EMBC alone provides 9 different communication sources. With the exception of USGS, the remaining organizations are used to distribute the notifications at a similar count to EMBC, with a difference of only 4%.

Source Organization		
Owner	Sum	% total
<i>EMBC</i>	230	50.22%
<i>Government</i>	52	11.35%
<i>NOAA</i>	49	10.70%
<i>First Response</i>	43	9.39%
<i>Regional Districts</i>	34	7.42%
<i>Other Organizations</i>	33	7.21%
<i>USGS</i>	17	3.71%
Total	458	100%

Table 9
Source Organizations

In Figure 36, the data for source organization was separated into First Nations, Incorporated and Unincorporated local authorities. The data represents the sum of method used and not the total percentage.

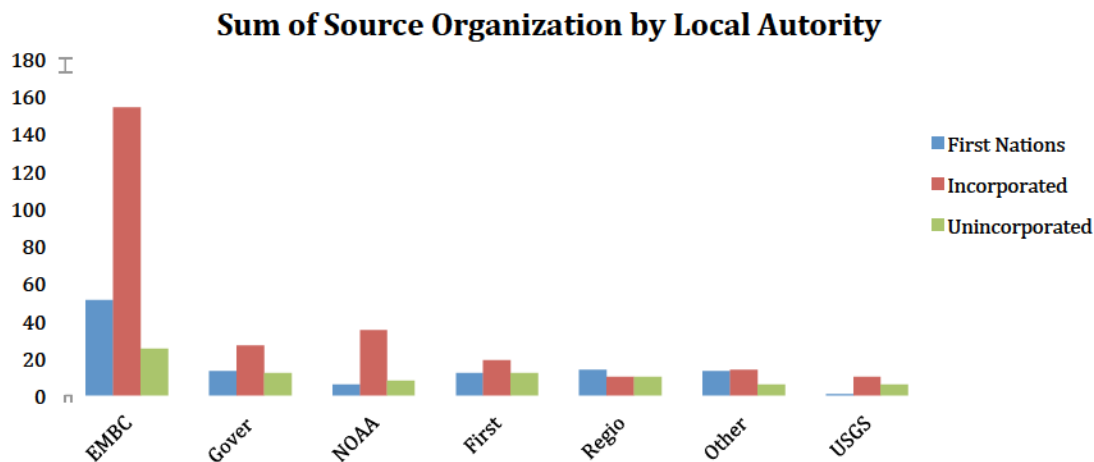


Figure 36
Source Organizations by Local Authority Category

In Table 10, all media were grouped according to type, such as “telephone”, “email”, or “Twitter”. Entries under “First Response” were placed under “Other” as it is uncertain which form of communication is used specifically. Results are listed as sums per community, and because some communities subscribe to more than one media for a group or type category, the numbers appear elevated. Thus the totals represent the cumulative total across all communities for a given field.

With the independent outlets merged into similar categories, email (38%) is the most utilized form of external notifications. This is composed of 6 different emails out of the 29 identified means of notification. Twitter, telephone, WWW and SMS combined to almost the equivalent of email (39%). Fax, radio, RSS and other bring in the remaining forms of notification, with RSS being the least utilized.

Source Media		
Media	Sum	% total
<i>Email</i>	175	38.21%
<i>Twitter</i>	55	12.01%
<i>Telephone</i>	54	11.79%
<i>WWW</i>	35	7.64%
<i>First Response</i>	32	6.99%
<i>SMS</i>	32	6.99%
<i>Fax</i>	27	5.90%
<i>Radio</i>	20	4.37%
<i>RSS</i>	10	2.18%
<i>Other</i>	18	3.93%
Total	458	100%

Table 10
Source Media

In figure 37, the data for source media was separated into First Nations, Incorporated and Unincorporated local authority categories. The data represents the sum of method used and not the total percentage.

□

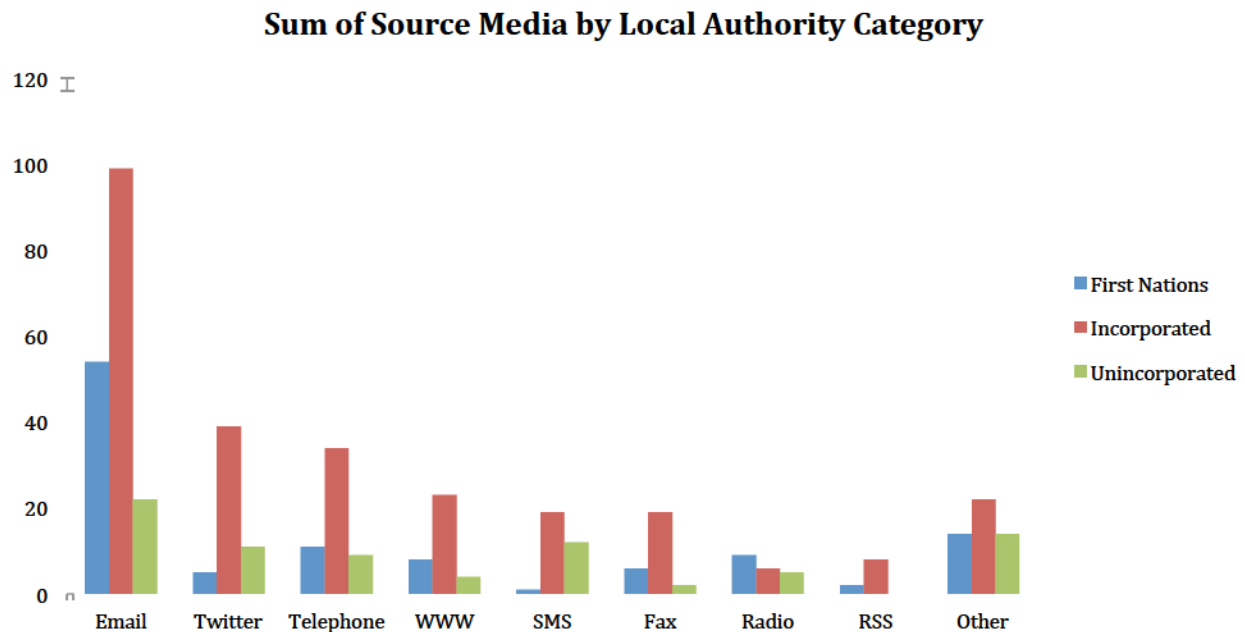


Figure 37
Source Media by Local Authority Category

5.4 Local Tsunami Notification Methods

Participants were then asked to then identify which means of notification was used to notify its population from a predetermined list.

The options were, as follows:

- Siren
- Local telephone – landline and cell
- Automated mass notification system
- Local broadcast radio
- Local broadcast television
- Local cable television community channel
- Pager
- Marine radio
- Mobile notification (e.g., vehicle or boat with PA system)
- Door-to-door
- Agency two way radio
- Amateur radio
- FRS/GMRS two-way radio
- Email
- Twitter
- Facebook
- WWW
- Other

The reported results for all local authority notification methods are displayed in Table 11. Although technological communication prevailed in *external* notification, in location population notification, door-to-door notification was marked as the most used for all local authorities. However, local telephone, Facebook, email and Twitter combine to have the most utilized form of notification. Radio, pager and television are the methods least utilized.

Local Notification Methods		
<i>Method</i>	Sum	% Total
<i>Siren</i>	17	5%
<i>Local telephone</i>	39	11%
<i>Automated mass notification system</i>	13	4%
<i>Local broadcast radio</i>	25	7%
<i>Local broadcast television</i>	7	2%
<i>Local cable television community channel</i>	8	2%
<i>Pager</i>	7	2%
<i>Marine radio</i>	7	2%
<i>Mobile notification</i>	23	6%
<i>Door-to-door</i>	60	17%
<i>Agency two way radio</i>	11	3%
<i>Amateur radio</i>	9	3%
<i>FRS/GMRS two-way radio</i>	2	1%
<i>Email</i>	32	9%
<i>Twitter</i>	30	8%
<i>Facebook</i>	41	11%
<i>WWW</i>	19	5%
<i>Other</i>	8	2%
Total	358	100%

Table 11
Local Notification Methods

Figure 38 provides a visual representation for all local authority methods used for local population tsunami notifications. The data represents the sum of the method used and not the total percentage.

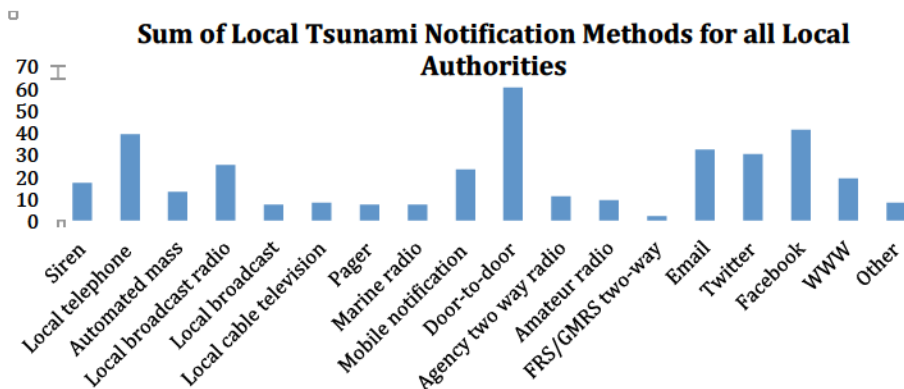


Figure 38
Sum Total for Local Notification Methods for all Local Authorities

Figure 39 is a detailed representation of individual local authority methods used for local population tsunami notifications. The data represents the sum of method used, not the total percentage.

