

Canada – United States Border Radio Coverage

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IMPORTANT INFORMATIVE STATEMENTS

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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

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1.	Acknowledgements	1
2.	Important Notes	3
3.	Executive Summary	4
1	Introduction	5
3	Conclusion.....	17
4	Follow-on Work	18
Annex A	Document Survey and Context Definition	20
Annex B	Define Radio Coverage Area of Interest.....	43
Annex C	Manage the Scope of the Coverage Analysis	55
Annex D	Define Operational Availability Metrics Analysis	62
Annex E	Range Calculation Error Budget Analysis.....	74
Annex F	Propagation Analysis	91
Annex G	Coverage Visualization Maps.....	110
Annex H	Assess Severity of Coverage Gaps	121

Acknowledgements

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The first analogy that came to my mind is that the Canada-United States border area is a 9000km long ice hockey rink. Most Canadians live on that frontier, it is our highway and we thrive on the emotions it creates in our everyday life.

The border is composed of fences and lines and uses rules enforced by referees. Every face-off is a significant event. If you get hurt on that rink, you will be quickly get cared for by the emergency personnel. If the game gets too hot, there will be security forces to respond. Overall, it is a fun and safe place to play at.

Thank you to:

The league managers, Jack Pagotto from the Center for Security Science and to Claude Bélisle from the Communications Research Center (CRC) for the funding, for setting-up the teams and supporting the entire project from start to finish.

The CRC's technical "all star team" directly working on the project: Philippe-André Bonneau, Daniel Boudreau, Joe Fournier, Eric Lafond and David Rogers.

Chantal Davis from Industry Canada, the referee and analyst who provided guidance and technical support for radio licensing information at the start of the project.

Roger Coudé, leader on the scoreboard, who allowed the free use of his software, Radio Mobile for Windows, and for providing the high end tech support and engineering expertise to get the job done.

Jonathan Ferland and Suzanne Talon from the Réseau Québécois de Calculs de Haute Performance (RQCHP) for crunching all the "statistics" on their supercomputer.

Martin Hart from the Royal Canadian Mounted Police, Lucia Bakker from the Canadian Coast Guard, and Stephen Disipio from the Canadian Border Services Agency for reviewing the game live and providing comments and feedback between the periods.

Thanks to our "linesmen referees" Bob Johnson from NRCAN and the International IBC and John Ells and Stacey S Kirkpatrick from the Canadian Hydrographic Service for providing area definitions and precise border waypoints for our area definition.

Rob Hickley, Andrew Van Veen, and Brian Ward from the Cornwall Fire Department and Harold Harvey from the Lancaster Fire Department for allowing the CRC to perform radio propagation tests in their area of operation. Their contribution was akin to the "coache's practice" before the big game.

To the Canadian Interoperability Technology Interest Group (CITIG) and to all the first responder participants of the five regional meetings held across Canada for the feedback received. They ensured, though their active participation, that this report and its findings have a place in their local rulebooks for emergency response.

All the above should get credited for the fact that "we are now better ready" when the puck drops on our ice rink.

If an important multi-agency first responder event occurs in Canada requiring custom radio coverage calculations as contained in this report, MDSC will be pleased to provide this support on site and on a volunteer basis.

A handwritten signature in blue ink, appearing to read "Richard Cayouette", with a long, sweeping horizontal stroke extending to the right.

Richard Cayouette

Important Notes

1.1 Term of Use

Due to the magnitude of generating a complete coverage analysis over a ~9000 km border, this project was carried out using simplified engineering methodologies and assumptions intended to align the required data processing effort with the actual scope of work. While the analysis framework uses sound radio propagation principles, this simplified methodology and associated results contain a margin of error and as such are for high level guidance and should not be used for detailed planning purposes or the procurement of radio systems. When these two latter considerations move to the forefront, it is recommended that a more detailed analysis be conducted.

The RF coverage analysis and predictive simulations contained herein are based on received signal strength and have not taken interference into account (C/N+I).

Furthermore, for the purpose of this analysis, it is assumed that all radio systems on both sides of the border are fully interoperable, although it is broadly understood that this is not representative of the reality.

1.2 Traduction en français

Ce document a été rédigé uniquement en anglais toutefois il nous fera plaisir d'en traduire ou d'en expliquer une portion en français afin d'assurer le lecteur d'une compréhension totale du contenu.

Pour une traduction en ligne de mots techniques, nous vous recommandons d'utiliser le dictionnaire de l'Office québécois de la langue française à:

http://www.granddictionnaire.com/BTML/FRA/r_MotClef/index800_1.asp

Executive Summary

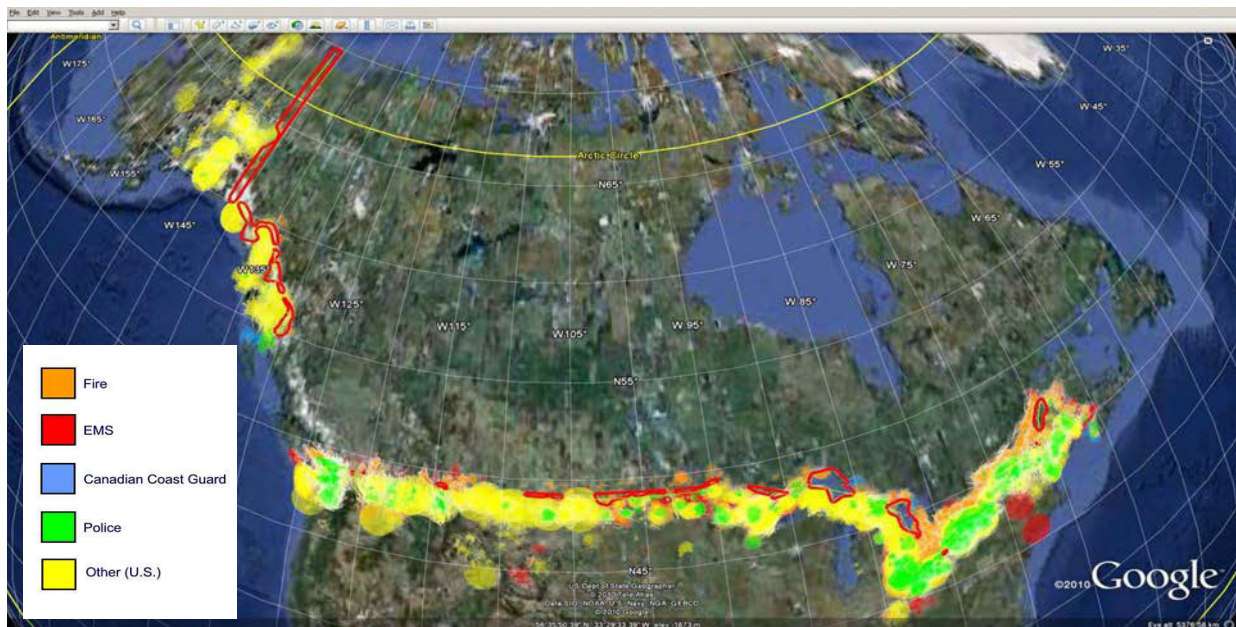
The Canada – United States border is almost 9000km long. The area where first responders from both countries will interact through wireless radio systems is defined as a 60 km wide band that contains 140,000 radio licenses are related to fire, Emergency Medical Services (EMS), police, coast guard and other units.

A complete geographical radio coverage plot of the border region was produced, taking into consideration the maximum operational range for a good voice quality. The radio coverage plot is a mosaic of more than 7000 color-coded images representing first responder fixed radio base station and repeater sites from the Atlantic to the Pacific and from the Pacific to the Beaufort Sea.

Coverage statistics were computed yielding an average geographic coverage of 80% for the border region while **assuming all the radio systems were interoperable** (for example: police can directly talk to fire, fire can talk directly to Coast Guard and all combinations thereof including EMS and other units).

Caution: the **operational coverage = interoperability x geographical coverage**. For example if only half the police cars can talk directly to the fire dispatch and half the EMS vehicles can talk to the fire dispatch, assuming the fire dispatch is the event command, the operational coverage in this case would be only 20% (= (50% x 50%) x 80%). The notion of operational coverage for multi-agency incident response is very important and must be further studied. It must however use, as a foundation, the geographical coverage which is provided in this study.

The coverage plot displayed 16 gap regions in the border area where the radio coverage was insufficient or very fragmented. For each gap region, root cause and mitigation techniques are proposed. These techniques are further amplified in the technology solution options and capability roadmap produced by the Communication Research Center.



1 Introduction

Martello Defence Security Consultants inc. (MDSC) and Industry Canada's Communications Research Center (CRC) have established a partnership to perform a Public Security Technical Program (PSTP) study on Canada - United States (CANUS) Border Radio Coverage in collaboration with the Canadian Border Services Agency (CBSA), Industry Canada (IC), the Canadian Coast Guard (CCG), and Mr. Roger Coudé.

1.1 Problem Statement

One of the most challenging issues facing first responder and military forces on an incident scene is communications interoperability, or the ability to establish communications seamlessly and on demand to transmit and receive voice, video and data with multiple parties. Examples of interoperability failures during major incidents are numerous and many have cost lives.

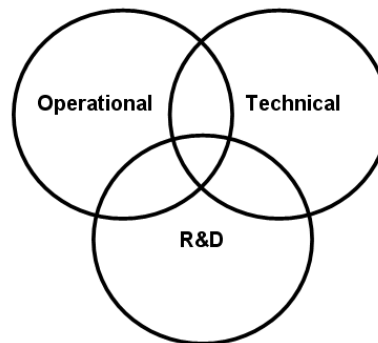
Along the CANUS border, this challenge is further amplified by the presence of forces from many jurisdictions, local, provincial, state, and federal - each having their own specific equipment and bands of operation that are frequently incompatible with others. In addition, the length and terrain characteristics of the border, forests, Great Lakes, and mountainous contour on the Yukon-Alaska border, create radio coverage problems whereby first responders are often outside of the range of connectivity.

1.2 Research Methodologies

The research methodology used analytical and experimental procedures to produce validated radio coverage performance assessments. The radio propagation computing tools that will be used in this regard will include Radio Mobile for Windows (developed and owned by Mr. Roger Coudé) and ATDI which are recognized by the radio communication community as first-class. The radio field test capabilities of Canada's Communications Research Center (CRC) Wireless Applications and Systems Research (WASR) group will also be utilized extensively to achieve overall project objectives. The technology solution options and capability roadmap proposed to mitigate radio coverage gaps will also be corroborated by world-class scientific Subject Matter Experts [SMEs] made available through partnering with the CRC.

5 MainTasks:

- **Coverage Analysis**
- **High Res. Coverage of Gaps**
- **Severity of Gaps**
- **Technology Options**
- **Capability Roadmap**



1.3 Summary of Project Tasks

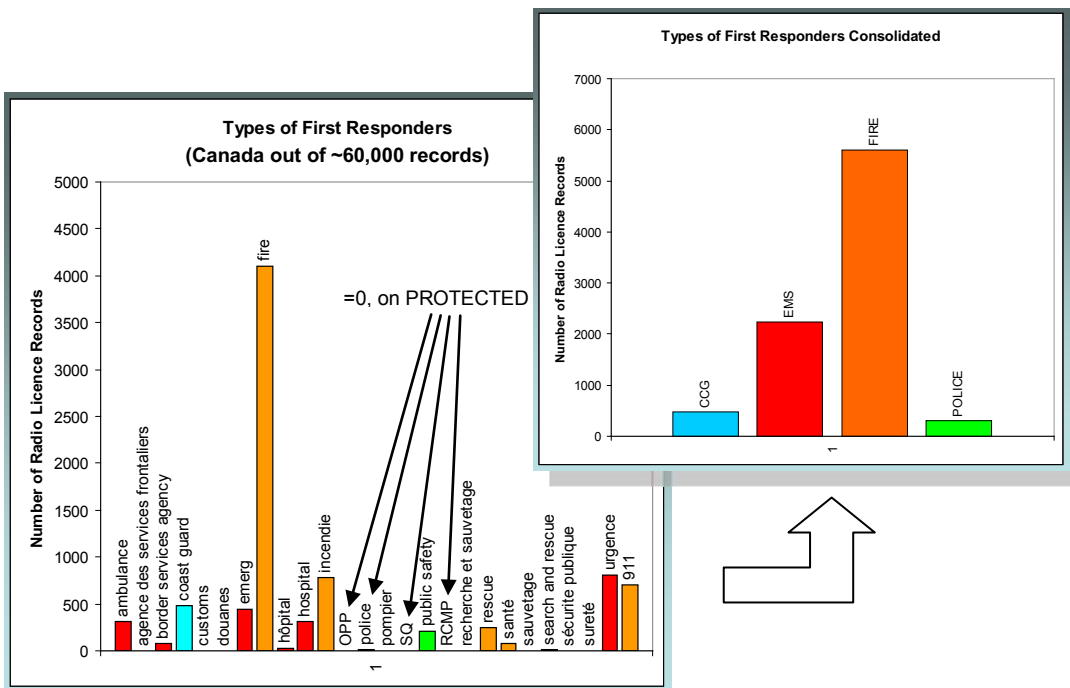
The technical work is divided by the following Work Packages (WP):

- WP 2100 Document Survey and Context Definition
- WP 2200 Define Radio Coverage Area of Interest
- WP 2300 Manage the Scope of the Coverage Analysis
- WP 2400 Define Success Criteria (as two sub-WPs)
 - WP 2410 Define Operational Availability Metrics
 - WP 2420 Error Budget
- WP 3100 Perform Propagation Analysis
- WP 3200 Produce Coverage Visualization Maps
- WP 3300 Assess Severity of Coverage Gaps
- WP 3400 Validate With Field Measurements
- WP 4100 Identify Technology Solution Options
- WP 4200 Produce Capability Roadmap
- WP 4300 Coverage Analysis and Training

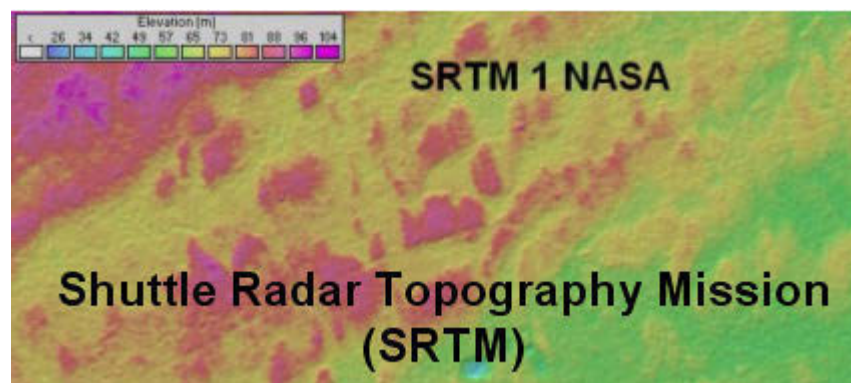
For each WP follows a summary description of the work performed. The complete WP reports are provided in section 9.

WP 2100 DOCUMENT SURVEY AND CONTEXT DEFINITION

Data from Industry Canada Spectrum Direct database and United States Federal Communication Commission Universal License Server was used to produce a list of relevant first responder emitters including (but not limited to) frequencies, power, tower heights, antenna orientation

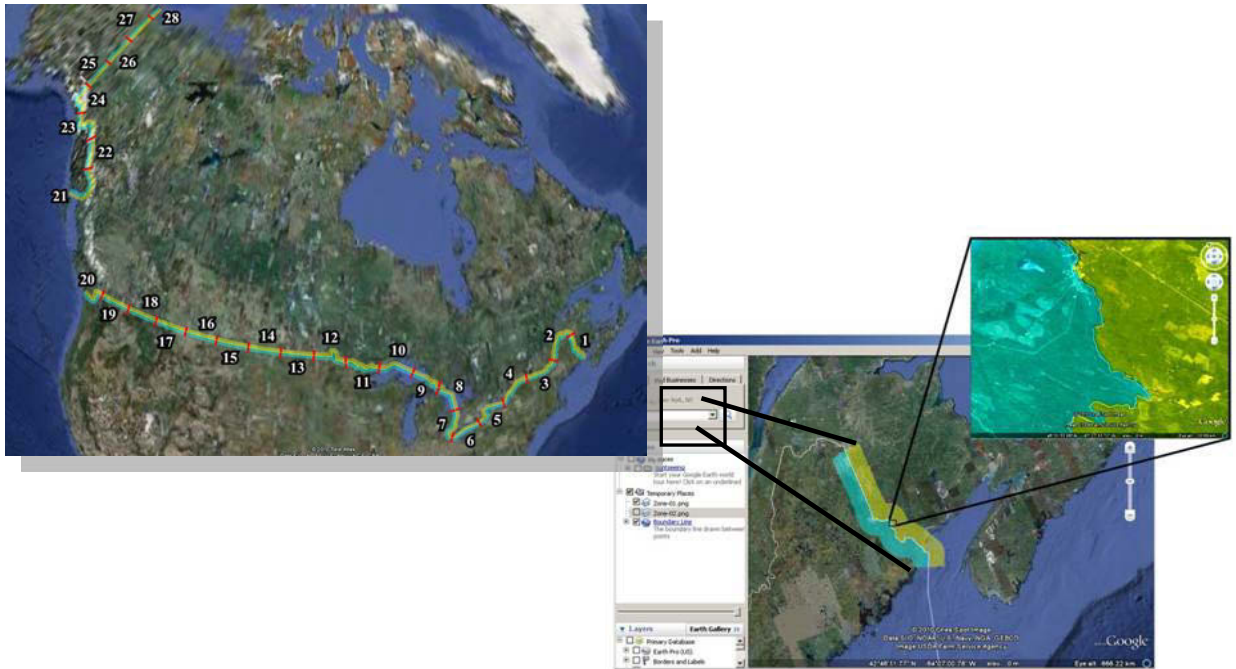


Natural Resources Canada, Surveyor General Branch to obtain border maps; and NASA Space Shuttle Radar Topography Mission (SRTM1 v2) to obtain the highest quality terrain information.



WP 2200 DEFINE RADIO COVERAGE AREA OF INTEREST

The Area Of Interest (AOI) has been expanded to include all roads and mission critical spots in a 60km wide band (30 km in Canada and 30km in the U.S) on the border. First responder radio systems in a 200km wide band were considered as relevant radio emitters for the AOI.



28 zones defined on the border.

WP 2300 MANAGE THE SCOPE OF THE COVERAGE ANALYSIS

Based on the output of WP 2100 and 2200, the coverage analysis scope was simplified as the number of combinations of radio and antenna characteristics was quite large. Notwithstanding the above, the radio coverage of each radio system was calculated with its own parameters to ensure a high level of fidelity, this required massive data processing and the use of supercomputers.

WP 2400 DEFINE SUCCESS CRITERIA

In this WP, operational availability metrics, expected coverage in % of total area was identified. A custom program called ZoneCov (for Zone Coverage) to calculate the statistics was created as part of WP 2410. An error budget in terms of SNR was calculated in WP 2420 to define the coverage reliability.