Figure 40 represents the total percent of method for each local authority used.

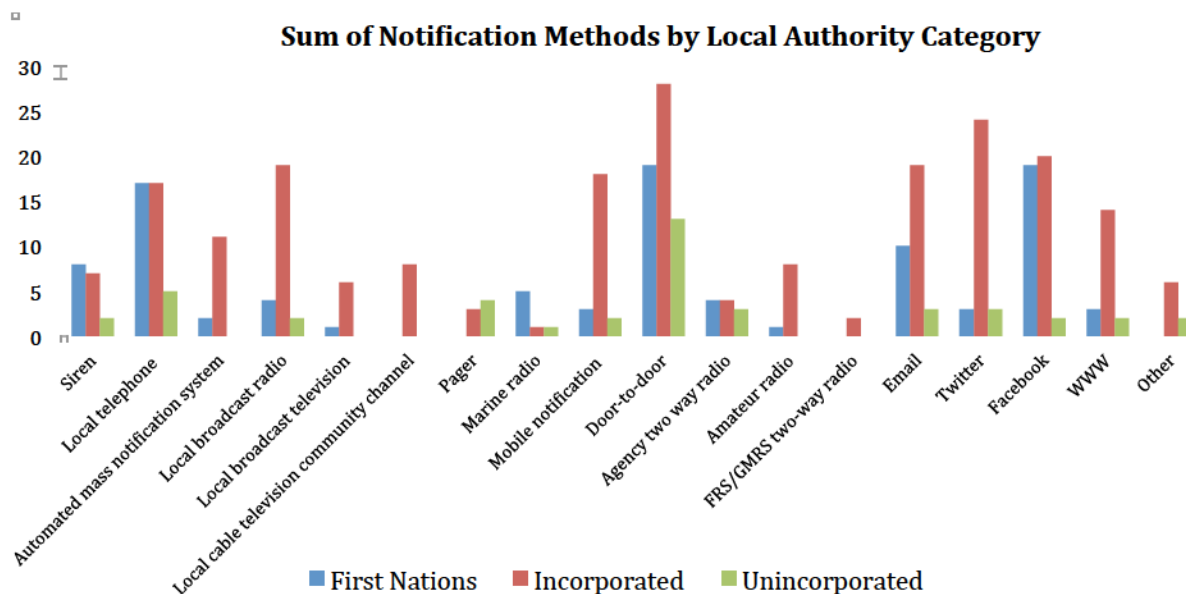


Figure 39
Sum Total for Local Notification Methods by Local Authority Category

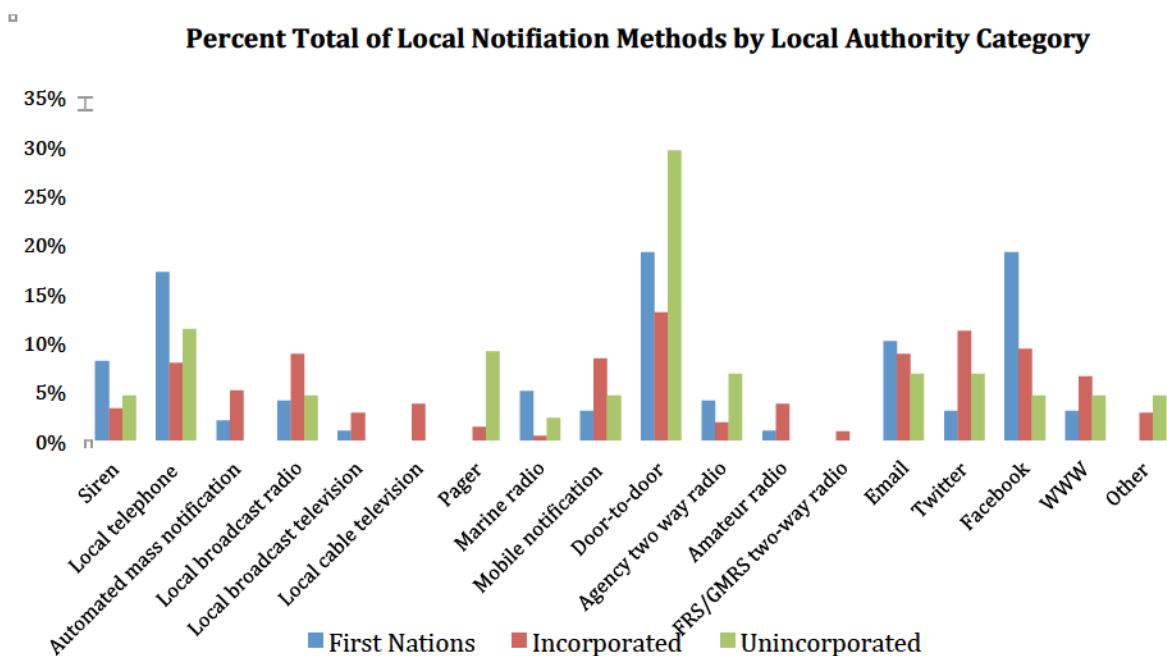


Figure 40
Percent Total of Local Notification Methods by Local Authority Category

It is important to take into account what notification infrastructure is available locally and we will be analyzing methods chosen in much more detail in Phase 2.

5.5 Local Tsunami Notification Capabilities

Lastly, participants were asked to select which means of tsunami notification plans and capabilities were available to their communities from a predetermined list. The options were, as follows:

- An emergency communications plan
- A tsunami action plan
- A means to receive external tsunami notifications and carry out necessary actions on a 24 hour per day basis
- A means to disseminate local tsunami messages on a 24 hour per day basis
- A tsunami education/awareness program

The response results for all local authority plans and capabilities are displayed in Table 11. Out of all 84 local authorities, 61% have reported to have an emergency communication plan. At just over a half, however, 52% indicated that they have a tsunami action place and another 52% have the means to receive external tsunami notification and carry out necessary actions on a 24-hour per day basis. More significantly, only 40% have the means to disseminate local tsunami messages on a 24-hour per day basis and only 40% have a tsunami education or awareness program.

Local Tsunami Notifications and Capabilities		
<i>Plans and Capabilities</i>	Sum	% Total
<i>Emergency communications plan</i>	51	61%
<i>Tsunami action plan</i>	44	52%
<i>Means to receive external tsunami notifications and carry out necessary actions on a 24 hour per day basis</i>	44	52%
<i>Means to disseminate local tsunami messages on a 24 hour per day basis</i>	34	40%
<i>Tsunami education/awareness program</i>	34	40%

Table 12
Local Plans and Capabilities for all Local Authorities

Figure 41 provides a visual representation for all local authority tsunami notification plans and capabilities. The data represents the sum of method used and not the total percentage.

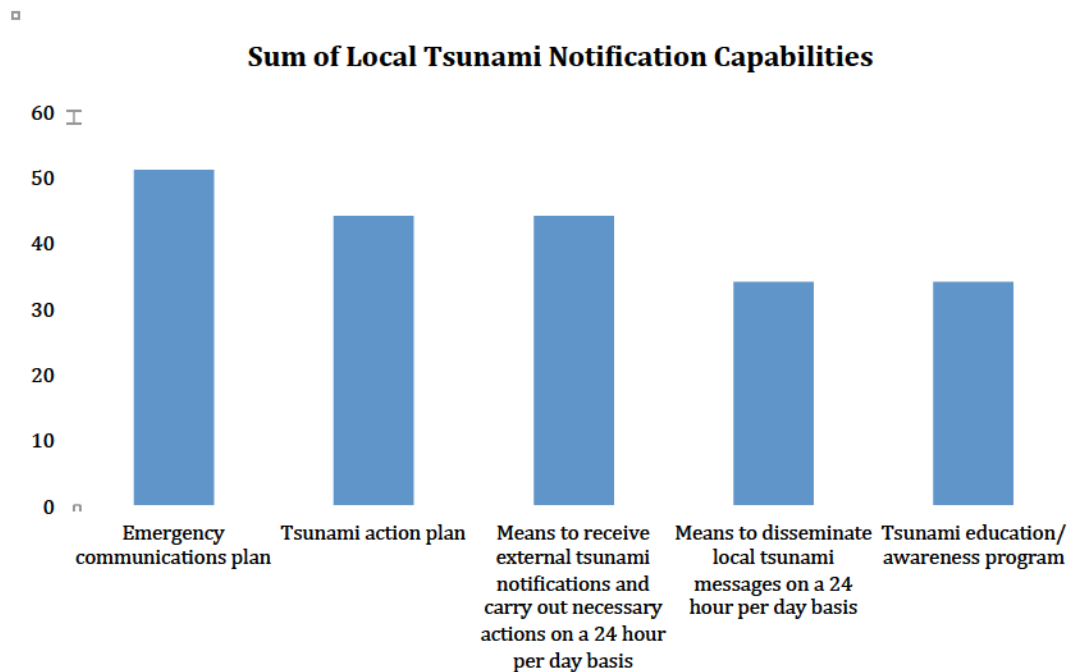


Figure 41
Sum Total for Tsunami Plans and Notification Capabilities for All Local Authorities

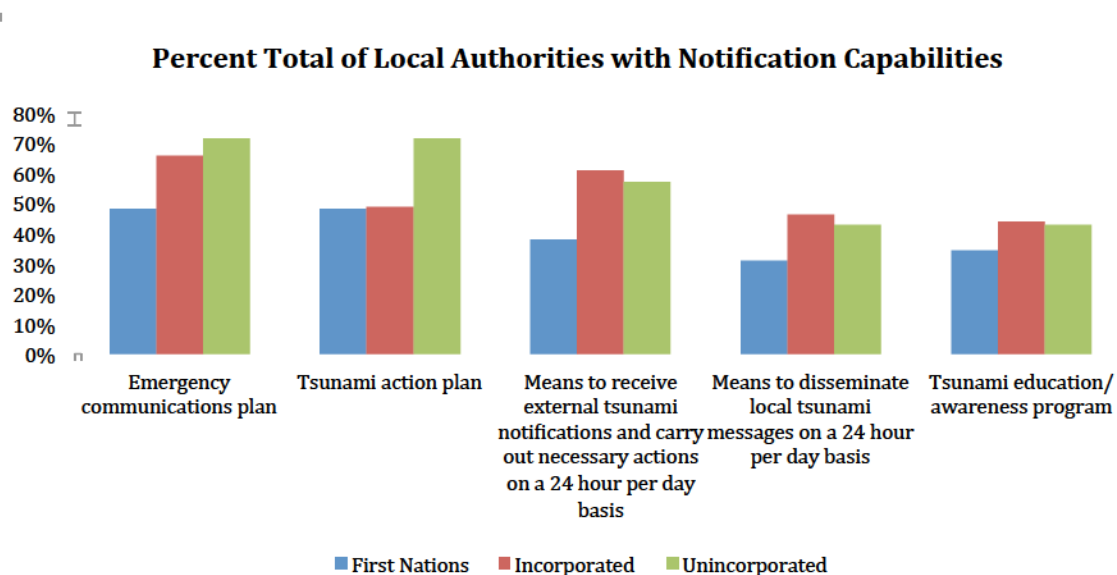


Figure 42
Percent Total for Tsunami Plans and Notification Capabilities by Local Authority Category

Figure 42 represents the total percent of method used by local authority category. Incorporated local authorities lead in notification capabilities and education, although these numbers are still low – 44%. Only 49% of these local authorities have a tsunami notification plan, but 66% have an emergency communication plan. In comparison to incorporated communities, unincorporated communities appear to lead in emergency communications and tsunami action plans, but it must be remembered that only 14 unincorporated communities were surveyed. Within each

notification and capability category, First Nations local authorities reported lower rates of capacity. However, again, there may be wide variations across TNZs, especially among rural and more urban centred First Nations communities. These and other factors will be analyzed further in Phase 2.

6. Connecting the Dots

Using the collected baseline data, and community notification survey results, we will be in a position in Phase 2 to analyze and assess notification arrangements from a variety of perspectives, including location, notification method and coverage, community profile, population classification (fixed, transient), tsunami notification zone, administrative unit (EMBC region, Regional District, RCMP District), as well as identify and factor in additional considerations such as other existing and emerging services and infrastructure not currently considered. The GIS component will be especially useful for gaining better insights into underserved areas and developing new methodologies for identifying and ranking sub-regions by various levels of vulnerability, including communication vulnerability.

We conclude with an example. In Figure 43, by combining data from a transient population group such as kayakers with a coastal base map, we are able to chart known kayaking routes and stopover locations and then overlay communications coverage to reveal potential communication gaps within higher tsunami risk zones (especially channels with steep slopes and poor line-of-sight communication). The results reveal both potential physical and communication vulnerabilities for those venturing into these areas and the requirement for innovative strategies to ensure timely and accurate tsunami notification.

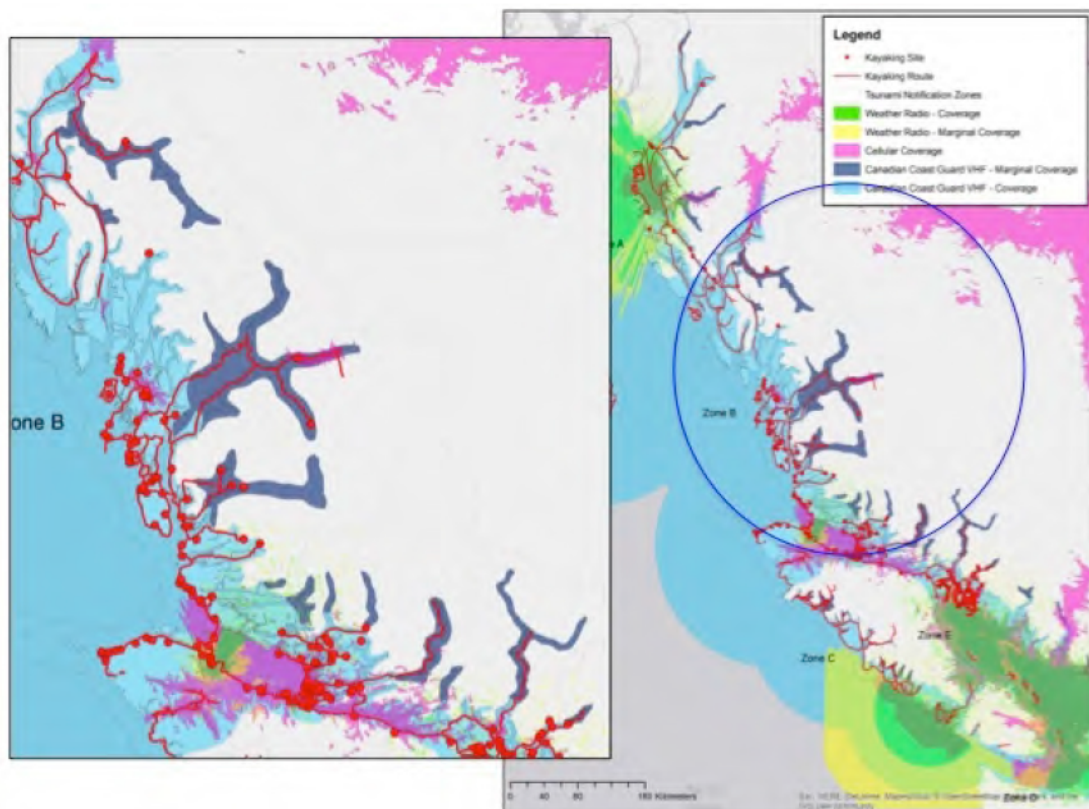


Figure 43
Kayaking Locations with Marginal Tsunami Notification Coverage

7. Summary

In closing, this report summarizes the key activities of the Phase 1 study to inventory and assess existing coastal warning and communication networks and last-mile segments. The primary purpose of this initial research and analysis is to serve as a baseline study to support carrying out pilot projects in a select number of communities in Phase 2 in order to validate existing preferred systems and to test and evaluate new warning techniques and supporting technologies. Another significant contribution of the current research will also support the development of a Tsunami Warning Methods Planning Tool Kit Guide and an all-hazards alerting roadmap for British Columbia. As such, much of the data presentation and discussion presented in this report is intended to be viewed as a work-in-progress.

References

- Adams, J. (1990). Paleoseismicity of the Cascadia Subduction Zone—evidence from turbidites off the Oregon–Washington margin. *Tectonics*, 9 (1990), pp. 569–583.
- Atwater, B.F., Stuiver, M., Yamaguchi, D.K. (1990). Radiocarbon test of earthquake magnitude at the Cascadia Subduction. *Zone. Nature*, 353 (1991), pp. 156–158.
- Anderson, P. S. & Gow, G. (2004). *Tsunamis and coastal communities in British Columbia: An assessment of the BC Tsunami Warning System and related risk reduction practices*. Public Safety and Emergency Preparedness Canada.
- Anderson, P. S. & British Columbia. (2006). *British columbia tsunami warning methods: a toolkit for community planning*. Victoria, B.C.: Ministry of Public Safety and Solicitor General, Provincial Emergency Program.
- B.C. Emergency Health Services. (2013). *2012/2013 Annual Report*. Retrieved from: http://www.bcas.ca/?media_dl=4214
- B.C. Stats. (2014). *Tourism Indicators 2012*. Retrieved from: <http://www.bcstats.gov.bc.ca/StatisticsBySubject/BusinessIndustry/Tourism.aspx>
- Bobrowsky, P T and Dominguez, M J. (2012). Landslide susceptibility map of Canada; *Geological Survey of Canada*, Open File 7228, scale 1:6 million doi:10.4095/291902.
- Canadian Public Safety Operations Organization. (2014). *National Public Alerting System*. Retrieved from: <http://capan.ca/index.php?/en/npas>
- Canadian Radio-television and Telecommunications Commission. (2007). *Emergency alert services*, Broadcasting Public Notice CRTC 2007-20, 28 February 2007.
- Canadian Radio-television and Telecommunications Commission. (2009). *Mandatory distribution order for The Weather Network and Météomédia*, Broadcasting Order CRTC 2009-340, 11 June 2009.
- Canadian Radio-television and Telecommunications Commission. (2104). *Amendments to various regulations, the standard conditions of licence for video-on-demand undertakings and certain exemption orders - Provisions requiring the mandatory distribution of emergency alert messages*. Broadcasting Regulatory Policy CRTC 2014-444 and Broadcasting Orders CRTC 2014-445, 2014-446, 2014-447 and 2014-448, 29 August 2014.
- Canadian Radio-television and Telecommunications Commission. (2104). *Communications Monitoring Report*. Ottawa, October 2014. Retrieved from: <http://crtc.gc.ca/eng/publications/reports/PolicyMonitoring/2014/cmr.htm>