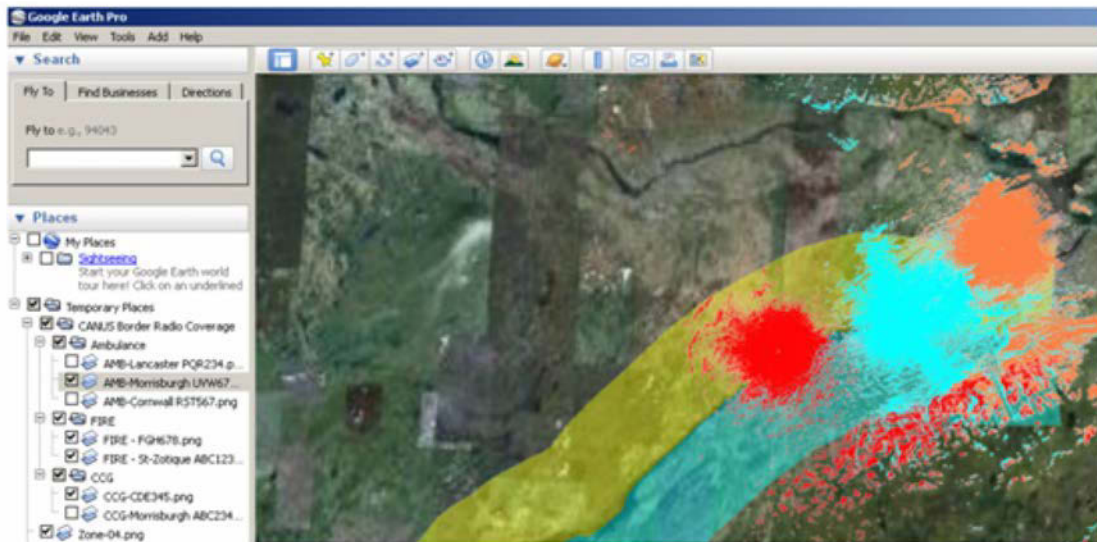


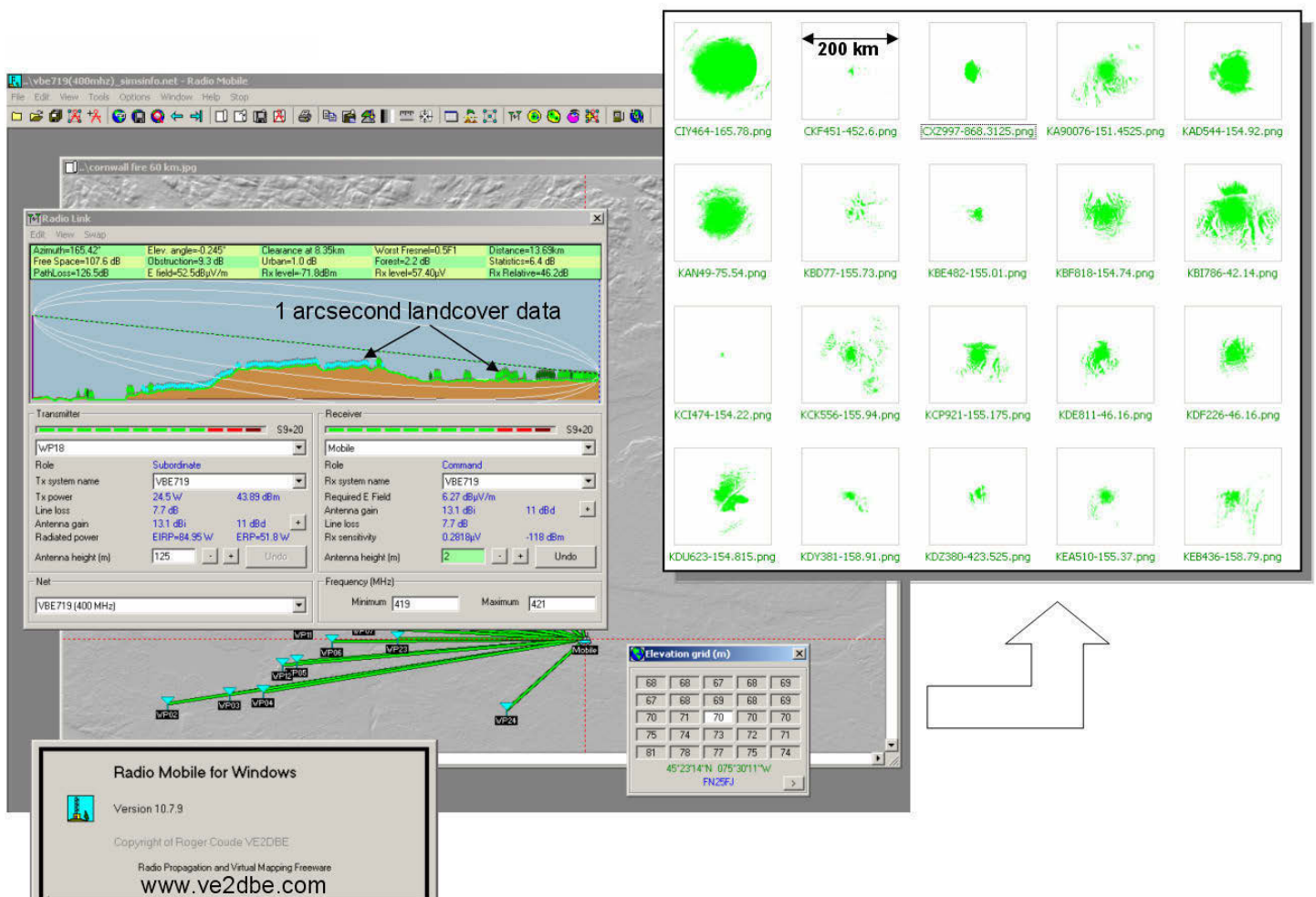
Figure 5 - Coverage Example Cornwall Generic in Zone 4

	A	B	C	D	E	F	G	H	I
1	Zone picture	Coverage picture	Pixels Zone Canada	Pixels Covered Canada	Pixels Combined Canada		Pixels Zone USA	Pixels Covered USA	Pixels Combined USA
2	M:\Projects\CANIM\Projects\CANUS		905884	4953	4953		1033709	12509	12509
3	M:\Projects\CANIM\Projects\CANUS		905884	7886	8464		1033709	17016	18474
4	M:\Projects\CANIM\Projects\CANUS		905884	0	8464		1033709	896	18520
5	M:\Projects\CANIM\Projects\CANUS		905884	11332	13092		1033709	11692	19230
6	M:\Projects\CANIM\Projects\CANUS		905884	0	13092		1033709	82	19236

WP 3100 PERFORM PROPAGATION ANALYSIS

In this WP element, the data of WP 2100 was entered in the radio coverage modeling tool and a composite coverage map drawn. The software utilized was Radio Mobile for Windows (RMW) (www.ve2dbe.com) which is free to use and publicly available. RMW uses the Irregular Terrain Model (Longley-Rice) for propagation calculation as published by the Institute for Telecommunications Sciences. RMW is recognized worldwide by the radiofrequency (RF) operator community and has served distinguished agencies like the UN and Red Cross as well as many public services. The first responder community will be able to use it on its own after the project is completed.

To ensure scientific accuracy, the RMW results were validated with a sophisticated RF planning tool (ATDI see: www.atdi-us.com) and by field testing in WP3400.



Radio Mobile for Windows and output.

WP 3200 PRODUCE COVERAGE VISUALIZATION MAPS

RMW is also a very powerful tool for terrain visualization as it includes aerial photography and any map to be overlaid to create 2D, 3D and stereoscopic views. In this WP element, the analysis results were formatted to provide an all-embracing situation awareness map that will be comprehensible for all public safety operators and not only to radio engineers. The map products were also produced in Google Earth™ format.

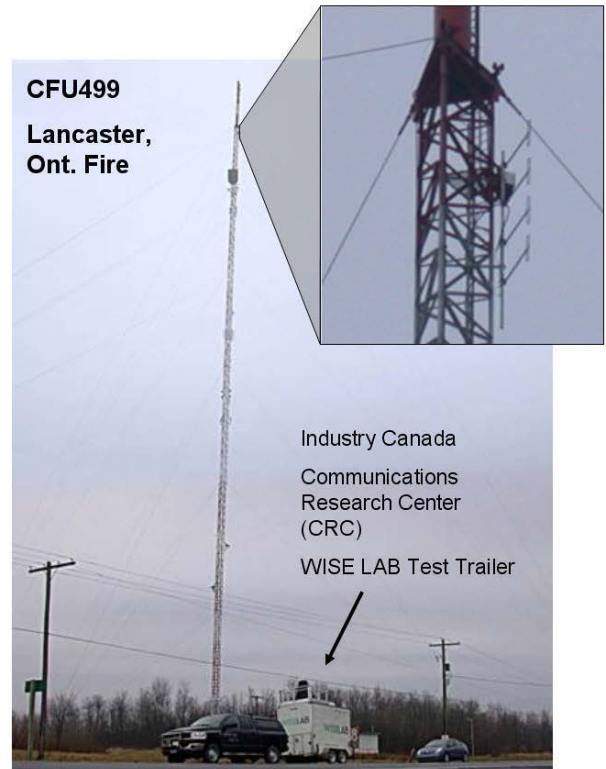
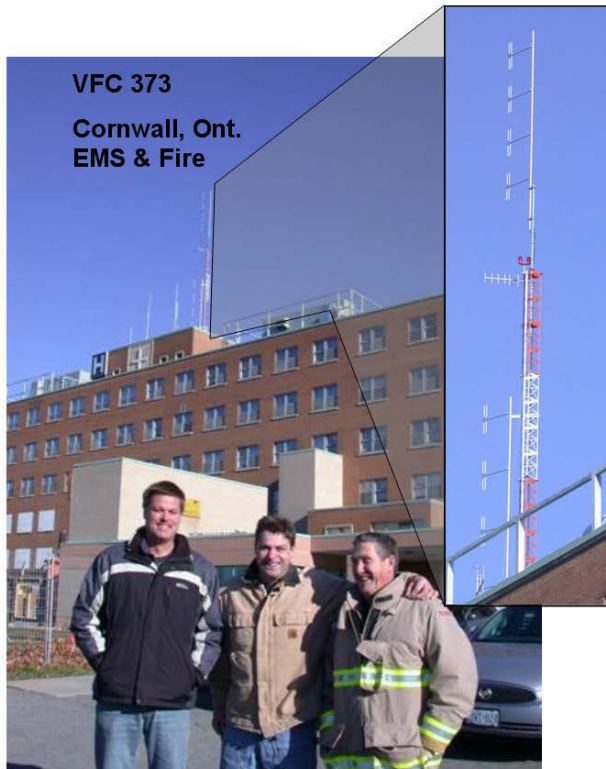
To **highlight the impact of interoperability** look at the coverage plots independently in Google Earth™ by selecting police only, Coast Guard only, fire only and EMS only. Gaps are much more obvious and visible.

WP 3300 ASSESS SEVERITY OF COVERAGE GAPS

Based on the output of WP 3100 and WP 2400 and some input from CBSA and CCG operational experts, the study identified root causes and proposed mitigation techniques for the 16 radio coverage gaps.

WP 3400 VALIDATE WITH FIELD MEASUREMENTS

In this WP element, the scientific accuracy of results was validated by the CRC by conducting a field testing campaign. Measured results were compared with the predicted coverage maps and adjustment to both the error budget (WP 2420) and propagation models (WP 3100) were proposed.



Field testing in Cornwall and Lancaster Areas

WP 4100 IDENTIFY TECHNOLOGY SOLUTION OPTIONS

Based on the WP 2300, 3200 and 3300, this WP element identifies potential technology solutions for coverage and interoperability.

WP 4200 PRODUCE CAPABILITY ROADMAP

A roadmap for the development and deployment of various advanced technologies annotated with the appropriate Technology Readiness Level (TRL) score is be proposed including actions that could be undertaken within the next 5 years as well as longer term activities involving research and development.

WP 4300 COVERAGE ANALYSIS OPERATIONAL DEBRIEFING AND TRAINING

In this WP element, five on-site debriefings to end users were conducted including work sessions on how to use RMW: this was the key in-kind contribution from MDSC:

- Maritimes in Fredericton , 14 Feb 2011: 12 participants
- Ottawa+QC in Ottawa, 17 and 18 Feb 2011: 20 participants
- Prairies, in Regina 21 Feb 2011: 6 participants
- Pacific, in Surrey 24 and 25 Feb 2011: 14 participants

- Yukon-Alaska, in Whitehorse 28 Feb and 01 Mar: 9 participants



Yukon Emergency Management Operations – Check all the antennas!

2 Study Recommendations

2.1 Canadian Public Safety Pool Radio Service Code

The most difficult task of the project was to sort out first responder radio license records from the Industry Canada database. Many various search scripts were written and file conversions required to sort and prune the data to form a comprehensive list of users. For the US database, this task was very simple as radio service codes metadata are specifically implemented in the database.

The FCC uses radio service codes for its public safety pool and the following codes and criteria were used:

Exact Matches Only=Y

Exclude Leases=Y

Radio Services (all public safety)

GE	Pub/Saftey/SpecEmer/PubSafteyNtlPlan,806-817/851-862MHz,Conv
GF	Public Safety Ntl Plan, 821-824/866-869 MHz, Conv.
GP	Public Safety/Spec Emerg, 806-821/851-866 MHz, Conv.
PW	Public Safety Pool, Conventional
QM	Non-Nationwide Public Safety/Mutual Aid, 220MHz
SG	Conventional Public Safety 700 MHz
SL	Public Safety 700 MHz Band-State License
SP	700MHz Public safety Broadband Nationwide License
SY	Trunked Public Safety 700 MHz
YE	PubSaftey/SpecEmer/PubSafteyNtlPlan,806-817/851-862MHz,Trunked]
YF	Public safety Ntl Plan, 821-824/866-869 MHz, Trunked
YP	Public Safety/Spec Emerg, 806-821/851-866 MHz, Trunked
YW	Public Safety Pool, Trunked

Status= Active

Auth. Type = Regular

The screenshot shows the 'Advanced License Search' page of the FCC's Universal Licensing System. It includes a 'Call Sign & Radio Services' section with a 'Call Sign' input field and a 'Service Group' dropdown menu set to 'All'. Below this, there are checkboxes for 'Exact Matches Only' and 'Exclude Leases'. A section titled 'Match only the following radio service(s):' contains a list of radio services with checkboxes, including 'PA - Public Safety 430-435 MHz Band', 'PC - Public Coast Station, Auctioned', 'PE - Digital Electronic Message Service - Private', 'PW - Public Safety Pool, Conventional', and 'QA - 220-222 MHz Band, Auctioned'.

It is highly recommended that Industry Canada implements a similar tagging of first responder records in its Spectrum Direct database. The database would also benefit in having specific fields to identify:

- P25 radios,
- first responders as payloads on commercial networks,
- type of encryption used,
- type of first responder (fire, police, medical, hazmat, Coast Guard, public works etc...), and
- what other first responders, by call sign, are "over-the air" interoperable.

2.2 Revision of Coverage Plot for Specific Emission Bandwidth and Radio Waveform

In generating the radio coverage plots in this study, all emitters were considered to be analog frequency modulated (FM) voice systems, as indicated in “WP 2420 Range Calculation Error Budget Analysis” section.

While this singular approximation is deemed acceptable so as to limit the scope and simplify the overall RF coverage calculation, a more accurate calculation of system gain can be performed by each end-user taking into account its specific radio receiver and transmitter chains. To this effect, a small sample of specific receiver thresholds is presented in the aforementioned error budget section.

For P25 radios which use digital voice, the degradation of voice quality is sudden and does not present a "graceful degradation" as an analog radio would. Although the bandwidth is smaller yielding a system gain improvement of up to 8 dB, there is a hysteresis effect that prevents the voice to fully and instantly recover after an outage. This has been verbally reported during the Pacific debrief session held in Surrey B.-C.

It was also reported that the 8 kHz bandwidth voice was of insufficient quality to perform the first responder's mission.

It is recommended that each radio user produces and refines its own propagation model (notably the system gain parameter) vs. voice quality to reflect the area coverage measured during field testing (remote radio checks).

2.3 The 10 Commandments for First Responder Radio Communications

- 1- You are responsible for your own radio coverage.
- 2- All your staff should be aware of the radio coverage and its limitations.
- 3- Test your coverage limits regularly by dispatching your staff for remote radio checks during quiet times. Do it from the car and from the handset, both have very different ranges.
- 4- Investigate "dead zones" and get your local radio supplier and installer to implement fixes.
- 5- Ensure your radio license reflects exactly what is deployed at your transmitter sites.
- 6- Do not rely on your cell phones; the lines will be busy if a significant event occurs.
- 7- Ensure you have a mobile repeater with a quick erecting tower that you can deploy.
- 8- Conduct interoperability exercises to ensure your radio channel plan works with other services. Do not assume the landline telephone network will work if a significant event takes place.

9- Have a few key personnel trained on the use of radio planning tools; ask for the help of your local amateur radio operators and your local Industry Canada representative.

10 – Go for range, not for aesthetics on your vehicles. Long antennas ($\frac{1}{2}$ wave) are ugly and conspicuous but they give you range and best voice quality; give them the highest elevation real-estate on your vehicle. Insist for the best real-estate for your antennas on fixed towers, top mounted antennas are the best, side mounted antennas are obstructed by the tower.



3 Conclusion

The report conclusions are:

- a) The global calculation of the high level border radio coverage with a sufficient level of fidelity and resolution for all first responders is feasible both from a data mining and data processing standpoint.
- b) The visualization of the global radio coverage on a continent-wide map and the detailed radio coverage up to 100m/pixel on regional maps is possible.
- c) The "free to use" tools and necessary geographic information (terrain elevation and land cover) are available and produce accurate results when proper input parameters are selected.
- d) The user community is very receptive to use the framework, method and tools proposed.
- e) There is available and emerging technology that will enhance both geographic coverage and interoperability.

From a geographic coverage standpoint, first responder radios on the Canadian 30km border band cover 76% of the area; for the U.S. 30 km border band, 83% of the area is covered.

4 Follow-on Work

Opportunities for follow-on work that would be beneficial to the study have been identified:

Item #	Description	Priority (H/M/L)	Cost (H/M/L)
1	Add the PROTECTED Canadian radio license records to the dataset and recalculate the radio coverage maps and coverage % metrics.	H	L
1a	Add the PROTECTED U.S. radio license records (NTIA database + other) to the dataset and recalculate the radio coverage maps and coverage % metrics.	H	M to H ?
2	Augment the coverage maps with satellite phone coverage especially for Maine and Yukon gap areas.	M	M
3	Create a Protected Web service where first responders can get their radio coverage plotted on-line.	M	M
4	Build an interoperability matrix and associated network diagrams for nearest neighbors based on class of emission codes (radio waveforms) and user surveys and calculate the operational coverage.	M	H
5	Make an equipment purchase guide based on findings of technology solutions options and capability roadmap.	L	M

Item #	Description	Priority (H/M/L)	Cost (H/M/L)
6	Perform a P25 specific radio prediction model taking into account voice quality and perform field test validation.	M to H	H
6a	Perform a handset specific radio prediction model and field test validation.	M to H	H
7	Perform a broadband data radio (700MHz) radio coverage prediction model.	M	L
8	Perform a broadband data radio (700MHz) data network (traffic and congestion) model with OPNET or Qualnet.	L	H
9	Define and produce a procurement specification for a transportable radio repeater shelter.	M	L
10	Implement and test for improvements in landcover data for Radio Mobile for Windows.	L	H

Project number: PSTP 02-302 EMSI

Document Survey and Context Definition

WP 2100

Document number: MDSC-ANA-0006 v01, 07 Mar 2011

1. Purpose

This document provides the detailed radio emitter data which is representative of the Public Safety users located 100km either side of the Canada – United States (US) border.

The distance of 100 km has been identified as pertinent for identifying emitters that have a confirmed influence in the 30km area of interest (AOI) defined in "WP 2200 Define Radio Coverage Area of Interest" because some emitters located on very high mountains or towers can radiate into the AOI over relatively flat and unobstructed terrain.

The data has been retrieved from the official data distribution sites of Industry Canada and of the US Federal Communications Commission (FCC).

2. Scope

This document applies to the following: "WP 3100 Propagation Analysis".

2.1 References

2.1.1 Industry Canada References

IC Antenna Radiation Patterns.txt
IC Channel Capacity Codes.txt
IC Class of Emission Codes.txt
IC Spectrum Field Description.txt
IC Spectrum File Layout.txt
IC Spectrum Signature Codes.txt

2.1.2 FCC References

FCC ULS Code Definitions.pdf
FCC ULS Data File Formats.pdf
FCC ULS Intro and File Definitions incl. Service Codes.pdf
601main - Feb 2008.pdf
601d - Feb 2008.pdf
601h - Feb 2008.pdf
FCC ULS Database Field Definitions.xls

3. References

3.1 Hyperlinks

<http://sd.ic.gc.ca> (Industry Canada Spectrum Direct)

<http://wireless2.fcc.gov/UlsApp/UlsSearch/searchAdvanced.jsp>
(FCC Universal Licensing System)

www.citig.ca (Canadian Interoperability Technology Interest Group (CITIG))

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4. Canadian Emitter Data from Industry Canada

The Industry Canada data made available for this project is unclassified. Approximately 10% of the database is unavailable as it consists of protected records for police, including the Royal Canadian Mounted Police (RCMP), and other services. To address this issue, MDSC has published a Request For Information (RFI) to the first responder community (see 4.1.2 and 6.2).

4.1 Canadian Data

The Canadian data has been provided by Industry Canada in a single file named "mks_24718_extracts.zipx" and contains the following frequency subsets of 70,680 license records:

138_144_MHz_extr.xls	19/11/2010 10:58 AM	693,200
148_174_MHz_extr.xls	19/11/2010 11:26 AM	11,502,150
406pt1_430_MHz_extr.xls	19/11/2010 1:07 PM	3,150,982
450_470_MHz_extr.xls	19/11/2010 11:37 AM	7,230,393
768_776_MHz_extr.xls	19/11/2010 11:40 AM	10,240
798_806_MHz_extr.xls	19/11/2010 11:43 AM	10,752
806_824_MHz_extr.xls	19/11/2010 11:53 AM	1,948,111
821_824_MHz_extr.xls	19/11/2010 11:48 AM	1,135,708
851_869_MHz_extr.xls	19/11/2010 12:01 PM	7,292,773
mks_24718_extract_columns.txt	19/11/2010 12:03 PM	1,529

Figure 1 - Canadian Emitter Data Files

The data files contain all emitters that match the following criteria:

- License Type (e.g. 1 = Land Mobile) only land fixed base stations and repeaters are considered, as generic mobiles have been defined for the propagation analysis.
- TX Frequency Ranges = 138-144, 148-174, 406.1-430, 450-470, 768-776, 798-806 821-824, 806-824, 851-869 MHz
- Distance from the border including Alaska/Yukon = 100 km

4.1.1 Canadian Data Filtering for Border Distance

A special script was performed by IC's team using their Geographic Information System (GIS) tools for performing the selection of sites. For verification purposes, a custom algorithm was produced in MathCad™ which yielded the diagram in Figure 2. The algorithm is a simple least square distance (D) calculation of the separation of each station (S) to each border point (B) in x and y coordinates (i,j) normalized for angular to planar distance using the factor (dtr). The details of this model are provided in "WP 2200 Define Radio Coverage Area of Interest" section.

$$dtr := \frac{\pi}{180}$$

$$D_{i,j} := dtr \cdot 6378 \cdot \sqrt{\left[\left(S_{i,1} - B_{j,0} \right)^2 + \left[\left(S_{i,2} - B_{j,1} \right) \cdot \cos \left[\left(S_{i,1} + B_{j,0} \right) \cdot 0.5 \cdot dtr \right] \right]^2 \right]}$$

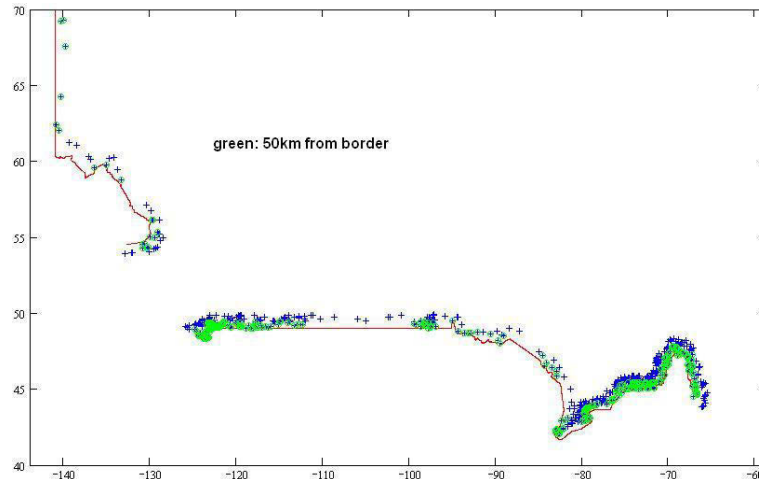


Figure 2 - Example of Canadian Emitter East-West Distribution (subset of all records) 50km splits the data in two as a test case for validating the 100km selection criteria

4.1.2 Canadian Data Filtering for Public Safety Pool

The Canadian database does not have a "Radio Service" code like on the FCC data. A special script was developed and tested specifically for this project by Martello Defence Security Consultants inc. (MDSC).

An initial survey of the Canadian Licensees Name keywords was performed to extract a Public Safety (PS) Pool of users:

All Regions (except Prince Edward Island and Yukon) on 60,423 records => 2,985 first responder related

```
*ambulance*=179
*agence des services frontaliers*=
*border_services_agency*=21
*coast_guard*=66
*douanes*=2
*emergenc*= 124    (emergencies, emergency)
*_feu_*=0
*fire*=1268
*hôpital*=
*hospital*=338
*incendie*=346
*_OPP_*= 0
*police*=357
*pompier*=6
*public_safety*=26
*RCMP*=5
*recherche et sauvetage*=
*rescue*=139
*search_and_rescue*=34
*sécurité*=31
*sécurité_publique*=0
*securite publique*=4
NOT USED *securite*=38
NOT USED *security*=149
*sûreté du québec*=0
```

surete= 17 (but surete universite d'ottawa)
urgence=289

Notes:

- a) the Police, Royal Canadian Mounted Police, Sûreté du Québec and like results are very low because it is likely that these records are on the PROTECTED list and not available for this study for security reasons. It is recommended that a second study, in the classified domain, using the same framework and methodologies be conducted to incorporate these services.
- b) the word "security" and "securite" yielded mostly private security agencies not related to the Public Safety pool.

The Microsoft Access™ database "IC All Records All Frequencies v01.mdb" containing the concatenated tables of Figure 1 and the Search Query Language (SQL) queries is provided as an attachment.

4.1.2.1 SQL Script for PS Pool

This confirmed the methodology therefore a detailed script was produced and executed in Microsoft Access. The SQL script in file "Public Safety Pool SQL Query in IC All Records All Frequencies v10.txt" is:

```
SELECT [IC All Records All Frequencies].COMPANY_NAME,
WHERE

((( [IC All Records All Frequencies].COMPANY_NAME) Like "**ambulance*" Or
([IC All Records All Frequencies].COMPANY_NAME) Like "**agence des services frontaliers*" Or
([IC All Records All Frequencies].COMPANY_NAME) Like "**border services agency*" Or
([IC All Records All Frequencies].COMPANY_NAME) Like "**coast guard*" Or
([IC All Records All Frequencies].COMPANY_NAME) Like "**douanes*" Or
([IC All Records All Frequencies].COMPANY_NAME) Like "**emerg*" Or
([IC All Records All Frequencies].COMPANY_NAME) Like "**fire*" Or
([IC All Records All Frequencies].COMPANY_NAME) Like "**hôpital*" Or
([IC All Records All Frequencies].COMPANY_NAME) Like "**hospital*" Or
([IC All Records All Frequencies].COMPANY_NAME) Like "**incendie*" Or
([IC All Records All Frequencies].COMPANY_NAME) Like "**police*" Or
([IC All Records All Frequencies].COMPANY_NAME) Like "**pompier*" Or
([IC All Records All Frequencies].COMPANY_NAME) Like "**public safety*" Or
([IC All Records All Frequencies].COMPANY_NAME) Like "**RCMP*" Or
([IC All Records All Frequencies].COMPANY_NAME) Like "**recherche et sauvetage*" Or
([IC All Records All Frequencies].COMPANY_NAME) Like "**rescue*" Or
([IC All Records All Frequencies].COMPANY_NAME) Like "**search and rescue*" Or
([IC All Records All Frequencies].COMPANY_NAME) Like "**sécurité publique*" Or
([IC All Records All Frequencies].COMPANY_NAME) Like "**urgence*"));
```

4.1.2.2 SQL Script for Converting RF parameters

The data obtained by the PS pool SQL has to be refined to be used as an input to Radio Mobile for Windows (RMW) as a .txt file. The IC to RMW database transfer schema is described in Figure 3:

Database Transfer Schema

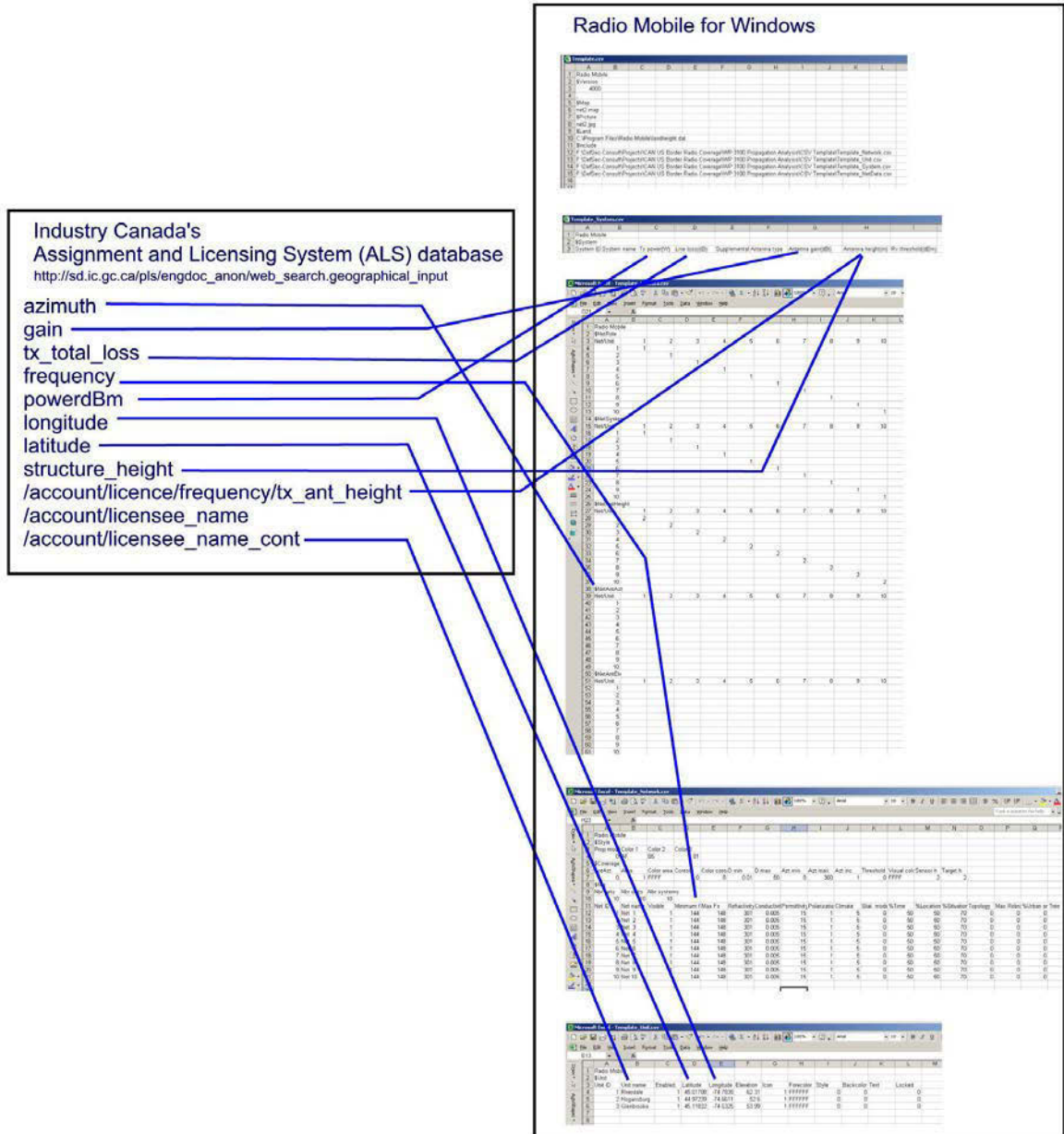


Figure 3 - IC to RMW Database transfer Schema

WP 3400 activities identified that the Latitude and Longitude metrics provided within the IC database is coarse and can differ from actual locations. For example,

1- South Lancaster Fire dept. CFU499 is referenced as 45°10'33" N and 74°31'37" W. Actual recorded location is 45°10'33.59" N and 74°31'37.31" W. There is an 18m difference between referenced and measured coordinates.

2- Cornwall Fire dept. VFC373 is referenced as 45°01'44" N and 74°43'06" W. Actual recorded location is 45°01'47.89" N and 74°43'4.44" W. There is a 124m difference between the referenced and measured coordinates.

These differences in location can have a significant impact on coverage, as radio paths (and associated obstructions) can vary greatly between the referenced and actual locations. Taking the VFC373 example above, the IC reference places the antenna in the middle of McConnell Ave. in downtown Cornwall while the actual antenna location is the rooftop in the middle of the Cornwall Community Hospital campus. Similarly, these differences may significantly impact radio coverage for those transmitters located in the vicinity of hill/mountain tops.

The SQL script to perform this task and for converting the units of measure (power, gains, losses) yielding " IC PS Pool for RMW Batch v14 for First Run 02 Dec 10.txt" as a batch file for RMW is as follows):

```
"c:\temp\" & [Expr5] & "\" & [IC All Records All Frequencies].[CALL_SIGN]&".png" AS Picture_file, "c:\temp\" & [Expr5] & "\" &
[IC All Records All Frequencies].[CALL_SIGN]&".png" AS Picture_file_freq,

IIf(([IC All Records All Frequencies].[TX_FREQ]<200),-1.25,IIf(([IC All Records All Frequencies].[TX_FREQ]<700),-1.9,3)) AS
Cor_Mob_Ant_Gain,

IIf(([IC All Records All Frequencies].[TX_FREQ]<200),86.2,IIf(([IC All Records All Frequencies].[TX_FREQ]<700),95.7,99.0))
AS Cor_Rx_Th,

[IC All Records All Frequencies].[TX_PWR_DBW]+30+Cor_Mob_Ant_Gain+(TX_ANT_GAIN+2.15)+Cor_Rx_Th-[IC All
Records All Frequencies].[TX_LOSS_TTL] AS System_gain,

[IC All Records All Frequencies].TX_ANT_PATRN, IIf([IC All Records All
Frequencies].[TX_ANT_PATRN]="8000","omni.ant",IIf([IC All Records All
Frequencies].[TX_ANT_PATRN]="8200","cardio.ant",IIf([IC All Records All
Frequencies].[TX_ANT_PATRN]="8800","ellipse.ant",IIf([IC All Records All
Frequencies].[TX_ANT_PATRN]="8400","omni.ant",IIf([IC All Records All
Frequencies].[TX_ANT_PATRN]="9400","omni.ant","error")))) AS Antenna_File,

IIf([IC All Records All Frequencies].TX_ANT_AZMTH Is Null), 0 ,[IC All Records All Frequencies].TX_ANT_AZMTH) AS
Ant_Az,

IIf([IC All Records All Frequencies].TX_ANT_ELEV_ANG Is Null), 0 ,[IC All Records All Frequencies].TX_ANT_ELEV_ANG)
AS Ant_Tilt, [IC All Records All Frequencies].TX_ANT_HGT AS Ant_Hgt,

[IC All Records All Frequencies].SITE_ELEV AS Elevation, "2" AS Mobile_Ant_Hgt,

[IC All Records All Frequencies].TX_FREQ AS Frequency, ROUND((LEFT([IC All Records All
Frequencies].LATITUDE,2)+MID([IC All Records All Frequencies].LATITUDE,3,2)/60+MID([IC All Records All
Frequencies].LATITUDE,5,2)/3600),5) AS Latitude_dec,

IIf([IC All Records All Frequencies].LONGITUDE<1000000),0&[IC All Records All Frequencies].LONGITUDE,[IC All Records
All Frequencies].LONGITUDE) AS Long_7, -1*ROUND((LEFT([Long_7],3)+MID([Long_7],4,2)/60+MID([Long_7],6,2)/3600),5)
AS Longitude_dec,

100 AS Map_Res, 200 AS Max_Range,

IIf([Expr5]="EMS"),"0000FF",IIf([Expr5]="FIRE"),"0099FF",IIf([Expr5]="CCG"),"FF9900",IIf([Expr5]="POLICE"),"00FF00",
"000000"))),

"f:\geodata\srtm1" AS SRTM_Path,
```

"f:\geodata\landcover*.lcv"

WP 3400 activities performed by CRC identified additional losses on top of the reported base station parameters contained in the IC database. For these losses to be considered, modifications of the **System_gain** RF parameters are required. The results of the findings and corresponding modifications to the respective error budget are presented in the "WP 2420 Range Calculation Error Budget Analysis" section of this document.

4.1.2.3 Results of Canadian Data Filtering for Public Safety Pool

	Function
ambulance	308 EMS
agence des services frontaliers	1 POLICE
border services agency	83 POLICE
coast guard	478 CCG
customs	2 POLICE
douanes	4 POLICE
emerg	439 EMS
fire	4104 FIRE
hôpital	24 EMS
hospital	316 EMS
incendie	786 FIRE
OPP	0 POLICE
police	16 POLICE
pompier	1 FIRE
SQ	0 POLICE
public safety	208 POLICE
RCMP	1 POLICE
recherche et sauvetage	0 EMS
rescue	252 EMS
santé	80 EMS
sauvetage	0 EMS
search and rescue	16 EMS
sécurité publique	0 POLICE
sureté	0 POLICE
urgence	808 EMS
911	706 FIRE
	8633

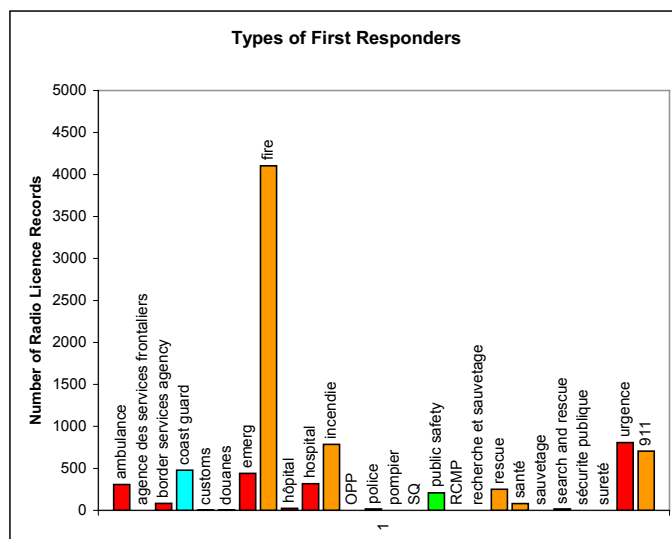


Figure 4 - Canadian Types of First Responders

The Canadian public safety pool has been consolidated to simplify the color coding of the coverage maps to the following 4 classes: FIRE, Emergency Medical Services (EMS), POLICE, CCG (note: totals vary because some records use words applicable to two classes) by the following SQL statement:

```

IIf([IC All Records All Frequencies]![COMPANY_NAME] Like "**FIRE**","FIRE",
IIf([IC All Records All Frequencies]![COMPANY_NAME] Like "**incendie**","FIRE",
IIf([IC All Records All Frequencies]![COMPANY_NAME] Like "**pompier**","FIRE",

IIf([IC All Records All Frequencies]![COMPANY_NAME] Like "**coast guard**","CCG",

IIf([IC All Records All Frequencies]![COMPANY_NAME] Like "**police**","POLICE",
IIf([IC All Records All Frequencies]![COMPANY_NAME] Like "**agence des services frontaliers**","POLICE",
IIf([IC All Records All Frequencies]![COMPANY_NAME] Like "**911**","FIRE",
IIf([IC All Records All Frequencies]![COMPANY_NAME] Like "**border services agency**","POLICE",
IIf([IC All Records All Frequencies]![COMPANY_NAME] Like "**customs**","POLICE",
IIf([IC All Records All Frequencies]![COMPANY_NAME] Like "**douanes**","POLICE",
IIf([IC All Records All Frequencies]![COMPANY_NAME] Like "**public safety**","POLICE",
IIf([IC All Records All Frequencies]![COMPANY_NAME] Like "**RCMP**","POLICE"

IIf([IC All Records All Frequencies]![COMPANY_NAME] Like "**ambulance**","EMS",
IIf([IC All Records All Frequencies]![COMPANY_NAME] Like "**emerg**","EMS",
IIf([IC All Records All Frequencies]![COMPANY_NAME] Like "**hôpital**","EMS",

```

If([IC All Records All Frequencies]![COMPANY_NAME] Like "**hospital**","EMS",
 If([IC All Records All Frequencies]![COMPANY_NAME] Like "**rescue**","EMS",
 If([IC All Records All Frequencies]![COMPANY_NAME] Like "**sante**","EMS",
 If([IC All Records All Frequencies]![COMPANY_NAME] Like "**search and rescue**","EMS",
 If([IC All Records All Frequencies]![COMPANY_NAME] Like "**urgence**","EMS",

in SQL			
coast guard	y	478	CCG
ambulance	y	308	EMS
emerg	y	439	EMS
hôpital	y	24	EMS
hospital	y	316	EMS
recherche et sauvetage	n	0	EMS
rescue	y	252	EMS
santé	y	80	EMS
sauvetage	n	0	EMS
search and rescue	y	16	EMS
urgence		808	EMS
		2243	EMS
fire	y	4104	FIRE
incendie	y	786	FIRE
pompier	y	1	FIRE
911	y	706	FIRE
		5597	FIRE
agence des services frontaliers	y	1	POLICE
border services agency	y	83	POLICE
customs	y	2	POLICE
douanes	y	4	POLICE
OPP	n	0	POLICE
police	y	16	POLICE
SQ	n	0	POLICE
public safety	y	208	POLICE
public security	n	0	
RCMP	n	1	POLICE
sécurité publique	n	0	POLICE
sureté	n	0	POLICE
		315	POLICE

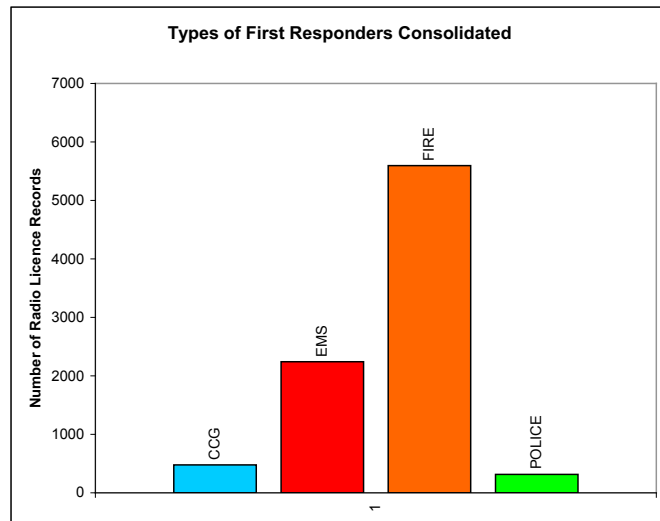


Figure 5 - Canadian Types of First Responders Consolidated

5. United States Emitter Data from Federal Communications Commission

The FCC's Universal Licensing System (FCC ULS) was used to retrieve the public safety pool data for the US.