- Chamber of Shipping of British Columbia. (2014). *British Columbia Ports Handbook. Vancouver*. Retrieved from: <http://cosbc.ca/images/docs/BCPortsHandbook2014.pdf>
- Clague, J.J., Bobrowsky, P.T. & Hutchinson, I. (2000). A review of geological records of large tsunamis at Vancouver Island, British Columbia, and implications for hazard. *Quaternary Science Reviews*, Volume 19, Issue 9, May 2000, Pages 849–863.
- Clague, J.J. (2001). Tsunamis. In *A Synthesis of Geological Hazards in Canada*. Brooks, G.R. (editor). Geological Survey of Canada, Bulletin 548, p.27-42.
- Dobson, J. E., Bright, E. A., Coleman, P. R., Durfee, R. C., & Worley, B. A. (2000). LandScan: A global population database for estimating populations at risk. *Photogrammetric Engineering and Remote Sensing*, 66(7), 849-857.
- Dobson, S. (Ed.) (2002, Dec. 5-7). *Workshop Proceeding: Policy Directions for Coastal Tourism*. Simon Fraser University, Vancouver.
- Environment Canada. (2014). *EC Alert Me Detailed Guide*.
- Environment Canada. (2014). *Forecast Regions*. Retrieved from: <http://www.ec.gc.ca/meteor-weather/default.asp?lang=En&n=9D0277B2-1>
- Environment Canada. (2014). What is Weatheradio? Retrieved from: <http://www.ec.gc.ca/meteor-weather/default.asp?lang=En&n=792F2D20-1>
- Federal Provincial Territorial Senior Officials Responsible for Emergency Management (SOREM) Public Alerting Working Group. (2013). *National Public Alerting System Common Look and Feel Guidance 1.0*. Retrieved from: http://cradpdf.drdc.gc.ca/PDFS/unc129/p538116_A1b.pdf
- Fisheries and Oceans Canada. (2013). *Socio-Economic Impact of Aquaculture in Canada*. Retrieved from: <http://www.dfo-mpo.gc.ca/aquaculture/sector-secteur/socio/index-eng.htm>
- Fisheries and Oceans Canada, Canadian Coast Guard. (2014), *Marine Communications and Traffic Services Regional Office*. Retrieved from: <http://www.ccg-gcc.gc.ca/e0003901>
- Fisheries and Oceans Canada, Canadian Coast Guard. (2014). *Marine Communications and Traffic Services Western Region, Tsunami Procedures Manual*, 10 April, 2014.
- Goldfinger, C., Nelson, C.H. & Johnson, J.E. (2003). Holocene earthquake records from the Cascadia Subduction Zone and northern San Andreas Fault based on precise dating of offshore turbidites. *Annual Review of Earth and Planetary Science*, 31 (2003), pp. 555–557.

- Haida Nation. (2013). *Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve, and Haida Heritage Site*. Retrieved from: http://www.haidanation.ca/Pages/programs/marine_planning/conservation_area.html
- Jacoby, G.C., Bunker, D.E. & Benson, B.E. (1997). Tree-ring evidence for an AD 1700 Cascadia earthquake in Washington and northern Oregon. *Geology*, 25 (11) (1997), pp. 999–1002.
- Leonard, L.J., Rogers, G.C., & Mazzotti, S. (2012). A preliminary tsunami hazard assessment of the Canadian coastline. *Geological Survey of Canada*, Open File 7201, 126 p. doi:10.4095/292067.
- LIRNEAsia. (2007). *Evaluating Last-Mile Hazard Information Dissemination (HazInfo)*. Colombo. Retrieved from: <http://lirneasia.net/projects/2006-07/evaluating-last-mile-hazard-information-dissemination-hazinfo>
- Losey, R. J. (2005) Earthquakes and tsunami as elements of environmental disturbance on the Northwest Coast of North America. *Journal of Anthropological Archaeology*, Volume 24, Issue 2, June 2005, pp. 101–116.
- Marine Harvest Canada. (2014). *Fish Farming Site Positions*. Retrieved from: http://www.marineharvestcanada.com/careers_position_profiles_farm_site.php
- Mosher, D. C. (2009). International year of planet earth 7. Oceans: submarine landslides and consequent tsunamis in Canada. *Geoscience Canada*, 36(4)
- National Defence and the Canadian Armed Forces. (2014). *JTF Pacific*. Retrieved from: <http://www.forces.gc.ca/en/operations-regional-jtf-pacific/jtf-pacific.page>
- National Marine Manufacturers Association Canada. (2012). *The Economic Impact of Recreational Boating in Canada*. Retrieved from: <http://mma.ca>
- National Oceanic and Atmospheric Association, National Weather Service, National Tsunami Warning Center. (2014). *Tsunami Frequently Asked Questions*. Retrieved from: <http://ntwc.arh.noaa.gov/?page=tsunamiFAQ> Accessed: 12 November, 2014.
- National Oceanic and Atmospheric Association, National Weather Service, National Tsunami Warning Center. (2014). *User's Guide for the Tsunami Warning System in the U.S. National Tsunami Warning Center Area-of-Responsibility*. Retrieved from: <http://ntwc.arh.noaa.gov/operations/opsmanual.pdf>
- National Research Council. (2009). Canadian Ocean Technology Sector Map. *Cinmaps: Canada Industry Mapping System*. Almada Ventures Inc. Retrieved from: <http://ocean.cinmaps.ca>. Accessed: 26 October, 2014.
- Natural Resources Canada. (2012). *Earthquake reports for 2012*. Retrieved from: <http://www.earthquakescanada.nrcan.gc.ca/recent/2012/index-eng.php>

- Nelson, A.R. Atwater, B.F., Bobrowsky, P.T., Bradley, L., Clague, J.J., Carver, G.A., Darienzo, M.E., Grant, W.C., Krueger, H.W. Sparks, R., Stafford, T.W. & Stuiver, M. (1995). Radiocarbon evidence for extensive plate-boundary rupture about 300 years ago at the Cascadia subduction zone. *Nature*, 378 (1995), pp. 371–374.
- Parks Canada. (2014). *Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve, and Haida Heritage Site*. Retrieved from: <http://www.pc.gc.ca/eng/pn-np/bc/gwaiihaanas/plan.aspx>
- Peters, R., Jaffe, B., & Gelfenbaum. (2007). Distribution and sedimentary characteristics of tsunami deposits along the Cascadia margin of western North America. *Sedimentary Geology*, Volume 200, Issues 3–4, 15 August 2007, pp. 372–386
- Province of British Columbia, Ministry of Justice. (2012). *FACTSHEET: Criteria for provincial tsunami notification*. Retrieved from: <http://www.newsroom.gov.bc.ca/ministries/justice/factsheets/factsheet-criteria-for-provincial-tsunami-notification.html>
- Province of British Columbia, Ministry of Justice. (2013). *TSUNAMI: Fact Sheet BC Tsunami Notification Zones*. Retrieved from: http://www.embc.gov.bc.ca/em/hazard_preparedness/Description_Tsunami_Notification_Zones_BC.pdf
- Province of British Columbia, Ministry of Justice. (2013). *Tsunami Notification Process Plan*. Retrieved from: http://www.embc.gov.bc.ca/em/hazard_plans/TsunamiNotificationProcessPlan.pdf
- Rabinovich, A. B., Thomson, R. E., Bornhold, B. D., Fine, I. V. & Kulikov, E. A. (2003). Numerical modelling of tsunamis generated by hypothetical landslides in the Strait of Georgia, British Columbia. *Pure and Applied Geophysics*, Volume 160, Issue 7, pp. 1273-1313.
- Rohan, S., Malathy, K.J., Anderson, P., & Zainudeen, A. (2005). *National Early Warning System: A Participatory Concept Paper for the Design of an Effective All-Hazard Public Warning System*. LIRNEasia, Colombo, Sri Lanka. Retrieved from: <http://www.lirneasia.net/projects/completed-projects/national-early-warning-system/>
- Royal Canadian Mounted Police. (2014). *About RCMP in B.C.* Retrieved from: <http://bc.rcmp-grc.gc.ca/ViewPage.action?siteNodeId=24&languageId=1&contentId=-1>
- Royal Canadian Navy. (2014). *Maritime Forces Pacific*. Retrieved from: <http://www.navy-marine.forces.gc.ca/en/about/structure-marpac-home.page>
- Satake, K., Shimazaki, K., Tsuji, Y., & Ueda, K. (1996). Time and size of a giant earthquake in Cascadia inferred from Japanese tsunami records of January 1700. *Nature*, 379 (1996), pp. 246–251

- Sebert, L.M. & Munro, M. R. (1972). Dimensions and Areas of Maps of the National Topographic System of Canada. *Technical Report 72-1*. Ottawa: Department of Energy, Mines and Resources, Surveys and Mapping Branch.
- Statistics Canada. (2011). *Geographic Attribute File, 2011 Census*. Statistics Canada Catalogue no. 92-151-X.
- Statistics Canada. (2011). *Dissemination Area Boundary File, 2011 Census*. Statistics Canada Catalogue no. 92-169-X.
- Statistics Canada (2013) *Residential Telephone Service Survey: Percentage of households by type of telephone service, by province*. Retrieved from: <http://www.statcan.gc.ca/daily-quotidien/140623/t140623a001-eng.htm>
- Stephenson, F.E. and Rabinovich, A.B. (2009). Tsunamis on the Pacific Coast of Canada recorded in 1994–2007. *Pure and Applied Geophysics*. 166(1-2):177-210.
- Wigen, S.O. (1983). Historical study of tsunamis at Tofino, Canada. In, Iida, K., Iwasaki, T. (Eds.), *Tsunamis: Their Science and Engineering*. Terra Scientific Publishing Co, Tokyo, pp. 105-119.
- Yamaguchi, D.K., Atwater, B.F., Bunker, D.E., Benson, B.E. & Reid, M.S. (1997). Tree-ring dating the 1700 Cascadia Earthquake. *Nature*, 389 (1997), p. 922.

APPENDICES

Appendix A GIS Data Sources

List of Detailed GIS Data by Source

Host: DataBC	
Name	Description – Metadata directly from DataBC
BC Health Care Facilities Hospital	Health care and facilities
Coastal BC marine and fresh water Kayaking routes	The location of coastal British Columbia marine and freshwater kayaking routes
Coastal Rec and Pleasure Craft routes	The locations of coastal British Columbia recreational and pleasure craft cruising routes
Coastal BC campsites	The locations of coastal British Columbia overnight campsites and campgrounds
Coastal BC marinas	The location of coastal British Columbia marinas
Coastal BC Diving Sites	The locations of coastal British Columbia scuba diving sites
Coastal BC Marine Kayaking destinations	The location of coastal British Columbia marine kayaking point features, such as destinations and overnight campsites
Coastal BC marine industrial sites	The locations of coastal British Columbia industrial sites
Fish Processor Tenures	Information regarding processor facilities in British Columbia including location, company name and license tag information. British Columbia has been collecting coastal resource data in a systematic and synoptic manner since 1979. Resource information is collected using peer-reviewed provincial Resource Information Standards Committee which include standards for data management and analysis
Post Secondary education facilities	This dataset is comprised of Post-secondary Education Facilities offering education programs in British Columbia.
Recreational Points	This data set contains a small sub-set of the WHSE_FOREST_TENURE.FTEN_RECREATION_POLY_SVW layer, in point form, with minimal attribution for the purpose of displaying a select set of high value recreation sites. For access to complete listing of Forest Recreation sites please use WHSE_FOREST_TENURE.FTEN_RECREATION_POLY_SVW
Recreational Polygons	The spatial representation of a recreation feature. This can be either a recreation reserve, recreation site, or an interpretative forest
Recreational Feature Inventory	The RFI identifies areas of land and water encircling a recreation feature or combination of features that support, or have the potential to support, one or more recreation activities. These areas are rated for their significance or importance to recreation and for their sensitivity to alteration

Mineral, placer and coal tenure	Holds data for mineral, placer claims and leases, as well as, coal license applications, licenses and leases within the Province of British Columbia. This is the spatial view utilized by Mineral Titles Online tenure on the mineral, placer and coal viewers, respectively. It contains additional attributes related to each tenure
Guide outfitter areas	Areas defined by certificate under the British Columbia Wildlife Act to guide outfitters, for the purpose of guiding residents, non-residents or non resident alien hunters to hunt big game species.
Forest Tenure Harvesting Authority	This is a spatial layer that reflects operational activities for harvesting authorities
Recreational Lines	This is a spatial layer showing Ministry of Forests Recreation Lines. These are the linear spatial representation for features such as recreation trails
EMBC boundaries	Jurisdictional boundaries for Emergency Management BC (EMBC). This datasets represents the regional operational boundaries for the former Provincial Emergency Program (PEP).
CHS High water mark	An instantiated spatial layer that has the same structure and data as the spatial view SHZN CHS HIGH WATER MARK SVW except that it is refreshed from the spatial view using FME on a daily or as required basis
Coastal BC Bathymetry	Coastal British Columbia bathymetry
BC Geographical Names	Official names associated with geographical features
Salmon Hatcheries	A polygon file showing the location of Salmon hatcheries in the province that includes both salt water and inland locations
Shellfish Aquaculture Plan Unit Boundaries	The boundaries of a unit of a Shellfish Aquaculture Plan within a Coastal Plan
Saltwater Finfish	The distribution of saltwater finfish farm and hatchery sites in British Columbia. Information includes company name and license information. British Columbia has been collecting coastal resource data in a systematic and synoptic manner since 1979. Resource information is collected using peer-reviewed provincial Resource Information Standards Committee which include standards for data management and analysis
Shore unit Polygons	The shore unit polys are part of the Physical Shore-Zone Mapping System. It is a scheme designed for the classification of the materials, forms and processes that occur or operate along the coast of British Columbia. It has been specifically developed to provide an inventory of the physical character of the shore-zone and to show their distribution, extent and location

Tsunami Notification Zones	The Tsunami Notification Zone classifications are used to differentiate the notification areas along the coast of BC. These Zones are used to add BC specific information to tsunami alerts issued from West Coast Alaska Tsunami Warning Center. BC tsunami alerts are disseminated via the Provincial Emergency Notification System (PENS) which encompasses automated phone calls to key stakeholders, faxes, email distribution and updates on the emergencyinfo.bc.ca website as well as Environment Canada's WeatherOffice, WeatherRadio and MediaWeb services. Each zone has a corresponding level of general risk associated with it, based on a suite of potential tsunami scenarios, which allows emergency managers to estimate the level of risk in each zone.
Municipalities	A data layer containing all municipalities in BC that is a subset of the entire Tantalus Administrative Areas dataset
Landuse	This layer represents Land use polygons as determined by a combination of analytic techniques, mostly using Landsat 5 image mosaics . BTM 1 was done on a federal satellite image base that was only accurate to about 250m. The images were geo-corrected, not ortho-corrected, so there is distortion in areas of high relief. This is not a multipart feature
Coastal BC Moorages	The locations of coastal British Columbia moorages
Coastal BC airports	Location of coastal BC airports, helicopter landing pads and float plane facilities
Coastal BC anchorages	The location of safe anchorages in coastal British Columbia
Coastal BC boat launches	The locations of coastal British Columbia boat launches
Coastal BC Ferry Terminals	The locations of coastal British Columbia ferry terminals
Cruise Ship Routes	Routes that cruise ships travel off the coast of BC
MOT Rest Areas	A Rest Area is a developed roadside area for the use of the traveling public which must contain a washroom, and often has litter receptacles, picnic tables and other facilities. It is a Point feature
BC Police Jurisdiction Boundaries	Geographical representation of RCMP and Municipal Police jurisdiction boundaries in British Columbia
BC Schools - Locations	Current and historical contact and location information for BC schools to 2013/2014
Parks and protected areas - regional boundaries	The spatial representation for Parks and Protected Areas Administrative Regions. A Parks and Protected Area Administrative Region is an administrative area established by the Ministry and is an administrative area which is used to manage regional activities.
Indian Reserves - Administrative boundaries	Provide the administrative boundaries (extent) of Canada Lands which includes Indian Reserves. Administrative boundaries were compiled from Legal Surveys Division's cadastral datasets and survey records archived in the Canada Lands Survey Records.
Provincial Offshore Oil and Gas Tenures	Location of Provincial offshore oil and gas tenures

Host: Hectares BC	
Name	Description
BCTS Operating Areas	The main operational offices for BC Timber Sales (BCTS) are Timber Sales Offices (TSOs), which provide administration, management and planning for the respective Business Areas (BA). Each business area has field teams, which are comprised of a group of field-oriented staff reporting to a TSO. Field teams are located with TSOs and in other communities.
Elevation	This layer includes the elevation data for BC.
Regional Districts	A data layer containing all regional districts in BC that is a subset of the entire Tantalus Administrative Areas dataset. One of the components of the spatial fabric that includes other administrative areas, land parcels and reserves over Crown land.
Baseline Thematic Mapping: Land use/cover	A merged dataset incorporating both the BTM version 1 and 2 datasets where version 2 was given priority over version 1. BTM version 2 is an updated dataset of the BTM version 1 data - not a complete provincial dataset; only contains sections of the provincial dataset that have been updated to BTM version 2. BTM version 1 is present land use and generalized ground cover mapping derived primarily through the analytical interpretation of Landsat 5 imagery and aerial photography. MOF age class data, 1:250000 topographic base mapping and biogeoclimatic data were also used in the compilation of this dataset. Present land use and generalized ground cover mapping derived primarily through the analytical interpretation of Landsat 5 imagery and aerial photography.
Land Cover	An ecosystem physiognomic classification defined using the following classifications: 1. Human dominated from BTM (Version 1 and 2 combined), (urban, agri, rec, urban/agri mix, mining). 2: Wetlands from TRIM. 3: Glaciers from TRIM. 4. Grasslands from TRIM. 5: Alpine from BTM. 6: Water (salt/fresh) - (lakes, double line rivers, reservoirs, oceans). 7: Forest- whatever is left. Any hectare that falls outside of the BiM grid or is classified by the BTM as "outside BC" is flagged as NULL, a no-value hectare
Parks and Protected Areas	The Parks and Protected Areas dataset contains Provincial Protected areas boundaries for all protected areas designated by OIC or legislation. National parks areas are provided by the Canadian Lands Administrative Boundaries (CLAB) dataset. The provincial, regional, and national datasets were merged so each Hectare in BC was classified as a single park. In the case where the source datasets overlapped Provincial Parks took precedence followed by National then Regional parks.
First nation land reserve	This layer shows the lands that are owned by the First Nation as a result of the treaty and over which the First Nation has governance as described in the treaty. These boundaries should be treated as cartographic representations only. The official versions of these boundaries are contained within the treaty documents