The FCC uses radio service codes for its public safety pool and the following codes and criteria were used:

Exact Matches Only=Y
 Exclude Leases=Y

Radio Services (all public safety)

GE	Pub/Safty/SpecEmer/PubSaftyNtlPlan,806-817/851-862MHz,Conv
GF	Public Safety Ntl Plan, 821-824/866-869 MHz, Conv.
GP	Public Safety/Spec Emerg, 806-821/851-866 MHz, Conv.
PW	Public Safety Pool, Conventional
QM	Non-Nationwide Public Safety/Mutual Aid, 220MHz
SG	Conventional Public Safety 700 MHz
SL	Public Safety 700 MHz Band-State License
SP	700MHz Public safety Broadband Nationwide License
SY	Trunked Public Safety 700 MHz
YE	PubSafty/SpecEmer/PubSaftyNtlPlan,806-817/851-862MHz,Trunked]
YF	Public safety Ntl Plan, 821-824/866-869 MHz, Trunked
YP	Public Safety/Spec Emerg, 806-821/851-866 MHz, Trunked
YW	Public Safety Pool, Trunked

Status= Active
Auth. Type = Regular

Geosearch

Base Stations and repeaters (not mobiles) located within 100km of CANUS Border=custom geo search

Include Nationwide Area of Operation ? =N (yes would include mobiles)

Include Continental Area of Operation ? =N (yes would include mobiles)

Exclude leases =Y

An example of the output page is:

FCC Federal Communications Commission

[FCC Home](#) | [Search](#) | [Updates](#) | [E-Filing](#) | [Initiatives](#) | [For Consumers](#) | [Find People](#)

Universal Licensing System

FCC > [WTS](#) > [ULS](#) > [Online Systems](#) > License Search [FCC Site Map](#)

License Search

Search Results

[New Search](#) [Refine Search](#) [Printable Page](#) [Query Download](#) [Map License](#) [HELP](#)

Specified Search

State = New York
County = CATTARAUGUS, CAYUGA, CHAUTAUQUA, CLINTON, ERIE, ESSEX, FRANKLIN, GENESEE, JEFFERSON, LIVINGSTON, MONROE, NIAGARA, ONTARIO, ORLEANS, OSWEGO, SENECA, ST. LAWRENCE, WAYNE
Radio Service = GE, GF, GP, PW, QM, SG, SL, SP, SY, YE, YF, YP, YW
Authorization Type = Regular
Status = Active
Exclude Leases

Matches 1- 10 (of 1932)

Page 1 2 3 4 5 6 7 8 9 10 [NEXT](#)













	Call Sign/Lease ID	Name	FRN	Radio Service	Status	Expiration Date
1	KA79508	WALES, TOWN OF	0003393220	PW	Active	10/13/2012
2	KA90076	CAYUGA COUNTY 9-1-1 COMMUNICATIONS	0003419504	PW	Active	12/19/2015
3	KA97048	St. Lawrence Psychiatric Center	0007488620	PW	Active	01/03/2014
4	KAN682	CHAUTAUQUA COUNTY EMS NEW YORK	0003397791	PW	Active	10/10/2014
5	PA KAR972	JAMESTOWN, CITY OF	0003397999	PW	Active	05/21/2012
6	KAS410	FIRE COORDINATOR/NIAGARA COUNTY	0003397676	PW	Active	09/12/2011
7	KAT537	FIRE COORDINATOR/NIAGARA COUNTY	0003397676	PW	Active	12/17/2011
8	KAX896	AUBURN MEMORIAL HOSPITAL	0004127692	PW	Active	01/30/2015
9	KAY997	WAYNE, COUNTY OF	0003419116	PW	Active	02/01/2014
10	KBA481	PHELPS, CITY OF	0003412996	PW	Active	02/02/2015

Page 1 2 3 4 5 6 7 8 9 10 [NEXT](#)

Legend:
PA= Pending Application(s)
TP= Termination Pending
L= Lease

Figure 6 - FCC ULS Output page for the State of New York

The data can be saved as a "download" and the following files will be used for "WP 3100 Propagation Analysis" interpreted with "FCC ULS Database Field Definitions.xls".

 Alaska UL201011151358379.txt	864 KB	Text Document	15/12/2010 1:59 PM
 Idaho UL201011151252609.txt	277 KB	Text Document	15/12/2010 1:10 PM
 Maine UL201011141430707.txt	1,827 KB	Text Document	14/12/2010 2:33 PM
 Michigan UL20101115119774.txt	3,724 KB	Text Document	15/12/2010 11:12 AM
 Minnesota UL201011151159360.txt	1,607 KB	Text Document	15/12/2010 12:00 PM
 Montana UL201011151244974.txt	1,045 KB	Text Document	15/12/2010 12:46 PM
 New Hampshire UL20101115918238.txt	181 KB	Text Document	15/12/2010 9:28 AM
 New York UL201011151046627.txt	7,219 KB	Text Document	15/12/2010 10:47 AM
 North Dakota UL20101115123847.txt	557 KB	Text Document	15/12/2010 12:39 PM
 Ohio UL2010111511356.txt	4,401 KB	Text Document	15/12/2010 11:06 AM
 Vermont UL201011151031607.txt	970 KB	Text Document	15/12/2010 10:32 AM
 Washington UL201011151317920.txt	2,959 KB	Text Document	15/12/2010 1:25 PM

The free text portion of the FCC data record **[EN 8] Entity Name**, will be exploited in an SQL statement in an attempt to regroup the users in the same classes as for Canada i.e. Fire, EMS and Police see "FCC Template v01.xls".

HD 2	HD 3	HD 5	HD 7	EN 8	FR 16	A3 36	FR 21	A3 12	A3 21	A3 17
Unique System Identifier	ULS File Number	Call Sign	Radio Service Code	Entity Name	Power Output	Line Loss	EIRP	Antenna Type Code	Azimuth	Tilt

Figure 7 - FCC Field Definitions (part 1)

A3 22	LO 19	FR 11	LO 20	LO 21	LO 22	LO 23	LO 24	LO 25	LO 26	LO 27
Height Above Avg Terrain	Ground Elevation	Frequency Assigned	Latitude Degrees	Latitude Minutes	Latitude Seconds	Latitude Direction	Longitude Degrees	Longitude Minutes	Longitude Seconds	Longitude Direction

Figure 8 - FCC Field Definitions (part 2)

Note: only records containing the value "F3E" (voice) in the class of emission codes from the EM 10 records were kept. This includes all single channel bandwidths from 11 to 25 KHz. For the resulting radio coverage, all F3E records were processed in a conservative manner i.e. as 25 KHz channel analog FM systems. See "WP 2420 Range Calculation Error Budget Analysis" section for a detailed explanation.

5.1 FCC Data Geographic Filtering

The FCC database did not provide a GIS tool for geographic filtering but they offer the possibility of using counties as a filtering tool for distance to the border.

A series of adjacent 100 km circles were drawn on Google Earth™ as the first delimiter for county selection (see: 100 Km Radius Circles.kml).

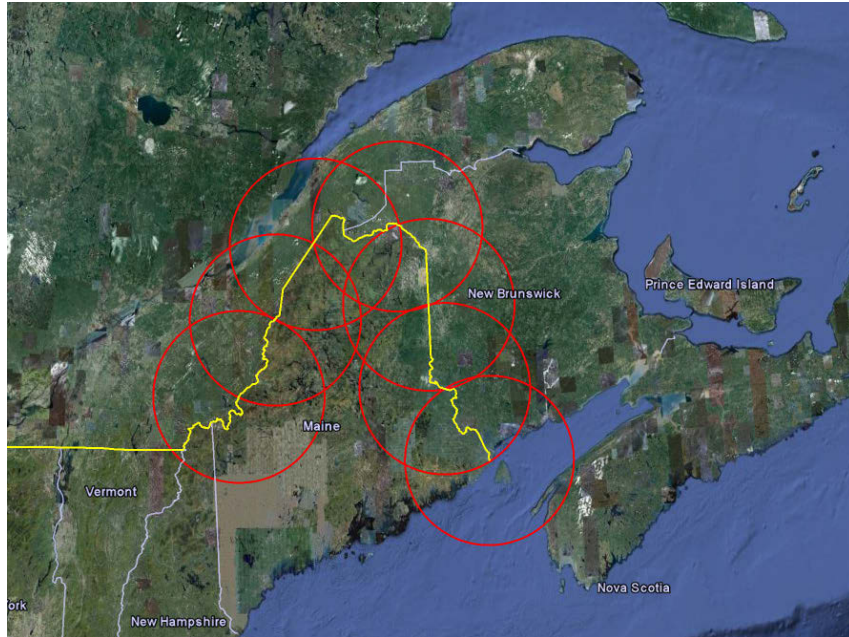


Figure 9 - 100 km Radius Circles Centered on Border

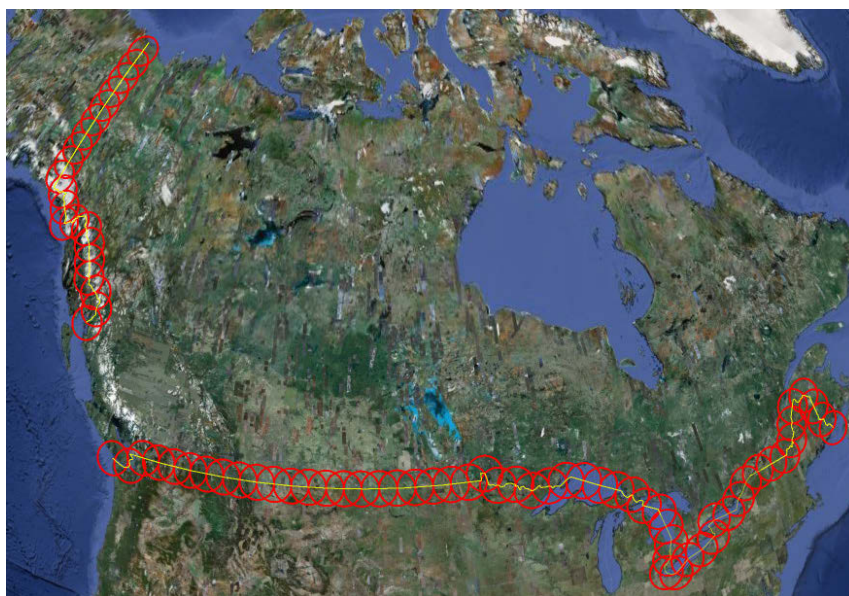


Figure 10 - 100 km Radius Circles Country Wide



Figure 11 - Google Earth's Primary Database/ Borders and labels / 2nd level Admin Regions

Using the feature of Figure 11, Counties matching the criteria were manually selected.

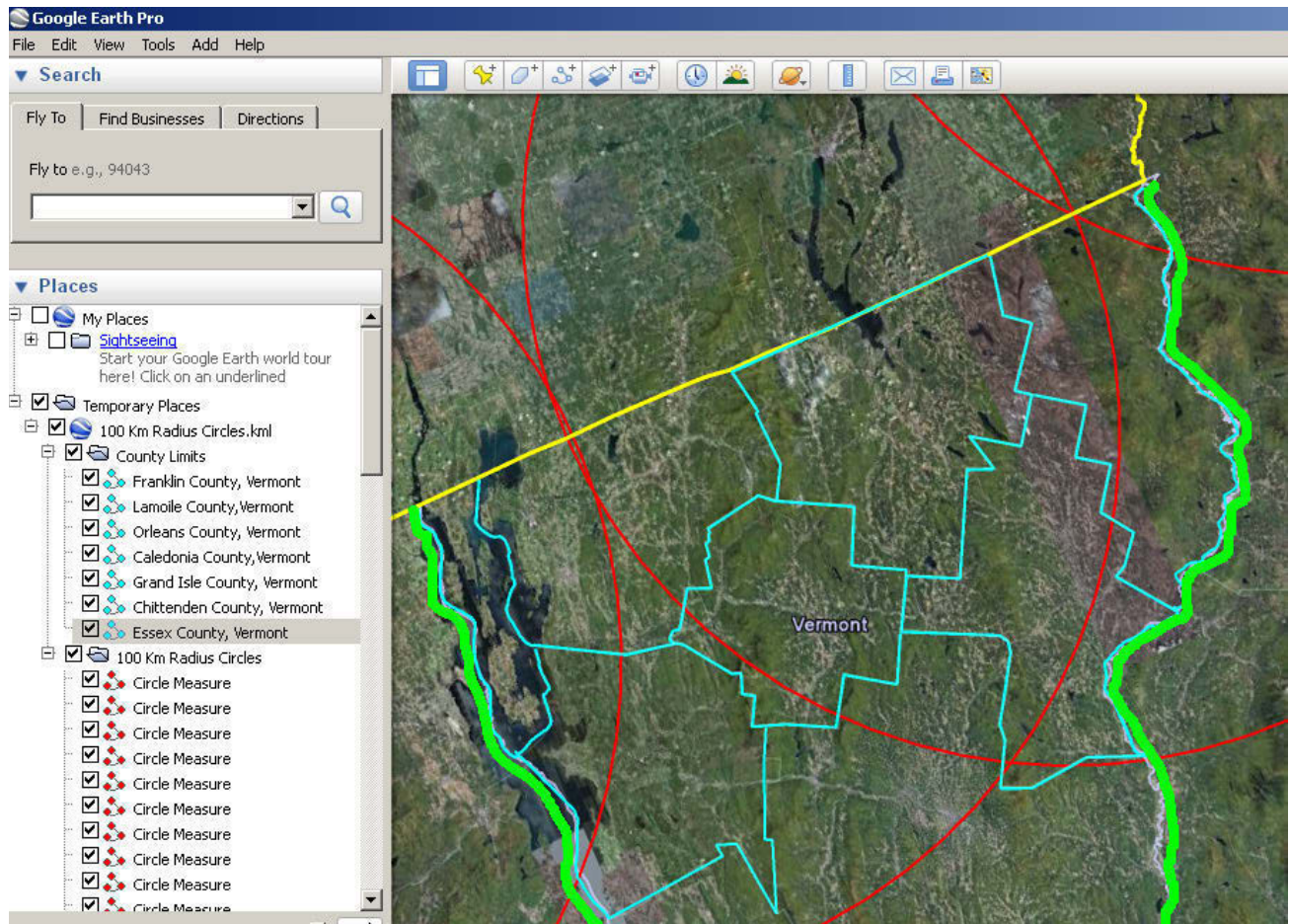


Figure 12 – Example of County Selection for Vermont where Counties are Within 100 km of Border

The assessment was performed for each state yielding the following counties which were added to the search criteria used in FCC ULS for each state:

	State		County	File
1	Maine	1	Aroostok	Maine UL201011141430707.txt
		2	Franklin	Maine UL201011141430707.txt
		3	Oxford	Maine UL201011141430707.txt
		4	Penobscot	Maine UL201011141430707.txt
		5	Piscataquis	Maine UL201011141430707.txt
		6	Somerset	Maine UL201011141430707.txt
		7	Washington	Maine UL201011141430707.txt
2	New Hampshire	8	Coos	New Hampshire UL20101115918238.txt
3	Vermont	9	Caledonia	Vermont UL201011151031607.txt
		10	Chittenden	Vermont UL201011151031607.txt
		11	Essex	Vermont UL201011151031607.txt
		12	Franklin	Vermont UL201011151031607.txt
		13	Grand Isle	Vermont UL201011151031607.txt
		14	Lamoille	Vermont UL201011151031607.txt
		15	Orleans	Vermont UL201011151031607.txt
4	New York	16	Cattaraugus	New York UL201011151046627.txt
		17	Cayuga	New York UL201011151046627.txt
		18	Chautauqua	New York UL201011151046627.txt
		19	Clinton	New York UL201011151046627.txt
		20	Erie	New York UL201011151046627.txt
		21	Essex	New York UL201011151046627.txt
		22	Franklin	New York UL201011151046627.txt

5	Ohio	23	Genesee	New York UL201011151046627.txt
		24	Jefferson	New York UL201011151046627.txt
		25	Livingston	New York UL201011151046627.txt
		26	Monroe	New York UL201011151046627.txt
		27	Niagara	New York UL201011151046627.txt
		28	Ontario	New York UL201011151046627.txt
		29	Orleans	New York UL201011151046627.txt
		30	Oswego	New York UL201011151046627.txt
		31	Seneca	New York UL201011151046627.txt
		32	St.-Lawrence	New York UL201011151046627.txt
		33	Wayne	New York UL201011151046627.txt
		34	Ashland	Ohio UL2010111511356.txt
		35	Ashtabula	Ohio UL2010111511356.txt
		36	Crawford	Ohio UL2010111511356.txt
		37	Cuyahoga	Ohio UL2010111511356.txt
		38	Erie	Ohio UL2010111511356.txt
		39	Fulton	Ohio UL2010111511356.txt
		40	Geauga	Ohio UL2010111511356.txt
		41	Henry	Ohio UL2010111511356.txt
		42	Huron	Ohio UL2010111511356.txt
		43	Lake	Ohio UL2010111511356.txt
		44	Lorain	Ohio UL2010111511356.txt
		45	Lucas	Ohio UL2010111511356.txt
		46	Medina	Ohio UL2010111511356.txt
		47	Ottawa	Ohio UL2010111511356.txt
		48	Portage	Ohio UL2010111511356.txt

		49	Richland	Ohio UL2010111511356.txt
		50	Sandusky	Ohio UL2010111511356.txt
		51	Seneca	Ohio UL2010111511356.txt
		52	Trumbull	Ohio UL2010111511356.txt
		53	Wood	Ohio UL2010111511356.txt
6	Michigan	54	Alcona	Michigan UL20101115119774.txt
		55	Alger	Michigan UL20101115119774.txt
		56	Alpena	Michigan UL20101115119774.txt
		57	Cheboygan	Michigan UL20101115119774.txt
		58	Chippewa	Michigan UL20101115119774.txt
		59	Genesee	Michigan UL20101115119774.txt
		60	Huron	Michigan UL20101115119774.txt
		61	Iosco	Michigan UL20101115119774.txt
		62	Keweenaw	Michigan UL20101115119774.txt
		63	Lapeer	Michigan UL20101115119774.txt
		64	Livingston	Michigan UL20101115119774.txt
		65	Luce	Michigan UL20101115119774.txt
		66	Mackinac	Michigan UL20101115119774.txt
		67	Macomb	Michigan UL20101115119774.txt
		68	Monroe	Michigan UL20101115119774.txt
		69	Oakland	Michigan UL20101115119774.txt
		70	Presque Isle	Michigan UL20101115119774.txt
		71	Sanilac	Michigan UL20101115119774.txt
		72	Schoolcraft	Michigan UL20101115119774.txt
		73	St.-Clair	Michigan UL20101115119774.txt
		74	Tuscola	Michigan UL20101115119774.txt

7	Minnesota	75	Washtenaw	Michigan UL20101115119774.txt
		76	Wayne	Michigan UL20101115119774.txt
		77	Beltrami	Minnesota UL201011151159360.txt
		78	Cook	Minnesota UL201011151159360.txt
		79	Kittston	Minnesota UL201011151159360.txt
		80	Koochiching	Minnesota UL201011151159360.txt
		81	Lake	Minnesota UL201011151159360.txt
		82	Lake of the Woods	Minnesota UL201011151159360.txt
		83	Marshall	Minnesota UL201011151159360.txt
		84	Roseau	Minnesota UL201011151159360.txt
8	North Dakota	85	St.-Louis	Minnesota UL201011151159360.txt
		86	Benson	North Dakota UL20101115123847.txt
		87	Bottineau	North Dakota UL20101115123847.txt
		88	Burke	North Dakota UL20101115123847.txt
		89	Cavalier	North Dakota UL20101115123847.txt
		90	Divide	North Dakota UL20101115123847.txt
		91	McHenry	North Dakota UL20101115123847.txt
		92	Montrail	North Dakota UL20101115123847.txt
		93	Pembina	North Dakota UL20101115123847.txt
		94	Pierce	North Dakota UL20101115123847.txt
		95	Ramsey	North Dakota UL20101115123847.txt
		96	Renville	North Dakota UL20101115123847.txt
		97	Rolette	North Dakota UL20101115123847.txt
		98	Towner	North Dakota UL20101115123847.txt
		99	Walsh	North Dakota UL20101115123847.txt
		100	Ward	North Dakota UL20101115123847.txt

		101	Williams	North Dakota UL20101115123847.txt
9	Montana	102	Blaine	Montana UL201011151244974.txt
		103	Daniels	Montana UL201011151244974.txt
		104	Flathead	Montana UL201011151244974.txt
		105	Glacier	Montana UL201011151244974.txt
		106	Hill	Montana UL201011151244974.txt
		107	Liberty	Montana UL201011151244974.txt
		108	Lincoln	Montana UL201011151244974.txt
		109	Phillips	Montana UL201011151244974.txt
		110	Roosevelt	Montana UL201011151244974.txt
		111	Sheridan	Montana UL201011151244974.txt
		112	Toole	Montana UL201011151244974.txt
		113	Valley	Montana UL201011151244974.txt
10	Idaho	114	Bonner	Idaho UL201011151252609.txt
		115	Boundary	Idaho UL201011151252609.txt
11	Washington	116	Clallam	Washington UL201011151317920.txt
		117	Ferry	Washington UL201011151317920.txt
		118	Island	Washington UL201011151317920.txt
		119	Jefferson	Washington UL201011151317920.txt
		120	Kitsap	Washington UL201011151317920.txt
		121	Okanogan	Washington UL201011151317920.txt
		122	Prend Oreille	Washington UL201011151317920.txt
		123	Skagit	Washington UL201011151317920.txt
		124	Stevens	Washington UL201011151317920.txt
		125	Whatcomb	Washington UL201011151317920.txt

12	Alaska	126	Haines	Alaska UL201011151358379.txt
		127	Juneau	Alaska UL201011151358379.txt
		128	Ketchikan Gateway	Alaska UL201011151358379.txt
		129	North Slope	Alaska UL201011151358379.txt
		130	Prince of Wales- Hyder	Alaska UL201011151358379.txt
		131	Prince of Wales- Outer Ketchikan	Alaska UL201011151358379.txt
		132	Sitka	Alaska UL201011151358379.txt
		133	Skagway-Hoonah- Angoon	Alaska UL201011151358379.txt
		134	Skagway-Yakutat- Angoon	Alaska UL201011151358379.txt
		135	Southeast Fairbanks	Alaska UL201011151358379.txt
		136	Valdez-Cordova	Alaska UL201011151358379.txt
		137	Wrangell- Petersberg	Alaska UL201011151358379.txt
		138	Yukon-Koyukuk	Alaska UL201011151358379.txt

6. Other Sources

MDSC has briefed the Royal Canadian Mounted Police at their headquarters in Ottawa in mid September, RCMP stated that their information was PROTECTED and could not be supplied.