Host: Geobase	
Name	Description
Railway network	The National Railway Network (NRWN), version 1.0 focuses on providing a quality geometric description and a set of basic attributes of Canadian rail phenomena. Geographic Data Files (GDF) V4 from ISO/TC 204 were used as a guideline for this model.
Road networks	The NRN product is distributed in the form of thirteen provincial or territorial datasets and consists of two linear entities (Road Segment and Ferry Connection Segment) and three punctual entities (Junction, Blocked Passage, Toll Point) with which is associated a series of descriptive attributes such as, among others: First House Number, Last House Number, Street Name Body, Place Name, Functional Road Class, Pavement Status, Number Of Lanes, Structure Type, Route Number, Route Name, Exit Number.

Census		
Name	Description	Source
BC DA polygons	BC Dissemination Area boundaries polygons	Statistics Canada
BC 2011 Total Population	Table with the total population count. Joined with DA polygon with common field	Statistics Canada
BC Municipalities polygon	BC Municipality boundaries	Statistics Canada
BC Regional Districs polygon	BC Regional District boundaries	Statistics Canada
LandScan 2011 census	A raster depicting population density based on four attributes. See written section for details.	Department of Energy's Oak Ridge National Laboratory

Host: Other		
Name	Description	Source
Tectonic Plates	World plate boundaries	USGS
Ocean Paddling	Coverage of kayaking sites	Personal agreement
Cellular Coverage	Combination of Telus and Rogers cellular coverage	Personal agreement
Canadian Coast Guard	This data shows the coverage (full and marginal) for NAVTEX and VHF radio for BC	Personal agreement
Environment Canada Weather Radio	Coverage (full and marginal) for EC Weather Radio. In kml with png format	Personal agreement
Pacific DART and tide stations	Pacific coverage of DART and tide stations	Personal agreement
Broadcasting	TV, AM and PM station and coverage data	Industry Canada
BC Ambulance Services Stations	BC coverage of ambulance stations	Personal agreement
Police, Fire and Ambulance Stations	BC coverage of police, fire and ambulance stations	Personal agreement
MSAT	Coastal Communities with satellite coverage	Personal agreement
MOTI SPLAT data	Ministry of Highways VHF radio coverage	Derived from Industry Canada Spectrum Direct
CLC	Canadian Location Code polygons	Personal agreement

PTWC	3 tsunami events generated from NOAA	Personal agreement
Twitter	@NWS_NTWC and @EmergencyInfoBC followers	Derived
Coastal fixed locations	All coastal fixed locations	Derived
Surveyed local authorities	Fixed location surveyed	Survey
Network BC Broadband coverage	ADSL, Cable and Fixed Wireless coverage	Personal agreement
Coastal Population Census	Statistics Canada 2011 census data was spatially joined with the TNZ layer buffered at 1 km	Combination
Local Authority Notification Methods	On-line survey	Personal agreement
Light Gray Canvas Map	Gray world basemap with references	ESRI
Ocean Basemap	World ocean basemap with references	ESRI

Projections and Geographic Coordinate Systems used:

BC Albers

Plate Carrée - Prime Meridian altered to -180

WGS 1984

Software used:

ArcGIS 10.2.1

ESRI 2014. ArcGIS Desktop: Release 10.2.1. Redlands, CA: Environmental Systems Research Institute.

QGIS 2.6

Quantum GIS Development Team (2014). Quantum GIS Geographic Information System. Open Source Geospatial Foundation Project. <http://qgis.osgeo.org>

Databases and websites with spatial data download:

DataBC

Government of British Columbia. *DataBC – Data Catalogue*. (2014). Data retrieved from: <http://catalogue.data.gov.bc.ca/dataset>

Hectares BC

Hectares BC. *Raster Data*. Data retrieved from: <http://www.hectaresbc.org>. Accessed: 16 July, 2014.

Geobase

Canadian Council of Geomatics. *Geobase*. Data retrieved from: <http://www.geobase.ca>. Accessed: 16 July, 2014.

Statistics Canada – Census

Geographic Attribute File, 2011 Census . Statistics Canada Catalogue no. 92-151-X.

Dissemination Area Boundary File, 2011 Census. Statistics Canada Catalogue no. 92-169-X.

Boundary Files, 2011 Census. Statistics Canada Catalogue no. 92-160-X.

LandScan

East View Geospatial LandScan Global Archive. *LandScan 2011 Web Application*. Accessed: 27 November, 2014.

Industry Canada

Broadcasting contours – MapInfo. Data retrieved from: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/h_sf09484.html

Spectrum Direct - radio licence geocoded data. Data retrieved from:
<http://www.ic.gc.ca/eic/site/sd-sd.nsf/eng/home>

USGS

U.S Geological Survey. *Tectonic Plate Boundaries*. (2014). Data retrieved from:
<http://earthquake.usgs.gov/learn/kml.php>

Twitter

NWS Tsunami Alerts. @ NWS_NTWC follower data retrieved from:
https://twitter.com/NWS_NTWC

Emergency Info BC. @EmergencyInfoBC follower data retrieved from:
<https://twitter.com/EmergencyInfoBC>

Basemaps provided through ESRI's ArcGIS

ESRI, 2014. ESRI, DeLorme, HERE, MapmyIndia

ESRI, 2014. ESRI, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors

Appendix B NTWC Tsunami Message Samples

Example of NTWC Tsunami Warning Message

NWS-WCATWC Tsunami Warning

WEPA41 PAAQ 280307
TSUWCA

BULLETIN
TSUNAMI MESSAGE NUMBER 1
NWS WEST COAST/ALASKA TSUNAMI WARNING CENTER PALMER AK
807 PM PDT SAT OCT 27 2012

...A TSUNAMI WARNING IS NOW IN EFFECT WHICH INCLUDES THE
COASTAL AREAS OF BRITISH COLUMBIA AND ALASKA FROM THE NORTH
TIP OF VANCOUVER ISLAND BRITISH COLUMBIA TO CAPE DECISION
ALASKA/LOCATED 85 MILES SE OF SITKA/...

...THIS MESSAGE IS INFORMATION ONLY FOR COASTAL AREAS OF
CALIFORNIA - OREGON - WASHINGTON AND BRITISH COLUMBIA FROM
THE CALIFORNIA-MEXICO BORDER TO THE NORTH TIP OF VANCOUVER
ISLAND BRITISH COLUMBIA...

...THIS MESSAGE IS INFORMATION ONLY FOR COASTAL AREAS OF
ALASKA FROM CAPE DECISION ALASKA/LOCATED 85 MILES SE OF
SITKA/ TO ATTU ALASKA...

RECOMMENDED ACTIONS

PEOPLE IN LOW-LYING COASTAL AREAS SHOULD BE ALERT TO
INSTRUCTIONS FROM THEIR LOCAL EMERGENCY OFFICIALS. EVACUATIONS
ARE ONLY ORDERED BY EMERGENCY RESPONSE AGENCIES.
- IF IN A TSUNAMI WARNING COASTAL AREA MOVE INLAND TO HIGHER
GROUND.

PRELIMINARY EARTHQUAKE PARAMETERS

MAGNITUDE - 7.1
TIME - 1904 AKDT OCT 27 2012
2004 PDT OCT 27 2012
0304 UTC OCT 28 2012
LOCATION - 52.9 NORTH 131.9 WEST
25 MILES/40 KM S OF SANDSPIT BRITISH COLUMBIA
390 MILES/628 KM SE OF JUNEAU ALASKA
DEPTH - 12 MILES/19 KM

TSUNAMI WARNINGS MEAN THAT A TSUNAMI WITH SIGNIFICANT WIDESPREAD
INUNDATION IS IMMINENT... EXPECTED OR OCCURRING. WARNINGS INDICATE
THAT WIDESPREAD DANGEROUS COASTAL FLOODING ACCOMPANIED BY POWERFUL
CURRENTS IS POSSIBLE AND MAY CONTINUE FOR SEVERAL HOURS AFTER THE
INITIAL WAVE ARRIVAL.

PACIFIC COASTAL REGIONS OUTSIDE CALIFORNIA/ OREGON/ WASHINGTON/
BRITISH COLUMBIA AND ALASKA SHOULD REFER TO THE PACIFIC TSUNAMI
WARNING CENTER MESSAGES FOR INFORMATION ON THIS EVENT AT
PTWC.WEATHER.GOV.