6.1 Canadian Coast Guard (CCG)

See attached files: "Radio Site Survey Worksheet CCG-MCTS CA data.xls" and " Radio Site Survey Worksheet CCG-MCTS PAC.xls"

6.2 Canadian Interoperability Technology Interest Group (CITIG)

MDSC is a member of CITIG and has participated to two Border Interoperability Conferences (Sep. 2010 Windsor, Regina Nov. 2010).

To maximize the number of first responder radio stations included in the first issue of the coverage maps, a Request For Information (RFI) was sent to the CITIG user community on 01 Dec 2010.

The following form was posted on MDSC's website "Radio Site Survey Worksheet Draft End-User Version Only MDSC-ANA-0001 v04.xls" at: www.defsec-consult.ca/CANUS_RFI_En.htm and was broadly announced to the CITIG community through an e-News release on 24 Nov 10

(see: "CITIG eNews National Forum Sold Out Regional Forum Materials as well as MASAS and CANUS Information.htm" and "e-News Press Release.JPG" attached to this report).

The responses received from the user community were as follows:

Minnesota

DRAFT Border Commo Report 001.pdf
September 2010 ARMER Site Map 2010-08-03.pdf
September 2010 Fleetnet 800_Manitoba Southern Map (2).pdf
September 2010 MN-MANITOBA INTEROP PROPOSAL.docx

Montana

Copy of Northern Tier Frequency Re-Work Tracking_17JUN10.xls
Montana WBIWG 2010 Kevin Bruski IM.pdf

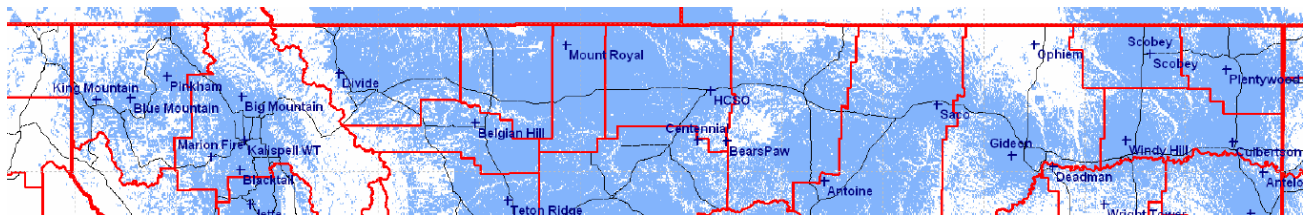


Figure 13 - Montana Trunking Coverage

North Dakota

North Dakota Mike Lynk Western Border Meeting 11-17-10.ppt



Figure 14 - North Dakota (new sites)

Saskatchewan

Saskatchewan Karl Reardon PPPSTN to WBIWG 20101118.ppt

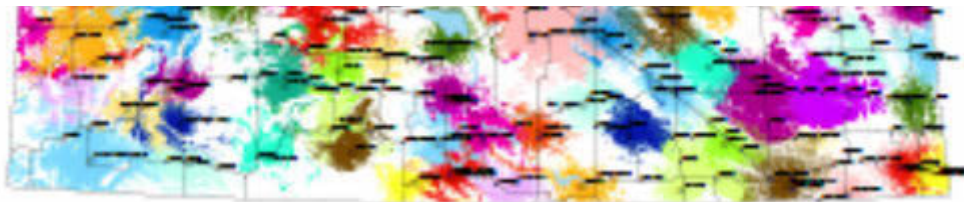


Figure 15 - Saskatchewan Coverage

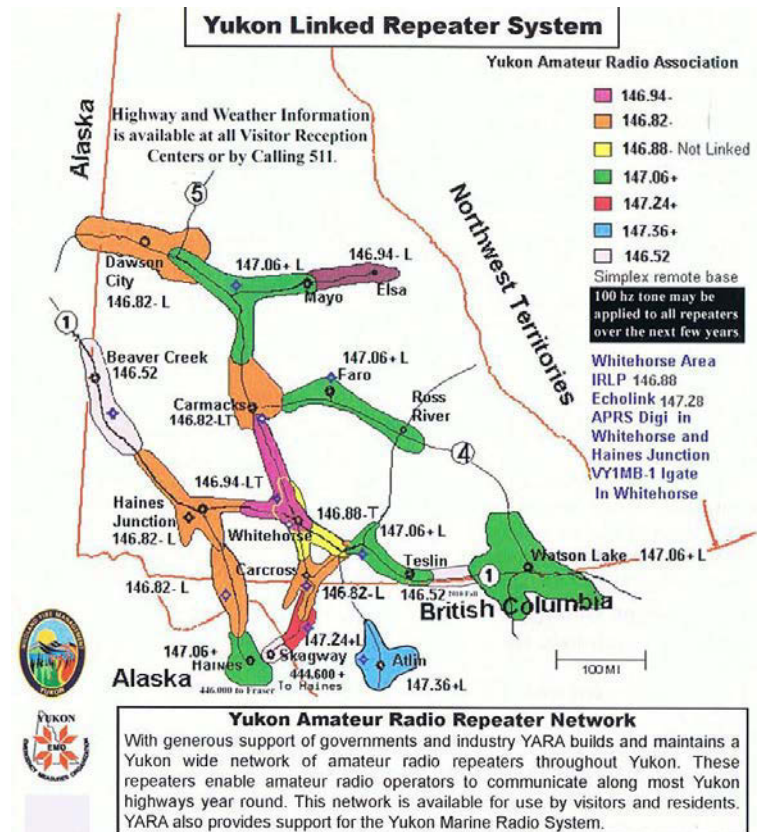


Figure 16 - Yukon Amateur Radio Coverage

The user information received was used to complement the coverage maps of "WP 3200 Produce Coverage Visualization Maps" and to augment the data of "WP 3100 Propagation Analysis" sections.

7. Assumptions, Constraints and Disclaimer

The following assumptions and constraints apply to this document:

- It is assumed that the data in the IC and FCC database is accurate.
- The PROTECTED information from IC (~10% of the database) is excluded.
- US Coast Guard and other federal agencies are not in the FCC database. They are contained in the NTIA database; records are not available to the public.

The following was confirmed by NPSTC:

The Government Master File (GMF) is a database of Federal frequency assignments. It is not available to the public. I would suggest they contact Tom Woods, frequency assignment branch for more information. His number is (202) 482-2802.

- Data from www.radioreference.com was not used as it could not be traced to valid end user records and necessary radio information such system gain, tower height and tower location is not available.

e) FCC disclaimer for ULS:

The FCC makes no warranty whatsoever with respect to the use of any remote software. In no event shall the Commission, its officers, employees or agents, be liable for any damages whatsoever (including, but not limited to, loss of business profits, business interruption, loss of business information, or any other loss) arising out of or relating to the existence, furnishing, functioning or use of any remote Commission software. Moreover, no obligation or liability will arise out of the Commission's technical, programming or other advice or service provided in connection with any remote Commission software.

8. Attachments

- All Records All Frequencies v01.mdb
- mks_24718_extracts.zipx
- List of Emitters from FCC.zip
- Radio Site Survey Worksheet Draft End-User Version Only MDSC-ANA-0001 v04.xls
- CITIG eNews National Forum Sold Out Regional Forum Materials as well as MASAS and CANUS Information.htm
- e-News Press Release.JPG
- IC Antenna Radiation Patterns.txt
- IC Channel Capacity Codes.txt
- IC Class of Emission Codes.txt
- IC Spectrum Field Description.txt
- IC Spectrum File Layout.txt
- IC Spectrum Signature Codes.txt
- FCC ULS Code Definitions.pdf
- FCC ULS Data File Formats.pdf
- FCC ULS Intro and File Definitions incl. Service Codes.pdf
- 601main - Feb 2008.pdf
- 601d - Feb 2008.pdf
- 601h - Feb 2008.pdf
- FCC ULS Database Field Definitions.xls
- FCC Template v01.xls
- DRAFT Border Commo Report 001.pdf
- September 2010 ARMER Site Map 2010-08-03.pdf
- September 2010 Fleetnet 800_Manitoba Southern Map (2).pdf
- September 2010 MN-MANITOBA INTEROP PROPOSAL.docx
- Copy of Northern Tier Frequency Re-Work Tracking_17JUN10.xls
- Montana WBIWG 2010 Kevin Bruski IM.pdf
- North Dakota Mike Lynk Western Border Meeting 11-17-10.ppt
- Saskatchewan Karl Reardon PPPSTN to WBIWG 20101118.ppt

9. Abbreviations

CCG	Canadian Coast Guard
CITIG	Canadian Interoperability Technology Interest Group
EMS	Emergency Medical Services
FCC	Federal Communications Commission
GIS	Geographic Information System

IC	Industry Canada
MDSC	Martello Defence Security Consultants inc.
NPSTC	National Public Safety Telecommunications
OPP	Ontario Provincial Police
PS	Public Safety
RCMP	Royal Canadian Mounted Police
RFI	Request For Information
RMW	Radio Mobile for Windows
SQL	Search Query Language
ULS	Universal Universal Licensing System
US	United States
WP	Work Package

Project number: PSTP 02-302 EMSI

WP 2200 Define Radio Coverage Area of Interest

WP 2200

Document number: MDSC-ANA-0004 v01, 07 Mar 2011

1. Purpose

The purpose of this document is to define the Canada and United States (CANUS) boundary area for the analysis of radio coverage of the Public Safety first responders. The area and its components called zones will be utilized in the computation of performance metrics in Work Package (WP) 2400 Define Success Criteria.

2. Scope

This document applies to all the following activities:

WP 2100 Document Survey and Context Definition (downloaded emitter data)
WP 2400 Define Success Criteria
WP 3100 Propagation Analysis
WP 3200 Produce Coverage Visualization Maps
WP 3300 Assess Severity of Coverage Gaps

3. Copyrights

See attached file "DULA CHS v01.pdf" for details.

This product has been produced by Martello Defence Security Consultants Inc. based on Canadian Hydrographic Service Charts and/or Data, pursuant to CHS Direct User Licence No. 2010-0924-1260-M

The incorporation of data sourced from CHS in this product shall not be construed as constituting an endorsement by CHS of this product.

This product does not meet the requirements of the Charts and Nautical Publications Regulations under the *Canada Shipping Act, 2001*. Official charts and publications, corrected and up-to-date, must be used to meet the requirements of those regulations.

4. References

- A. Direct User Licence Agreement (DULA) between Canadian Hydrographic Service and Martello Defence Security Consultants (MDSC).

4.1 Hyperlinks

4.1.1 Coordinates of the fishing lines (used for file: 1999TerrSea.dat)

<http://laws.justice.gc.ca/en/O-2.4/C.R.C.-c.1547/index.html>

<http://laws.justice.gc.ca/en/O-2.4/C.R.C.-c.1548/index.html>

<http://laws.justice.gc.ca/en/O-2.4/C.R.C.-c.1549/index.html>

PLEASE NOTE: These are not official coordinates and cannot be portrayed or used as an official boundary or limit. Note that over time the territorial sea limit will be updated and changed as new surveys are performed and information is incorporated. Consider this file a snapshot in time. Finally, some sections of the Territorial Sea have been intentionally omitted pending governmental approval.

4.2 Contacts

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Geographer
John Ells
Canadian Hydrographic Service
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Email: John.Ells@dfo-mpo.gc.ca

Geographer
International Boundary Commission / Natural Resources Canada
Bob Johnson
(613) 943-2373
Email: Bob.Johnson@NRCan-RNCan.gc.ca

5. Zone Definition

5.1 Territorial Zone

The CANUS border was defined as a 60km area of interest (AOI); two 30km wide bands on both sides of the border line (i.e. perpendicular) using color yellow for Canada and cyan for the US.

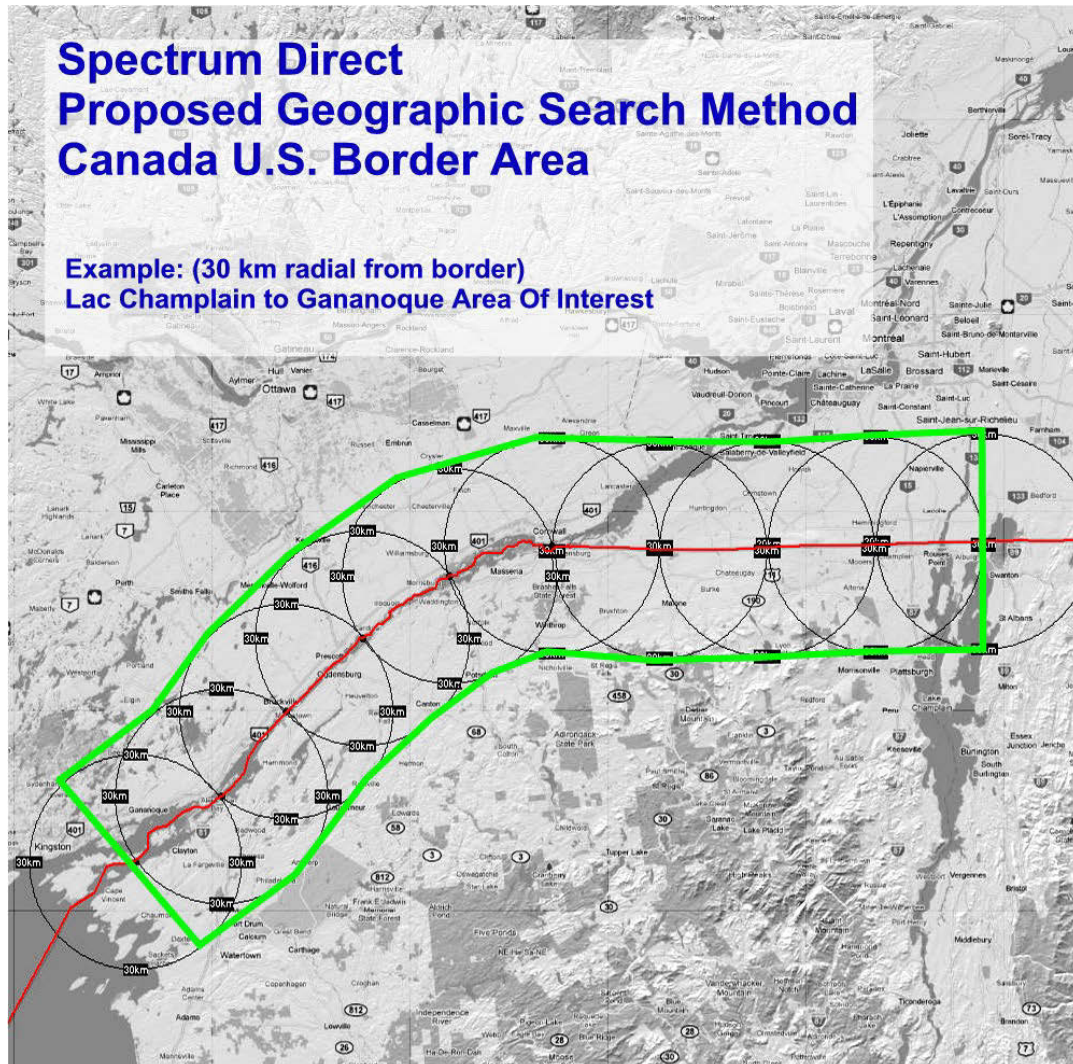


Figure 17 - Zone creation process

The 30km bands were selected to manage the overall scope of the project. As explained in “WP 2100 Document Survey and Context Definition”, only those first responder radio systems in a 200km wide band (100km in Canada and 100km in the US) were considered as relevant emitters for this AOI. This helped mitigate the final number of transmitter stations considered in the analysis and significantly reduced the overall data processing work required to produce the final radio coverage plots.

The length of the zone is "politically arbitrary" but was determined to generate image files that were approximately the same size. The zones were computer-generated by using the files obtained by the International Boundary Commission containing 11,406 records (red line in Figure 17) thereby allowing the definition of a very detailed zone outline. This is an important and very useful feature as multiple levels of zoom is allowed in the Google Earth™ viewer and image quality is maintained throughout.

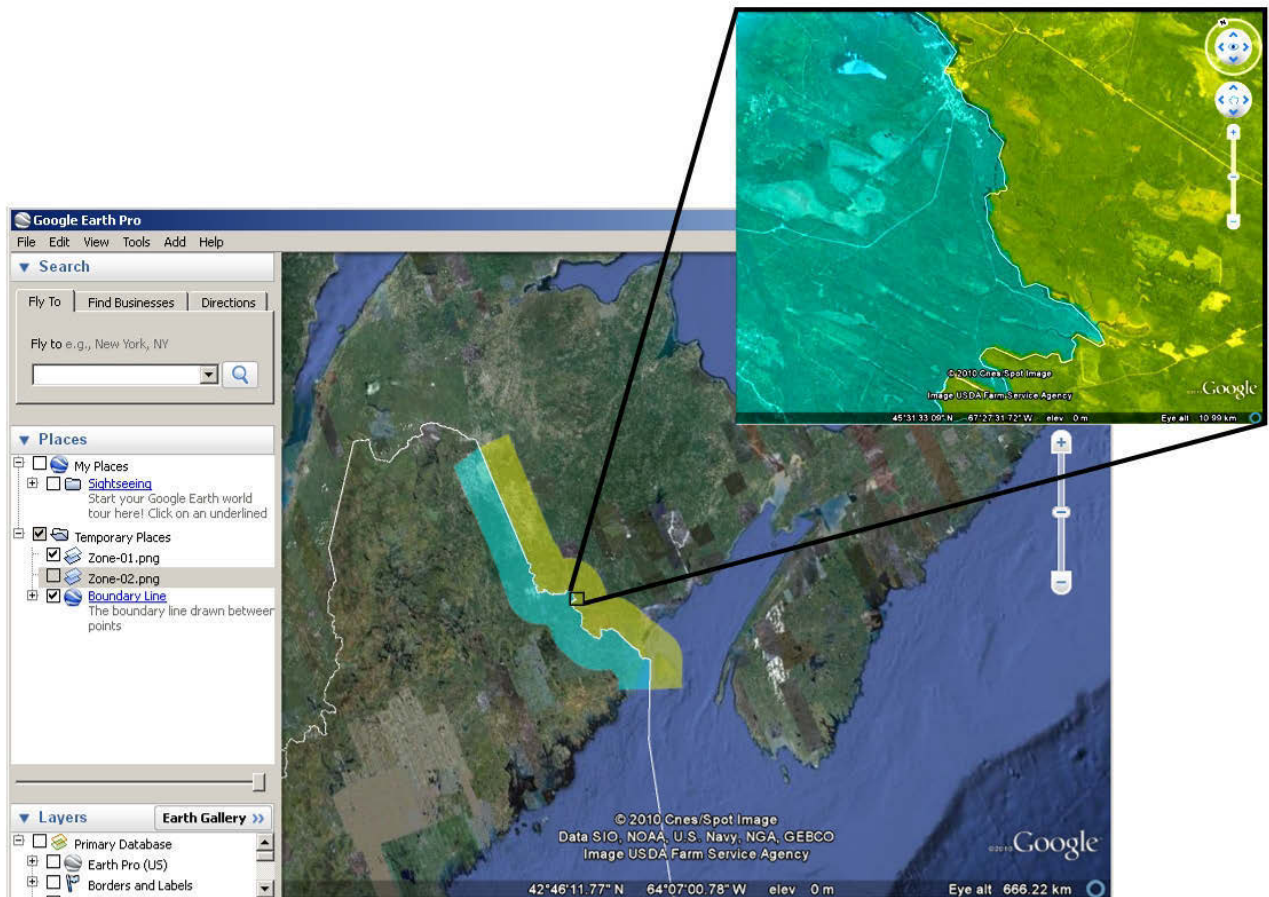


Figure 18 - High Quality Zone Image

Any polygon can be used to define a zone for the purposes of calculating performance metrics in "WP 2410 Define Operational Availability Metrics"; this allows end users to modify the zones to exactly fit their respective areas of interest and automatically generate their coverage metrics. The metrics are generated by calculating the number of pixel overlays of the "coverage plot" over a "zone band" (blue or yellow) at a single geographic position.