THIS MESSAGE WILL BE UPDATED IN 30 MINUTES OR SOONER IF THE SITUATION WARRANTS. THE TSUNAMI MESSAGE WILL REMAIN IN EFFECT UNTIL FURTHER NOTICE. REFER TO THE INTERNET SITE WCATWC.ARH.NOAA.GOV FOR MORE INFORMATION.

BCZ220-210-922-912-921-911-110-AKZ026>029-280407-
/O.NEW.PAAQ.TS.W.0024.121028T0307Z-000000T0000Z/
COASTAL AREAS BETWEEN AND INCLUDING THE NORTH TIP OF
VANCOUVER ISLAND BRITISH COLUMBIA TO CAPE DECISION
ALASKA/LOCATED 85 MILES SE OF SITKA/
807 PM PDT SAT OCT 27 2012

...A TSUNAMI WARNING IS NOW IN EFFECT WHICH INCLUDES THE
COASTAL AREAS OF BRITISH COLUMBIA AND ALASKA FROM THE NORTH
TIP OF VANCOUVER ISLAND BRITISH COLUMBIA TO CAPE DECISION
ALASKA/LOCATED 85 MILES SE OF SITKA/...

PEOPLE IN TSUNAMI WARNING COASTAL AREAS SHOULD MOVE INLAND TO
HIGHER GROUND.

TSUNAMI WARNINGS MEAN THAT A TSUNAMI WITH SIGNIFICANT WIDESPREAD
INUNDATION IS IMMINENT... EXPECTED OR OCCURRING. TSUNAMIS ARE A
SERIES OF WAVES POTENTIALLY DANGEROUS SEVERAL HOURS AFTER INITIAL
ARRIVAL TIME.

ESTIMATED TIMES OF INITIAL WAVE ARRIVAL FOR SELECTED
SITES IN THE WARNING ARE PROVIDED BELOW.

LANGARA	2116	PDT OCT 27	CRAIG	2110	AKDT OCT 27
---------	------	------------	-------	------	-------------

FOR ARRIVAL TIMES AT ADDITIONAL LOCATIONS SEE
WCATWC.ARH.NOAA.GOV

\$\$

Example of NTWC Tsunami Warning/Advisory Message

NWS-WCATWC Tsunami Warning/Advisory

WEPA41 PAAQ 280502

TSUWCA

BULLETIN

TSUNAMI MESSAGE NUMBER 5

NWS WEST COAST/ALASKA TSUNAMI WARNING CENTER PALMER AK

1002 PM PDT SAT OCT 27 2012

THE WARNING ZONES REMAIN THE SAME IN THIS MESSAGE.
AN ADVISORY HAS BEEN ISSUED FOR THE REST OF BRITISH COLUMBIA-
SOUTH OF THE NORTH TIP OF VANCOUVER ISLAND.

...THE TSUNAMI WARNING CONTINUES IN EFFECT FOR THE COASTAL
AREAS OF BRITISH COLUMBIA AND ALASKA FROM THE NORTH TIP OF
VANCOUVER ISLAND BRITISH COLUMBIA TO CAPE DECISION
ALASKA/LOCATED 85 MILES SE OF SITKA/...

...A TSUNAMI ADVISORY IS NOW IN EFFECT WHICH INCLUDES THE
COASTAL AREAS OF BRITISH COLUMBIA FROM THE
WASHINGTON-BRITISH COLUMBIA BORDER TO THE NORTH TIP OF
VANCOUVER ISLAND BRITISH COLUMBIA...

...THIS MESSAGE IS INFORMATION ONLY FOR COASTAL AREAS OF
CALIFORNIA - OREGON AND WASHINGTON FROM THE
CALIFORNIA-MEXICO BORDER TO THE WASHINGTON-BRITISH COLUMBIA
BORDER...

...THIS MESSAGE IS INFORMATION ONLY FOR COASTAL AREAS OF
ALASKA FROM CAPE DECISION ALASKA/LOCATED 85 MILES SE OF
SITKA/ TO ATTU ALASKA...

RECOMMENDED ACTIONS

A TSUNAMI HAS BEEN GENERATED WHICH IS EXPECTED TO CAUSE DAMAGE
TO THE WARNING AND/OR ADVISORY REGIONS LISTED IN THE HEADLINE.
PEOPLE IN LOW-LYING COASTAL AREAS SHOULD BE ALERT TO
INSTRUCTIONS FROM THEIR LOCAL EMERGENCY OFFICIALS. EVACUATIONS
ARE ONLY ORDERED BY EMERGENCY RESPONSE AGENCIES.

- IF IN A TSUNAMI WARNING COASTAL AREA MOVE INLAND TO
HIGHER GROUND.
- IF IN A TSUNAMI ADVISORY COASTAL AREA MOVE OUT OF
THE WATER... OFF THE BEACH AND OUT OF HARBORS AND MARINAS.

MEASUREMENTS OR REPORTS OF TSUNAMI ACTIVITY

LOCATION	LAT	LON	TIME	AMPL
DART46419PT NW SEATTLE	48.8N	129.6W	0345UTC	00.2FT/00.07M
CRAIG AK	55.5N	133.1W	0425UTC	00.3FT/00.09M
PORT ALEXANDER AK	56.2N	134.6W	0410UTC	00.3FT/00.08M

WINTER HARBOUR BC 50.7N 128.3W 0402UTC 00.5FT/00.15M

TIME - TIME OF MEASUREMENT

AMPL - TSUNAMI AMPLITUDES ARE MEASURED RELATIVE TO NORMAL SEA LEVEL.
IT IS ...NOT... CREST-TO-TROUGH WAVE HEIGHT.
VALUES ARE GIVEN IN BOTH METERS/M/ AND FEET/FT/.

PRELIMINARY EARTHQUAKE PARAMETERS

MAGNITUDE - 7.7

TIME - 1904 AKDT OCT 27 2012

2004 PDT OCT 27 2012

0304 UTC OCT 28 2012

LOCATION - 52.9 NORTH 131.9 WEST

25 MILES/40 KM S OF SANDSPIT BRITISH COLUMBIA

385 MILES/620 KM SE OF JUNEAU ALASKA

DEPTH - 12 MILES/19 KM

TSUNAMI WARNINGS MEAN THAT A TSUNAMI WITH SIGNIFICANT WIDESPREAD INUNDATION IS IMMINENT... EXPECTED OR OCCURRING. WARNINGS INDICATE THAT WIDESPREAD DANGEROUS COASTAL FLOODING ACCOMPANIED BY POWERFUL CURRENTS IS POSSIBLE AND MAY CONTINUE FOR SEVERAL HOURS AFTER THE INITIAL WAVE ARRIVAL.

TSUNAMI ADVISORIES MEAN THAT A TSUNAMI CAPABLE OF PRODUCING STRONG CURRENTS OR WAVES DANGEROUS TO PEOPLE IN OR VERY NEAR THE WATER IS EXPECTED. SIGNIFICANT WIDESPREAD INUNDATION IS NOT EXPECTED FOR AREAS UNDER AN ADVISORY. CURRENTS MAY BE HAZARDOUS TO SWIMMERS... BOATS... AND COASTAL STRUCTURES AND MAY CONTINUE FOR SEVERAL HOURS AFTER THE INITIAL WAVE ARRIVAL.

PACIFIC COASTAL REGIONS OUTSIDE CALIFORNIA/ OREGON/ WASHINGTON/ BRITISH COLUMBIA AND ALASKA SHOULD REFER TO THE PACIFIC TSUNAMI WARNING CENTER MESSAGES FOR INFORMATION ON THIS EVENT AT PTWC.WEATHER.GOV.

THIS MESSAGE WILL BE UPDATED IN 30 MINUTES OR SOONER IF THE SITUATION WARRANTS. THE TSUNAMI MESSAGE WILL REMAIN IN EFFECT UNTIL FURTHER NOTICE. REFER TO THE INTERNET SITE WCATWC.ARH.NOAA.GOV FOR MORE INFORMATION.

BCZ220-210-922-912-921-911-110-AKZ026>029-280602-
/O.CON.PAAQ.TS.W.0024.000000T0000Z-000000T0000Z/
COASTAL AREAS BETWEEN AND INCLUDING THE NORTH TIP OF
VANCOUVER ISLAND BRITISH COLUMBIA TO CAPE DECISION
ALASKA/LOCATED 85 MILES SE OF SITKA/
1002 PM PDT SAT OCT 27 2012

...THE TSUNAMI WARNING CONTINUES IN EFFECT FOR THE COASTAL
AREAS OF BRITISH COLUMBIA AND ALASKA FROM THE NORTH TIP OF
VANCOUVER ISLAND BRITISH COLUMBIA TO CAPE DECISION
ALASKA/LOCATED 85 MILES SE OF SITKA/...

PEOPLE IN TSUNAMI WARNING COASTAL AREAS SHOULD MOVE INLAND TO
HIGHER GROUND.

TSUNAMI WARNINGS MEAN THAT A TSUNAMI WITH SIGNIFICANT WIDESPREAD INUNDATION IS IMMINENT... EXPECTED OR OCCURRING. TSUNAMIS ARE A SERIES OF WAVES POTENTIALLY DANGEROUS SEVERAL HOURS AFTER INITIAL ARRIVAL TIME.