The choice of colors was made based on the use pure colors which are most appropriate for the visual acuity and for ease of computation using image analysis software as described in "WP 2410 Define Operational Availability Metrics". Zone images are high resolution images in the range of 3 megapixels and compressed in the .png format. The white areas in the .png format are transparent when viewed directly in Google Earth™; 28 zones in .kml and .png formats were created to cover the entire border area. Zone 1 is the most eastern; a .dat file associated with the zone contains the geographical coordinates of each zone image.

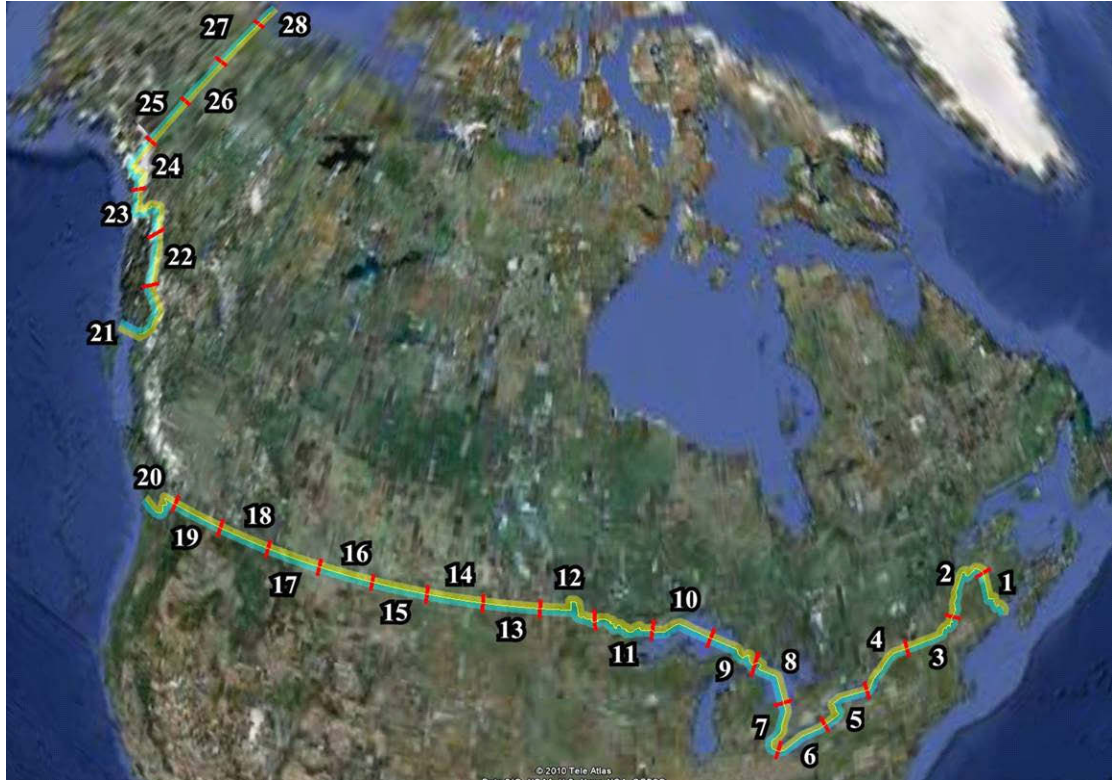


Figure 19 – 28 Zones along the Boundary Line

5.1.1 Zones for Use in Radio Mobile for Windows

The International Boundary Commission border vector was converted for use in Radio Mobile for Windows (RMW) with OziExplorer Track Point File Version 2.1 in WGS 84 format as .plt files. These files can be used to "draw objects" in RMW; 22 files were produced (see attachments).

5.2 Territorial Sea Limit

Note that there are no zones defined on the British Columbia border as these are international waters and therefore not part of the CANUS border. The same logic is applied to the Canadian Arctic regions.

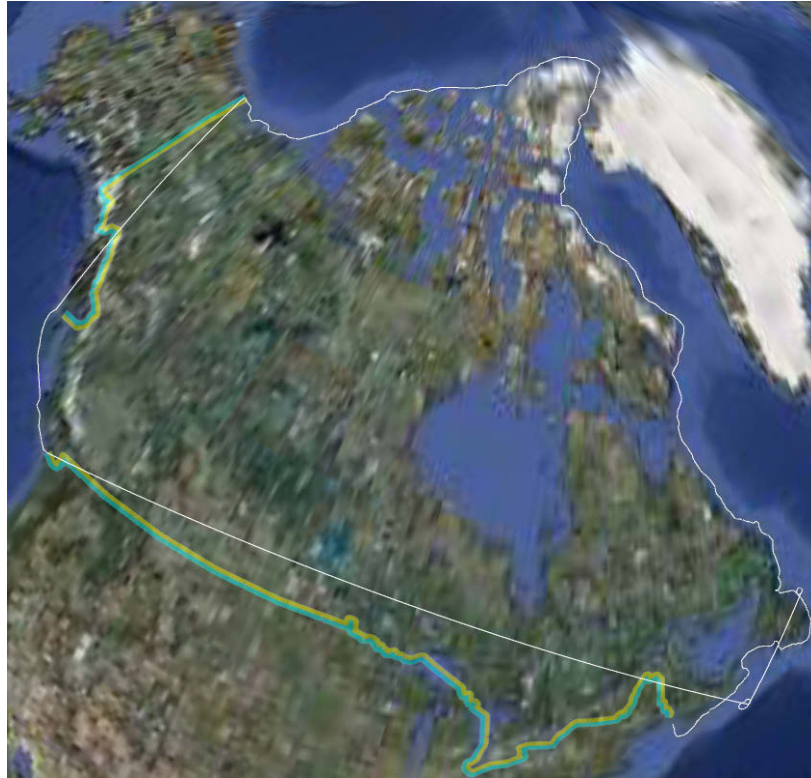


Figure 20 - Zones and the Territorial Sea Limits

5.3 Zone of Applicable Emitters

Because radio emitters located on high terrain like mountain tops can radiate over large distances, a selection criteria for candidate radios, similar to what is used in Figure 17 but with a 100 km radius, was used to generate the emitter database used in "WP 2100 Document Survey and Context Definition".

With a MathCad program, the selection of emitters located at 100km distance from the border was validated.

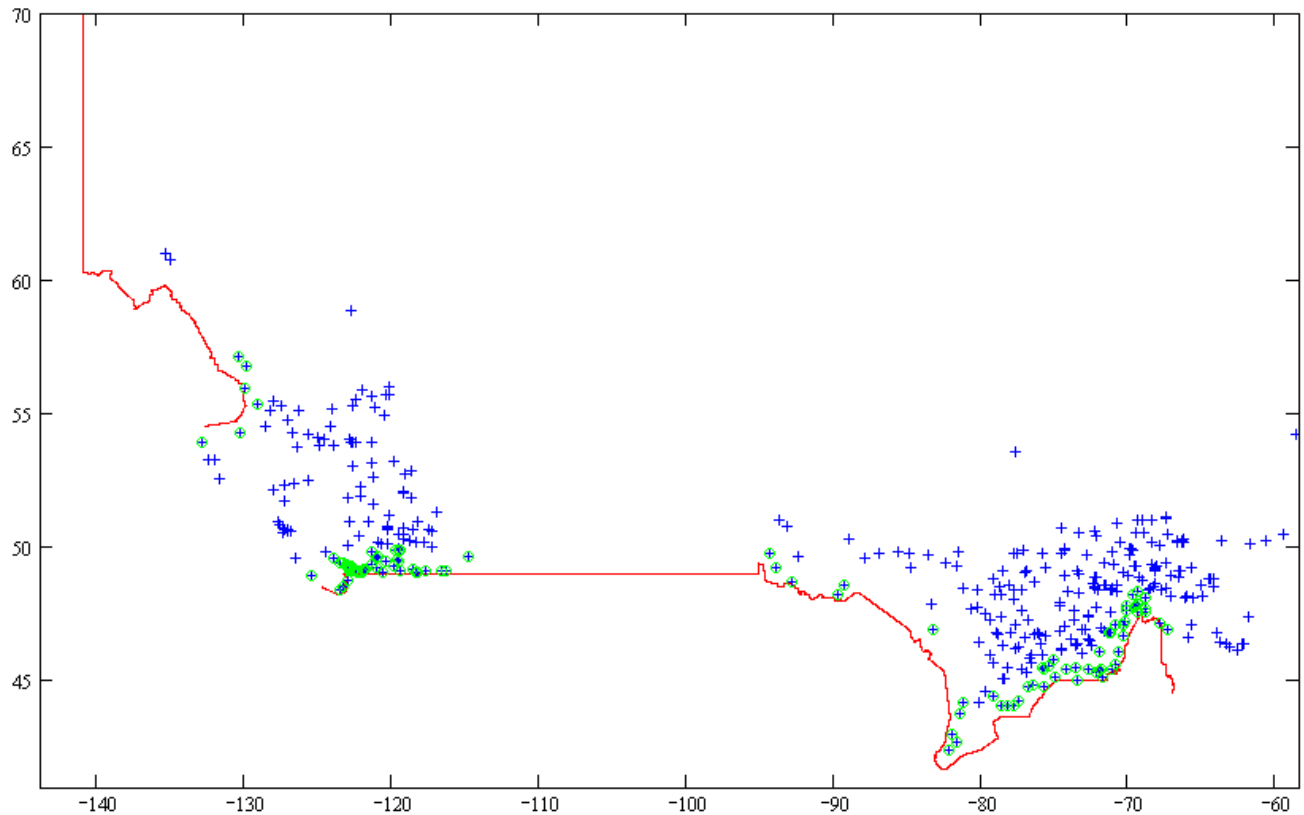


Figure 21 - MathCad Program Output for Database Subset
(Stations at < 100 km stations are circled in green in this example.)

6. Digital Elevation Model

Irrespective of the software tools used, Digital Elevation Model (DEM) data is required to perform accurate radio coverage maps. The most common datasets are Digital Terrain Models (DTMs) representing the bare ground surface and Digital Surface Models (DSMs) representing the ground surface including all objects on it such as trees, buildings, etc.

DTM variants of DEM datasets are available from several providers including DTED data from the United States Geological Survey (USGS) and CDED data from the Canadian Council on Geomatics (CCOG) which oversees GeoBase. Both these organisations freely provide DTM datasets created from geological surveys at ≤ 1 arc-resolution on a national scale.

Notwithstanding the above, the DTM chosen for this project is the NASA Shuttle Radar Topography Mission 1 (SRTM1 v2) data with a resolution of 1 arc-second ($\sim 30\text{m}$). The reason SRTM data is preferred for the CANUS border analysis is that of simplicity, as it offers seamless 30m resolution data along the entire border. Both CDED and DTED data are national, and as such, elevation data stops at the border. To arrive at comparable data to SRTM, one would need to combine both datasets and correct for any leftover discrepancies, which are guaranteed to exist. An example of the national datum limitations is shown in Figure 22 below. The SRTM data is automatically downloadable using RMW in the Internet settings. The data folder is of approximately 7GB size compressed.

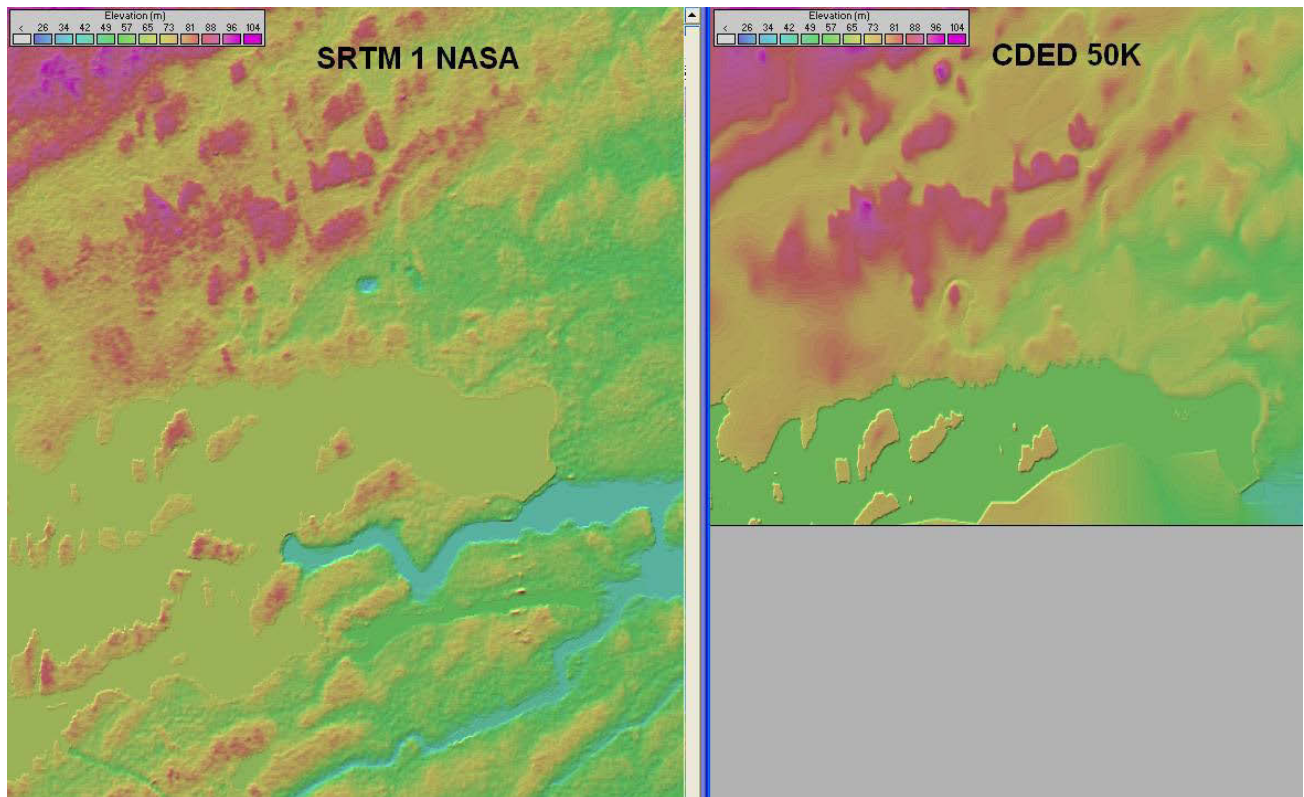


Figure 22 - SRTM1 v2 and CDED-50k CANUS Border Comparison (Cornwall Area)

Created from radar imagery, SRTM was originally in DSM format. The raw data was then processed by the Jet Propulsion Laboratory (JPL) to remove surface objects and produce 1 arc-second datum in DTM format, hence comparable to CDED/DTED datasets. Further editing of SRTM by the National Imagery and Mapping Agency (NIMA) produced the SRTM1 v2 datum, correcting existing data 'voids' and single pixel errors with interpolation. Coastlines and bodies of water have been refined with shoreline vectors as seen in Figure 23 below. While some surface objects and data voids are still present, the accuracy of the SRTM1 v2 datum is more than adequate for the scope of this project.

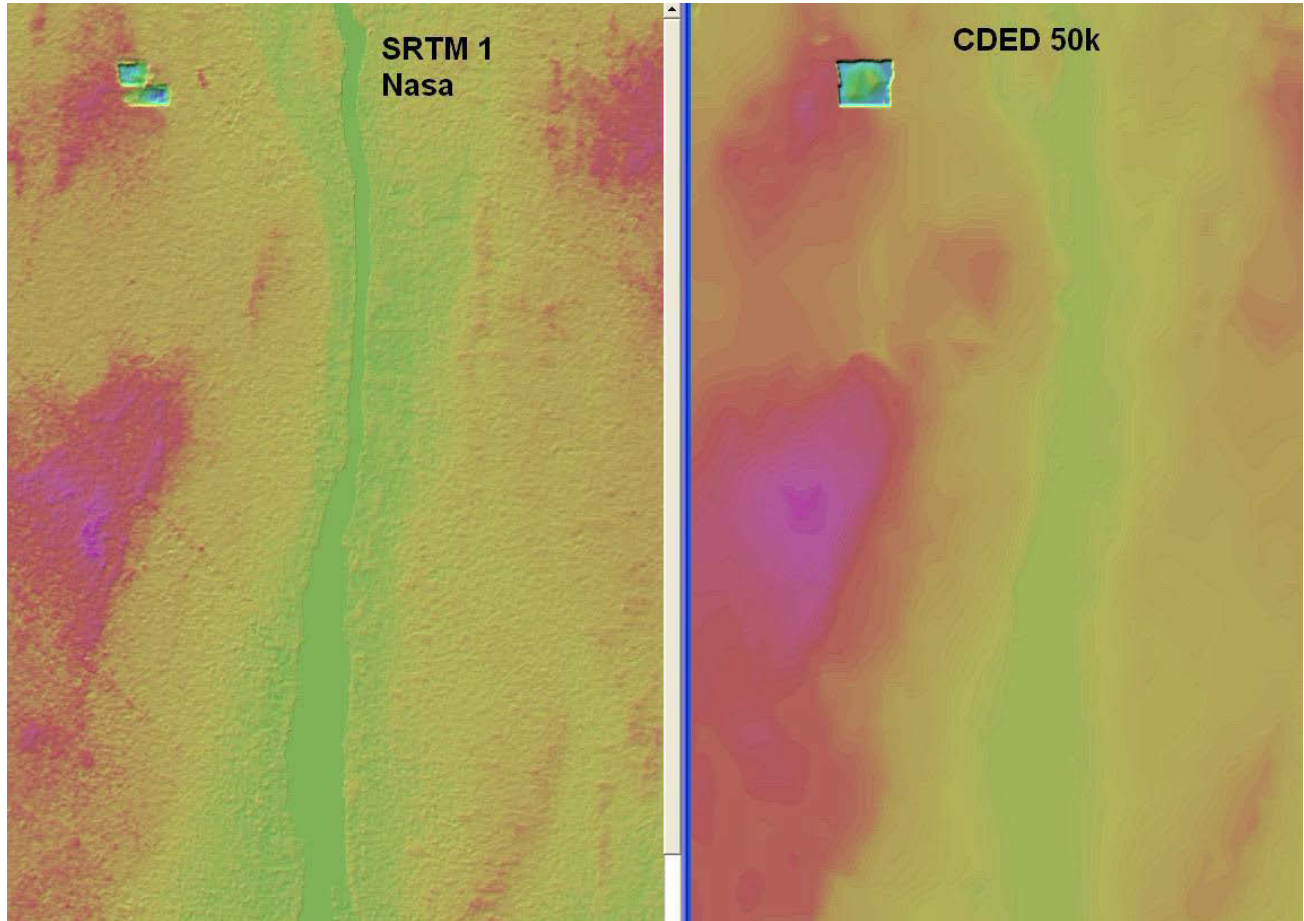


Figure 23 -SRTM1 v2 and CDED-50k Shoreline Comparison (along Richelieu River)

Using the SRTM1 v2 data, 2000 x 2000 pixel images will be drawn representing a 200x200km square radio coverage map with a resulting 100m/pixel resolution. An individual image will be created for each applicable radio emitter or base station (BS) within 100km on both sides of the border.

The “Map Properties” menu in RMW shows the DEM terrain resolution in m/pixel.

Properties of ..\net1.map

Centre
 45°00'36.0"N 074°45'00.0"W
 FN250A
 Latitude: 45.01 Longitude: -74.75
 Use cursor position
 World map
 Select a city name
 Enter LAT LON or QRA
 Select a unit

Size (pixel)
 Width(pixels): 2000 Height (pixels): 2000

Size (km)
 Width(km): 200.00 Height (km): 200.00

Elevation data source
 Drive or path: f:\geodata\srtm1
 Top layer: SRTM
 None
 None
 None
 None
 Ignore missing files: ☒
 Initialize matrix with elevation (m): 0

Buttons: Extract, Cancel

Coordinates:
 Top Left: 45°54'36"N 076°01'22"W
 Top Right: 45°54'36"N 073°28'38"W
 Bottom Left: 44°06'36"N 076°01'22"W
 Bottom Right: 44°06'36"N 073°28'38"W

Resolution: 100.0 m/pixel, 3.24 arcsecond

Figure 24 - RMW Map Settings

7. Land Cover Data

The DEM data used in this analysis is of digital terrain model format, hence only presenting the bare ground surface. In an attempt to account for physical objects located on the surface, land cover data with 1 arc-second resolution will be used. The data is automatically downloadable via RMW in the Internet settings. The data folder is of approximately 6 GB size compressed.