ESTIMATED TIMES OF INITIAL WAVE ARRIVAL FOR SELECTED SITES IN THE WARNING ARE PROVIDED BELOW.

LANGARA 2116 PDT OCT 27 CRAIG 2110 AKDT OCT 27

FOR ARRIVAL TIMES AT ADDITIONAL LOCATIONS SEE
WCATWC.ARH.NOAA.GOV

\$\$

BCZ130-230-250-260-280-160-142-141-150-121-122-280602-
/O.NEW.PAAQ.TS.Y.0024.121028T0502Z-000000T0000Z/
COASTAL AREAS BETWEEN AND INCLUDING THE WASHINGTON-BRITISH
COLUMBIA BORDER TO THE NORTH TIP OF VANCOUVER ISLAND
BRITISH COLUMBIA
1002 PM PDT SAT OCT 27 2012

...A TSUNAMI ADVISORY IS NOW IN EFFECT WHICH INCLUDES THE
COASTAL AREAS OF BRITISH COLUMBIA FROM THE
WASHINGTON-BRITISH COLUMBIA BORDER TO THE NORTH TIP OF
VANCOUVER ISLAND BRITISH COLUMBIA...

PEOPLE IN TSUNAMI ADVISORY COASTAL AREAS SHOULD MOVE OUT OF
THE WATER... OFF THE BEACH AND OUT OF HARBORS AND MARINAS.

TSUNAMI ADVISORIES MEAN THAT A TSUNAMI CAPABLE OF PRODUCING
STRONG CURRENTS OR WAVES DANGEROUS TO PEOPLE IN OR VERY NEAR
WATER IS IMMINENT... EXPECTED OR OCCURRING. SIGNIFICANT WIDESPREAD
INUNDATION IS NOT EXPECTED FOR AREAS IN AN ADVISORY. TSUNAMIS ARE
A SERIES OF WAVES POTENTIALLY DANGEROUS SEVERAL HOURS AFTER INITIAL
ARRIVAL TIME. ESTIMATED TIMES OF INITIAL WAVE ARRIVAL FOR SELECTED
SITES IN THE ADVISORY ARE PROVIDED BELOW.

TOFINO 2209 PDT OCT 27

FOR ARRIVAL TIMES AT ADDITIONAL LOCATIONS SEE
WCATWC.ARH.NOAA.GOV

\$\$

Appendix C On-line Community Tsunami Notification Survey

B.C. West Coast Community Tsunami Notification Survey

Purpose of Survey

This survey should only take a few minutes to complete and the collected information will be used to help construct a comprehensive overview of: 1) the means by which B.C. Coastal communities receive tsunami event notifications from outside agencies and 2) the means by which their local authorities communicate such information to their populations at risk. The survey is being undertaken by Simon Fraser University in support of EMBC.

Project Background

This survey is part of a larger project aimed at strengthening end-to-end tsunami notification procedures along Canada's West Coast. The project is funded by the Canadian Safety and Security Program managed through Defence Research and Development Canada (DRDC) Centre for Security Science (CSS). Emergency Management British Columbia is serving as the project champion in partnership with Simon Fraser University. Project contacts are: SFU - Peter Anderson (anderson@sfu.ca) and EMBC - Ralph Mohrmann (ralph.mohrmann@gov.bc.ca).

Q1 . Participation in this survey is completely voluntary. The only personal information that will be stored temporarily is your email address and only if you have chosen to provide it with your comments. Do you wish to continue?

☐ Yes

☐ No

Q2 . Please enter the name of your community.

Community Name :

External Tsunami Notification Sources

This next question asks you to indicate what means are used within your community to receive tsunami notifications sent by externally authorized agencies such as the National Tsunami Warning Center (Alaska) and Emergency Management British Columbia.

Q3 . Please select all that apply.

- ☐ EMBC PREOC Email
- ☐ EMBC ECC Email
- ☐ EMBC PENS - Telephone
- ☐ EMBC PENS - Fax
- ☐ EMBC PENS - Email
- ☐ Regional District - Telephone
- ☐ Regional District - Email
- ☐ Regional District - Other
- ☐ RCMP
- ☐ Fire Department Dispatch
- ☐ Canadian Coast Guard Radio Ch16
- ☐ BC Ambulance Service
- ☐ NAVCAN Aeronautical Radio
- ☐ Environment Canada ECAAlert email

- ☐ Environment Canada Weatheradio
- ☐ Twitter - @emergencyinfobc
- ☐ Twitter @NWS_NTWC
- ☐ Twitter @CANADAquakes
- ☐ Twitter @USGSted
- ☐ SMS @emergencyinfobc
- ☐ SMS @NWS_NTWC
- ☐ SMS @CANADAquakes
- ☐ SMS @USGSted
- ☐ RSS <http://www.emergencyinfobc.gov.bc.ca/atom.xml>
- ☐ RSS <http://wcatwc.arh.noaa.gov/events/xml/PAAQAtom.xml>
- ☐ WWW <http://www.emergencyinfobc.gov.bc.ca>
- ☐ WWW <http://wcatwc.arh.noaa.gov>
- ☐ Email tsunami-information-ioc@lists.unesco.org
- ☐ Other

Q4 . If you selected "Other", please provide additional details in the comment box below.

Q5 . Please rank the preferred methods for receiving external notifications (1 being highest priority) Only one rank for each method.

	1	2	3	4	5	6	7	8	9	10
Telephone voice - landline and cell :	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fax :	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Email :	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
SMS - text message :	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
CCG Radio - Channel 16 :	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Environment Canada Weatheradio :	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Twitter :	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
World Wide Web sites :	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Facebook :	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other :

<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------

Q6 . If you selected "Other", please provide additional details in the comment box below.

--

Local Tsunami Notification Methods

The next question asks you to identify the means that your local authority uses to notify its populations.

Q7 . Please select all that apply.

- ☐ Siren
- ☐ Local telephone - landline and cell
- ☐ Automated mass notification system
- ☐ Local broadcast radio
- ☐ Local broadcast television
- ☐ Local cable television community channel
- ☐ Pager
- ☐ Marine radio
- ☐ Mobile notification (e.g., vehicle or boat with PA system)
- ☐ Door-to-door
- ☐ Agency two way radio
- ☐ Amateur radio
- ☐ FRS/GMRS two-way radio
- ☐ Email
- ☐ Twitter
- ☐ Facebook
- ☐ WWW
- ☐ Other

Q8 . If you selected "Other", please provide additional details in the comment box below.

--

Local Tsunami Notification Capabilities

The next question asks about your community notification plans and capabilities.

Q9 . Please select all that apply. My community has:

- ☐ an emergency communications plan
- ☐ a tsunami action plan
- ☐ a means to receive external tsunami notifications and carry out necessary actions on a 24 hour per day basis
- ☐ a means to disseminate local tsunami messages on a 24 hour per day basis
- ☐ a tsunami education/awareness program

Q10 . Please feel free to provide any additional comments concerning local tsunami notification processes or information you would like to receive.

--

Appendix D Community and Regional District Local Authority Survey Participants

Community and Regional District Local Tsunami Notification Survey Participants

Alberni-Clayquot Regional District
Alert Bay
Bamfield
Belcarra
Bella Coola
Bowen Island
Burnaby
Capital Regional District
Central Saanich
Coal Harbour
Coquitlam
Cortes Island
Cowichan Tribes
Da'naxda'xw Awaetlala Nation
Delta
Ehattesaht/Chinehkint First Nation
Gitga'at Nation
Gitlaxt'aamiks
Gitxaala Nation
Gold River
Gwa'sala-'Nakwaxda'xw Nations
Heiltsuk Nation
Holberg
Hyde Creek
Jordan River
Juan de Fuca
Ka:'yu:'k't'h'/Che:k:tles7et'h' First Nations
Kitasoo Indian Band
Kitimat
Kwantlen First Nation
Kwikwasut'inuxw Haxwa'mis First Nation
Langley
Mahatta River
Masset
Matsqui First Nation
Mission
Mount Waddington Regional District
Mowachaht/Muchalaht First Nation
Namgis First Nation
Nanaimo
North Vancouver City (through North Shore Emergency Organization)
North Vancouver District (through North Shore Emergency Organization)
Nuchatlaht First Nation
Oak Bay

Pauquachin First Nation
Penelakut Tribe
Pitt Meadows
Port Alice
Port Clements
Port Coquitlam
Port Hardy
Port McNeil
Port Moody
Port Renfrew
Quatsino First Nation
Richmond
Saturna Island
Sayward
Shirley
Skeena-Queen Charlotte Regional District
Sointula
Songhees First Nation
Sooke
Squamish District Municipality
Squamish Nation
Squamish-Lillooet Regional District
Strathcona Regional District
Sts'ailes
Sullivan Bay
Sunshine Coast Regional District
Tahsis
Tofino
Tsartlip First Nation
Tsawwassen First Nation
Tseil-Waututh Nation
Tseshaht First Nation
Tseycum First Nation
Vancouver
Victoria
We Wai Kai Nation
West Vancouver (through North Shore Emergency Organization)
White Rock
Zeballos