Land cover data modifies simulations obtained using terrain data only by introducing a rough concept clutter (several categories of vegetation and building data is defined) into the analysis such that the simulated radio paths account for physical objects. An example of this is shown in Figure 25 below. Using the land cover data, the propagation model (Longley Rice) in RMW will compute additional path loss, based on statistics and the category of land cover encountered. While using land cover data in coverage simulations does take into account some of the effects of physical objects in the radio paths, it is not meant to replace high resolution clutter databases found in tools such as ICS Telecom from ATDI which, when properly employed can yield very high levels of accuracy.

Additional information on land cover values and RMW parameters used to perform the radio coverage simulations can be found in "WP 3100 Propagation Analysis" section of this document.

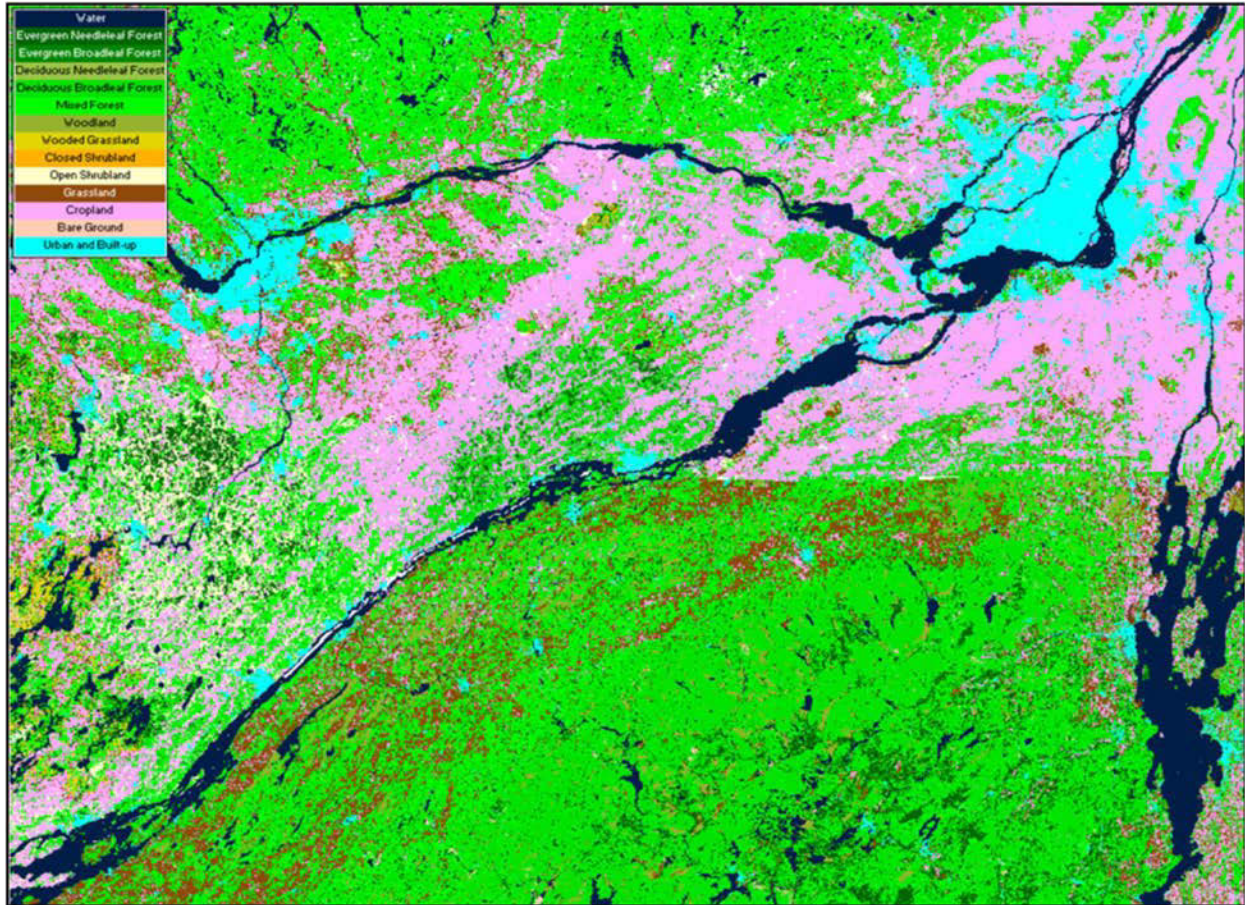


Figure 25 - land cover data (Ottawa to Montreal region shown)

8. Attachments

The following attachments are included with this analysis:

- Mathcad - Least Distance from Border v11.pdf
- Least Distance from Border v11.mcd
- 1999TerrSea v02.xls
- 1999TerrSea.dat
- Zones Directory 28 x (.dat, .kml, .png)
- 22 x .plt files (for use in RMW)
- BoundaryLineAvgCoord.kml
- BoundarySections.kml
- Canadian Territorial Sea Limit.kml
- DULA CHS v01.pdf

9. Abbreviations

AOR	Area Of Responsibility
CANUS	Canada and United States
CDED	Canadian Digital Elevation Data
DULA	Direct User Licence Agreement
MDSC	Martello Defence Security Consultants
RMW	Radio Mobile for Windows
SRTM	Shuttle Radar Topography Mission
WP	Work Package

Project number: PSTP 02-302 EMSI

Manage the Scope of the Coverage Analysis

WP 2300

Document number: MDSC-ANA-0007 v01, 07 Mar 2011

1. Purpose

The purpose of this document is to describe the data reduction approach that is used to produce the Canada-United States (CANUS) border radio coverage analysis. The task is colossal given the level of detail available in the radio license databases and the large geographic size of the border area.

Programmatic constraints such as budget, schedule and resource availability are also a fundamental limiting factor that is taken into account in the presented methods.

Administrative and process differences between the Canadian and US radio licence databases has required the identification of common denominators which resulted in a nominal, but unified database of public safety users.

To mitigate the above mentioned program and administrative concerns, progress in available computing power and advancement in sophistication of software used in this project has enabled an increase of level of fidelity and detail in the output of the radio coverage maps.

2. Scope

This document applies to the "WP 3100 Propagation Analysis" section of this document.

3. Contacts

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H3C 3J7

tel.: (514) 343-6111 ext. 5502
e-mail: talonsuz@rqchp.qc.ca

URL: www.rqchp.qc.ca

4. References

Rec. ITU-R M.1808 1 RECOMMENDATION ITU-R M.1808*
Technical and operational characteristics of conventional and trunked
land mobile systems operating in the mobile service allocations
below 869 MHz to be used in sharing studies
(Questions ITU-R 1-3/8 and ITU-R 7-5/8)

5. Magnitude of Task – Facts and Figures

The CANUS border is 8891km long and our area of interest for relevant radio emitters is a 100km wide band on each side of the border; an area of 1.8 million square kilometers! Within that area, it is foreseen that the radio coverage maps will be produced at a resolution of 100m/pixel so we are scaling up by a factor of 100 the number of pixels to be produced for a whopping 180 Mpixel composite image.

In "WP 2100 Document Survey and Context Definition", the following number of first responder base station radio license records were itemized: Canada = 7220, Unites States =7722. For each record, a radio coverage map of 2000 x 2000 pixels will be produced; an all-inclusive 59 Gpixel mosaic! Each radio coverage (potentially up 14942 in total) will then be compared to the border region in image processing software as described in "WP 2400 Define Success Criteria" to quantify the radio coverage gaps in the border area. Fortunately, Martello Defence Security Consultants inc. (MDSC) has secured an agreement with the Réseau québécois de calcul de haute performance (<https://rqchp.ca>) for the use of:



Cottos (highlighted in orange glow)
Operational from: August, 2009

Description

1024 CPU cores
128 compute nodes equipped with two Intel Xeon E5462 quad-core processors
@ 3 GHz
16 GB of memory per node (2 TB in total)
Non-blocking DDR Infiniband network
ROCKS+ (Linux CentOS 5) operating system (on which MDSC has run Radio
Mobile for Windows over Wine emulation, tests completed Dec. 2010)

Initial benchmark testing confirmed that the calculations take 1.51 CPU-hour per record (including the Windows emulation over Linux). The entire database can be calculated in 21 hours, assuming all CPUs are available, at a cost of approximately \$5,000. Typically, 300 CPUs are available at any given time due to job sharing, which results in 4 days of continuous calculations. Technology is not a major issue and using Cottos is an added benefit for end users as detailed maps will be available at the first round of the project. The RQCHP cost of the preliminary testing was \$750.00.

The data reduction means presented herein were applied to the initial 14942 records of first responder radio emitters database identified in WP 2100. This allowed minimizing the final database considered for this analysis to 7397 records; 2309 emitters on the Canadian side and 5088 emitters on the US side. The final calculations were performed by the RQCHP on the 7397 records and took 11161 CPU-hours to complete at a cost of \$2658.90. This amounts to a \$0.23 per CPU-hour based on a cost of \$0.15 per CPU-hour plus system's analyst time. The 7397 coverage plots performed at 100m/pixel resolution and associated metadata are included in the "WP 3200 Produce Coverage Visualization Maps" section.

6. Data Reduction Means for Radio License Database

In order to minimize the number of records, the following data reduction means were taken on the database:

Name	In project	Description	Issue	Impact on end user	Cost Impact	Alternative method
Paper documents (maps, textual reports)	no	A number of unformatted reports were received from various end users.	Time consuming to do data entry.	low	med	Image overlay only in "WP 3200 Produce Coverage Visualization Maps". Images will be converted and geo-referenced as Google Earth™ files.

Name	In project	Description	Issue	Impact on end user	Cost Impact	Alternative method
Incomplete license data from end users (obtained from partial responses to Request For Information)	no	IC database does not contain a "Public Safety" radio service code like in the FCC database. Lat/long, city name and frequency only.	Time consuming to manually research data on the IC and FCC license servers and then do manual data entry. Commercial carriers servicing public safety users are registered as commercial carriers in the license database, there is no field on which to filter and select the data. example: Ontario OPP is on Fleetnet Bell Mobility, Cowansville Fire is on Telus Mike network, Mont-Tremblant is on Bell Mobility. Some records are classified and not made available to the public.	med	low	Regional training sessions offered in "WP 4300 Coverage Analysis and Training" will allow the end users to plot their own radio coverage maps. The framework and methodology is in place so technical risk is low.
Voice radios	yes	All FM analog voice radios were selected.	Successfully yielded a large number of records = 14,942	n/a	med	n/a
P25 radios	partial	Voice radios using digital modems.	There is no metadata in the IC database that identifies a P25 radio. Some P25 radios may be missing (for Canadian database) if the radio licence records does not use the class of emission code F3EJN.	med	med	Industry Canada to provide database subset for P25 radios. Separate project in progress at IC, data is not ready for publication. Re-run the delivered propagation program.

Name	In project	Description	Issue	Impact on end user	Cost Impact	Alternative method
Use of generic emitter data and frequency band subsets per R-REC-M.1808E (Rec. ITU-R M.1808)	no	With the availability of a multi-CPU compatible batch file for RMW, exact RF parameters (including frequencies, antenna orientations and antenna gains) are used for each base station. Only the mobile is generic and this is to allow individual radio coverage to be compared to each other.	None. Best value offered to end user.	high	med	MDSC to use generic transmitter data to reduce scope and use a desktop machine to perform RF propagation calculations at lower fidelity.
Use of generic antenna patterns	yes	Limited to four types: omni, yagi, ellipse, cardio	Complex relational database and look-up tables required.	low	high	Design a relational database to extract the data for propagation analysis. These four types of antennas are retained (as an ease of use element) to allow end users to repeat their own coverage plots with RMW default values. Field test "WP 3400 Validate with Field Measurements" did provide additional insight on this issue, specifically regarding end user impact, details of which are presented in "WP 2420 Range Calculation Error Budget Analysis".

Name	In project	Description	Issue	Impact on end user	Cost Impact	Alternative method
Handset , mobile and transportable repeaters	no		Handsets have too many variables associated to them in terms of system performance i.e.: in-building penetration where antenna is worn on body audio quality in noisy environments Mobile and transportable repeaters cannot be assigned with a fixed location to be plotted on the coverage map.	med	low	Re-run the delivered propagation program with specific end user handset configuration.
Delete multiple occurrences of same call sign	yes	Typically selecting the highest system gain record for a given end user will indicate the longest range of operation for that particular user.	Some licenses have the same call sign.	low	low	Plot all records (higher cost).

7. Data Reduction Means for Digital Elevation Model

The resolution of the DEM data used in this analysis (SRTM1 v2) is 1 arc-second (~30m). Selecting a terrain resolution of 100m/pixel is time saving; effectively reducing the required CPU processing time to calculate the radio coverage maps by a factor of 10.

8. Data Reduction Means for RF Coverage Calculations

8.1 Maximum Range

The maximum range of 100km (radial) has been selected. Reducing that range to 25km for example would yield at least 16x reduction in CPU time plus the advantage of eliminating radios that are further than 25km from the border. Although worth while in terms of time and cost savings, this option may produce too many "artificial coverage gaps" in the output and was not retained.

8.2 Pruning Algorithm

An algorithm that sorts the radios in decreasing order of EIRP would allow plotting the largest coverage first. If any other radios are in that coverage area, the records would be skipped and then, for the next coverage gap, the nearest radio with the highest EIRP would be plotted. The sequence would continue until all the gaps are covered.

This method would be difficult to program but would converge fast. It would not, however, allow visibility of individual emitters and not allow a high fidelity visibility of functional groupings like fire, emergency medical services, coast guard and police. This method was not retained.

9. Abbreviations

CANUS	Canada - United States
CPU	Central Processing Unit
DDR	Double Data Rate
EIRP	Effective Isotropic Radiated Power
FCC	Federal Communications Commission
FM	Frequency Modulation
Gpixel	Giga pixel (10^9 pixel)
IC	Industry Canada
i.e.	id est, that is
MDSC	Martello Defence Security Consultants inc.
Mpixel	Mega pixel (10^6 pixel)
pixel	picture element
ITU	International Telecommunications Union
OPP	Ontario Provincial Police
RF	Radio Frequency
RQHCP	Réseau québécois de calcul de haute performance
RMW	Radio Mobile for Windows
TB	Tera Byte
Wine	Windows emulator
WP	Work Package

Project number: PSTP 02-302 EMSI

Define Operational Availability Metrics Analysis

WP 2410

Document number: MDSC-ANA-0005 v01, 07 Mar 2011

1. Purpose

The purpose of this document is to describe the methods used to calculate radio surface coverage availability metrics and provide first responders with a mean to perform their own availability metrics calculations based on their respective Area of Interest. The document also presents the software tool created to analyze and compare, based on pixel distribution, the radio coverage images to the CANUS area of interest (AOI); the 60km band defined in WP 2200.

2. Scope

This document is a subset of "WP 2400 Define Success Criteria" and applies to Work Package:

WP 2100 Document Survey and Context Definition,
WP 2200 Define Radio Coverage Area of Interest,
WP 3100 Propagation Analysis,
WP 3300 Assess Severity of Coverage Gaps, and
WP 4300 Coverage Analysis Training

3. Methodology

3.1 ZoneCov Program – User Interface

A program called ZoneCov.exe, for zone Coverage, has been created specifically for this project and the executable code is included as an attachment with this report.

ZoneCov calculates how many radio coverage pixels overlap the yellow and cyan zones that make up CANUS AOI defined in "WP 2200 Define Radio Coverage Area of Interest" for each base station. The user can make any selection of zones (left pane) and radio coverage plots (right pane).

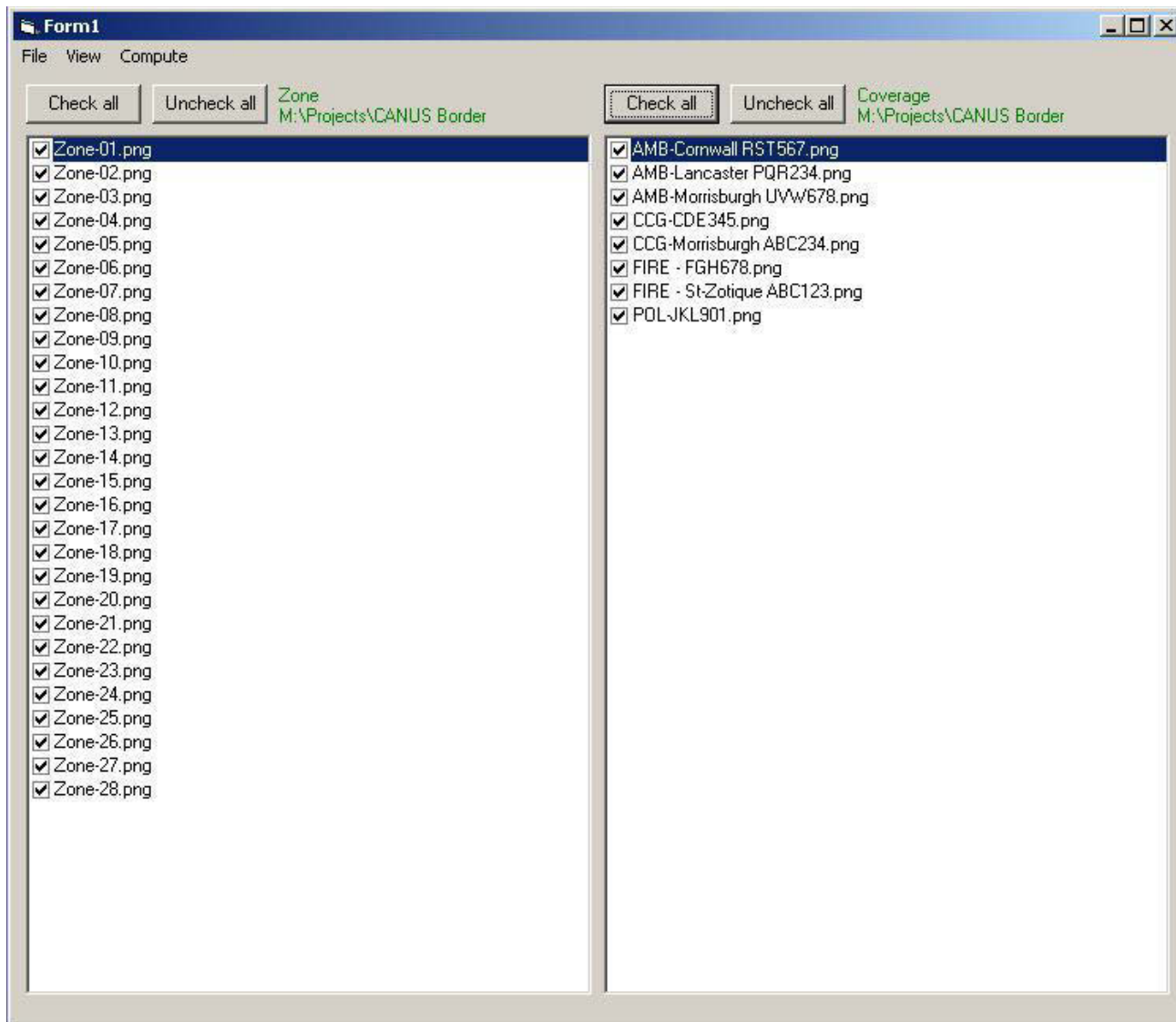
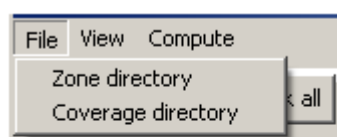
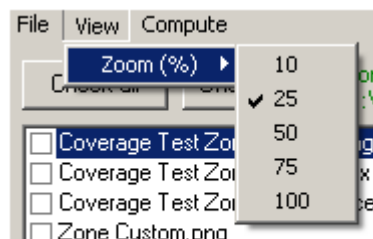


Figure 26 - Zone and Coverage Selection



File Menu



View Menu

Figure 27 - File and Zoom Menu

The zoom menu allows you to see the calculation progress in full screen mode. The Zone name and the radio coverage file name (call sign) are visible in the window title bar as well as a progress in %.

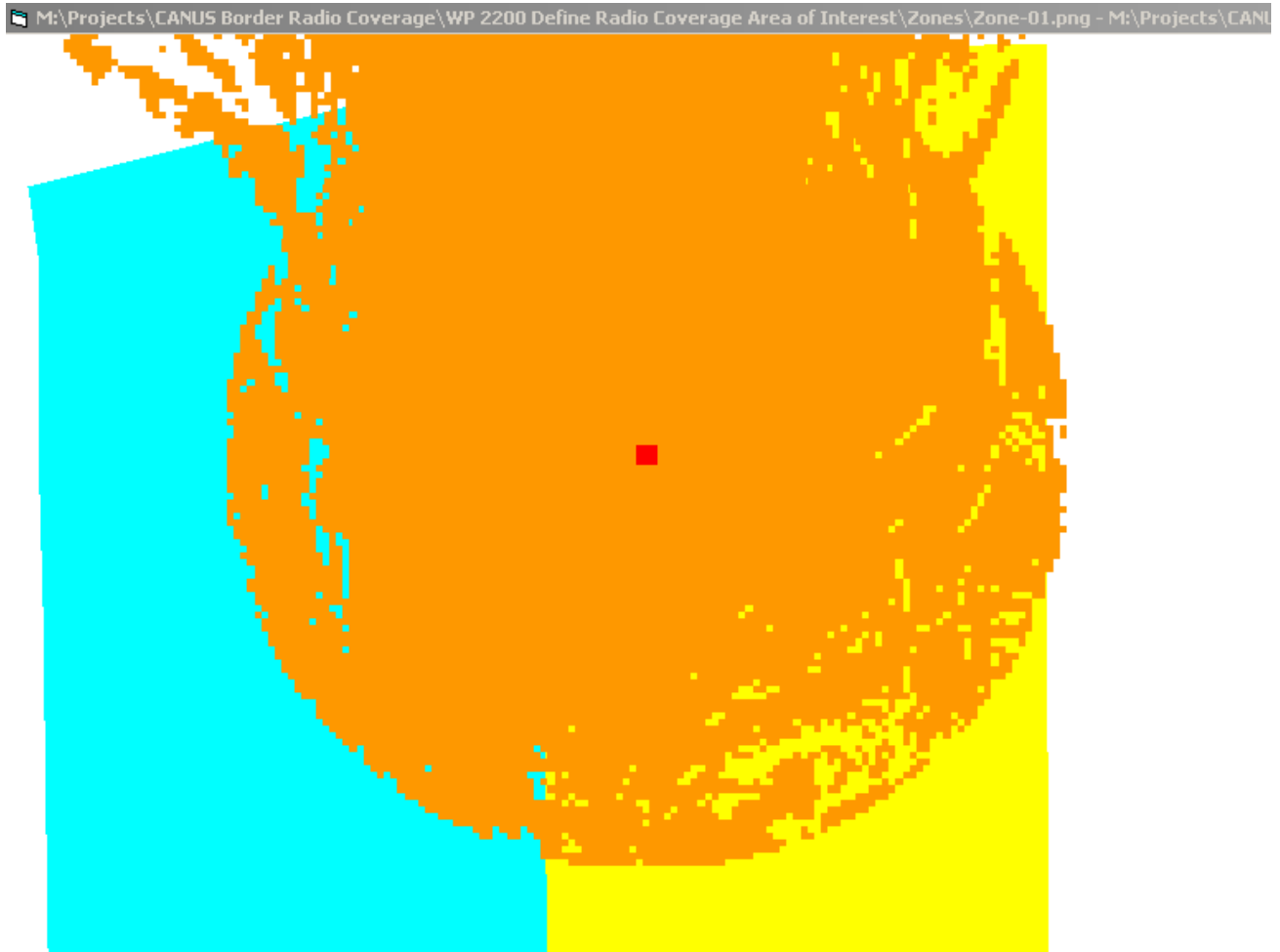


Figure 28 - Zoom / Progress Window

Calculation time is about 3 hours for ~1300 stations at low resolution (400m/pixel and 25 km max. range). Results are only compiled if the program completes the calculation. If interrupted by the user, results are not compiled and the .txt file is not saved so it is recommended to carefully plan the computing time before launching a job; use the combined pixel count of all coverage images divided by benchmark processing time of 7Mpixel/hour.

3.2 ZoneCov – Statistics

3.2.1 Evolution of Statistics for Radio Coverage

At the beginning of this project, a "linear coverage" metric was defined i.e. how many kilometres of border line at the "zero-mile" interface had no coverage (see red line in the figure below).

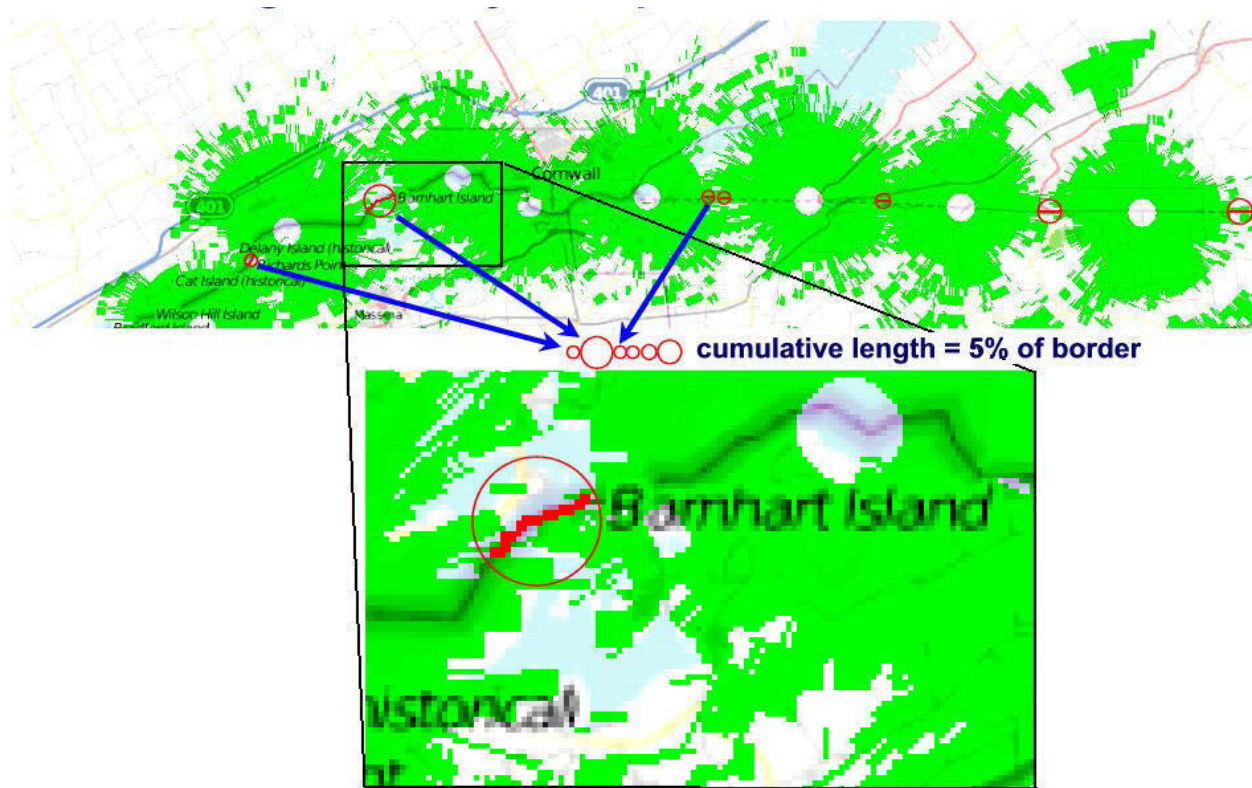


Figure 29 - Coverage Summary Example

It became apparent that the metric had to be two-dimensional because the surface of the coverage is more representative and its growth was the square of the distance (represented by the red circles); this led to the creation of ZoneCov.

3.2.2 ZoneCov – Statistics

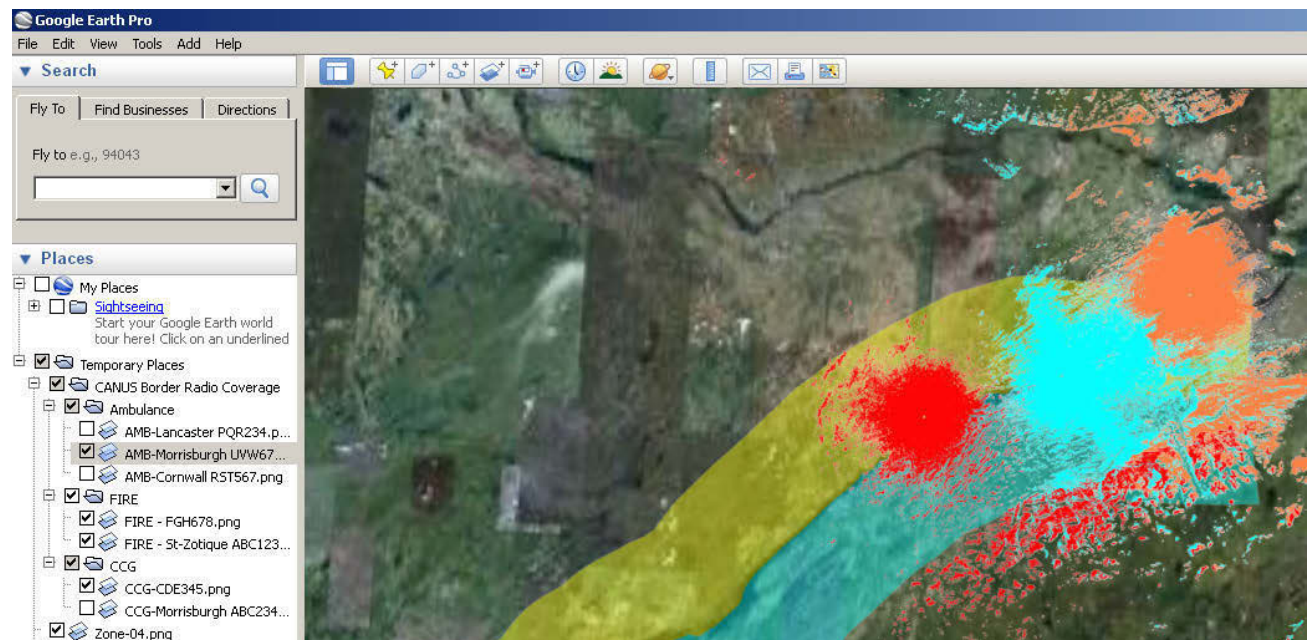


Figure 30 - Coverage Example Cornwall Generic in Zone 4

	A	B	C	D	E	F	G	H	I
	Zone picture	Coverage picture	Pixels Zone Canada	Pixels Covered Canada	Pixels Combined Canada		Pixels Zone USA	Pixels Covered USA	Pixels Combined USA
1	M:\Projects\CANIM\Projects\CANUS		905884	4953	4953		1033709	12509	12509
2	M:\Projects\CANIM\Projects\CANUS		905884	7886	8464		1033709	17016	18474
3	M:\Projects\CANIM\Projects\CANUS		905884	0	8464		1033709	896	18520
4	M:\Projects\CANIM\Projects\CANUS		905884	11332	13092		1033709	11692	19230
5	M:\Projects\CANIM\Projects\CANUS		905884	0	13092		1033709	82	19235
6	M:\Projects\CANIM\Projects\CANUS		905884	15339	18489		1033709	17093	21840
7	M:\Projects\CANIM\Projects\CANUS		905884	0	18489		1033709	5531	22080
8	M:\Projects\CANIM\Projects\CANUS		921924	95509	95509		919466	139634	139634
9	M:\Projects\CANIM\Projects\CANUS		921924	110232	144012		919466	99526	152697
10	M:\Projects\CANIM\Projects\CANUS		921924	75996	219445		919466	81941	203372
11	M:\Projects\CANIM\Projects\CANUS		921924	155514	245080		919466	134141	212237
12	M:\Projects\CANIM\Projects\CANUS		921924	129982	306134		919466	106365	253835
13	M:\Projects\CANIM\Projects\CANUS		921924	10622	306165		919466	4899	253861
14	M:\Projects\CANIM\Projects\CANUS		921924	64578	324327		919466	48019	256242
15	M:\Projects\CANIM\Projects\CANUS		921924	157253	364951		919466	118779	262715
16	M:\Projects\CANIM\Projects\CANUS		921924				919466		

Figure 31 - ZoneCov Statistics

ZoneCov will produce surface coverage statistics and store them in a .txt file. The "pixels covered" is representative of total surface area covered in a zone subset (yellow) or (cyan); if two radio stations cover the same pixel area it is only counted once. The "pixels combined" is a notion of redundancy: if two stations cover the same pixel area a count of 2 is kept. It is important to note that ZoneCov produces surface coverage availability statistics, **not** performance coverage availability statistics.

ZoneCov does not discriminate the pixel color of the radio coverage plots but is sensitive to the zone sun-band color (yellow) or (cyan) used to generate Canada and US specific statistics.

An example of "border-wide" statistics based on the first run of the IC database "IC PS Pool for RMW Batch v10 for First Run 02 Dec 10.xls" is presented in Figure 32 below.

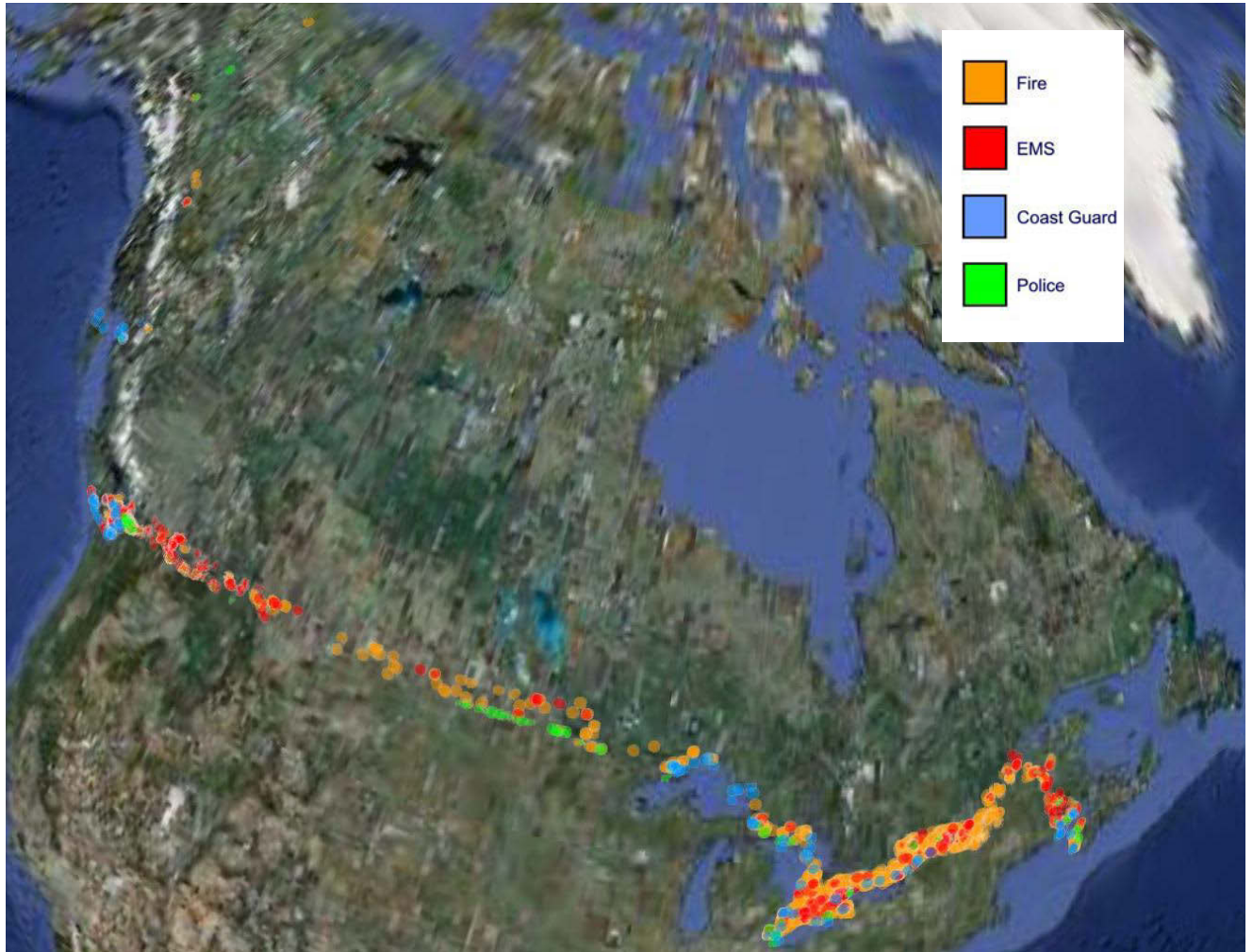


Figure 32 - IC PS Pool First Run (notional)

Note: Figure 32 and Figure 33 are notional only as this first run was performed in low resolution mode. The results contained in "WP 3100 Propagation Analysis" take precedence.

	Canada Overlap	Canada Coverage	US Overlap	US Coverage
Zone 1	317%	64%	67%	25%
Zone 2	195%	56%	89%	28%
Zone 3	626%	85%	88%	32%
Zone 4	1007%	91%	216%	43%
Zone 5	520%	56%	112%	21%
Zone 6	112%	33%	0%	0%
Zone 7	625%	83%	159%	40%
Zone 8	45%	25%	2%	2%
Zone 9	193%	46%	77%	23%
Zone 10	89%	20%	0%	0%
Zone 11	12%	11%	7%	6%
Zone 12	58%	37%	28%	23%
Zone 13	36%	36%	2%	2%
Zone 14	53%	38%	1%	1%
Zone 15	22%	20%	5%	5%
Zone 16	15%	15%	0%	0%
Zone 17	6%	5%	0%	0%
Zone 18	96%	33%	37%	17%
Zone 19	254%	43%	109%	16%
Zone 20	832%	65%	86%	18%
Zone 21	0%	0%	0%	0%
Zone 22	0%	0%	0%	0%
Zone 23	0	0	0	0
Zone 24	0	0	0	0
Zone 25	12%	12%	6%	6%
Zone 26	0%	0%	0%	0%
Zone 27	1%	1%	0%	0%
Zone 28	0%	0%	0%	0%

Figure 33 - Border-Wide Statistics Example (notional)

Note: The formal "Canada and US Border Zones" were defined and supplied in "WP 2200 Define Radio Coverage Area of Interest". Zone numbers increment East to West.

3.2.3 ZoneCov – Software Testing

The ZoneCov program was tested with the following files:

Report_12_13_2010_13_19_48 Test 50% Canada Zone 1.xls
 Report_12_13_2010_13_34_02 2 X CAN 5 X US Zone 1.xls
 Report_12_13_2010_14_19_14 Zone_Test.xls

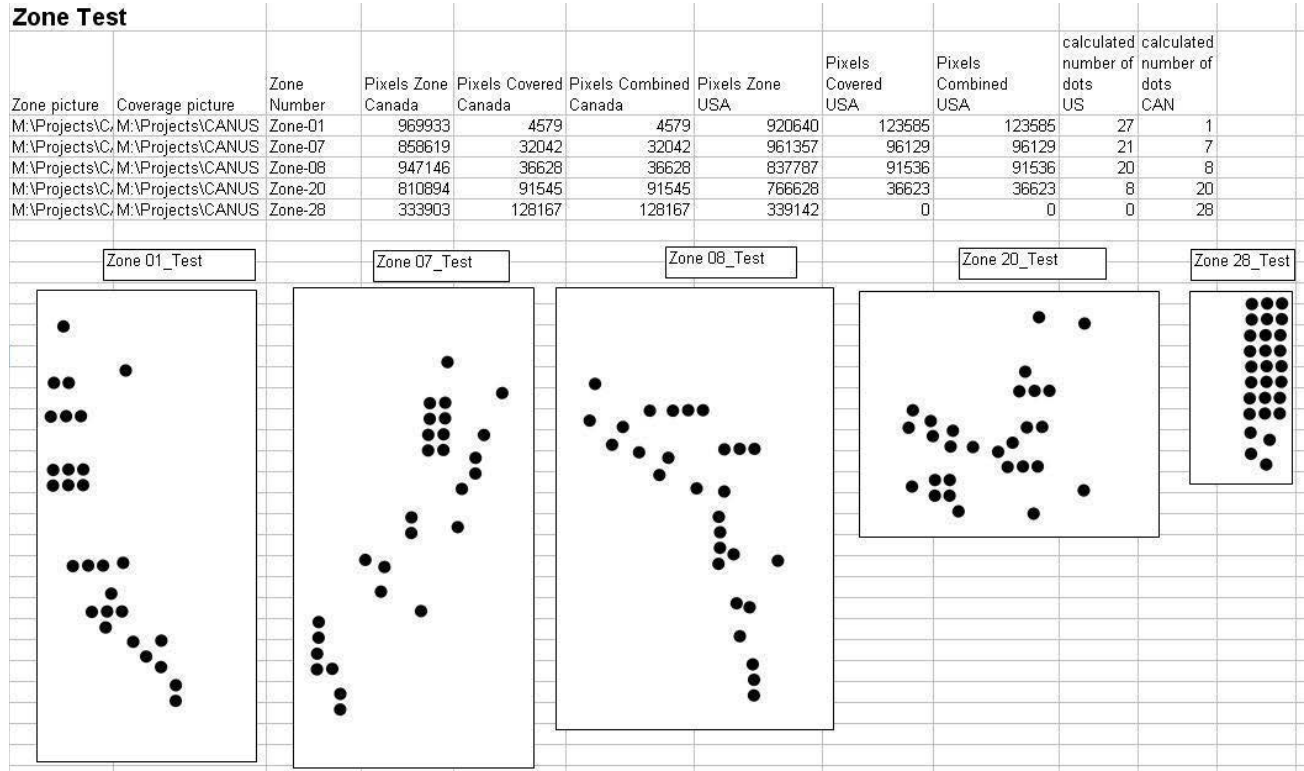


Figure 34 - Report_12_13_2010_14_19_14 Zone_Test.xls

The test in Figure 34 produced same size dots in alternating Canada and US zones with the following logic:

number of dots in US zone = 28- zone_number

The spreadsheet analyzed the results and confirmed the rule was observed in the data therefore ZoneCov properly calculated and reported the pixel distributions.

All test files are provided as an attachment to this report.

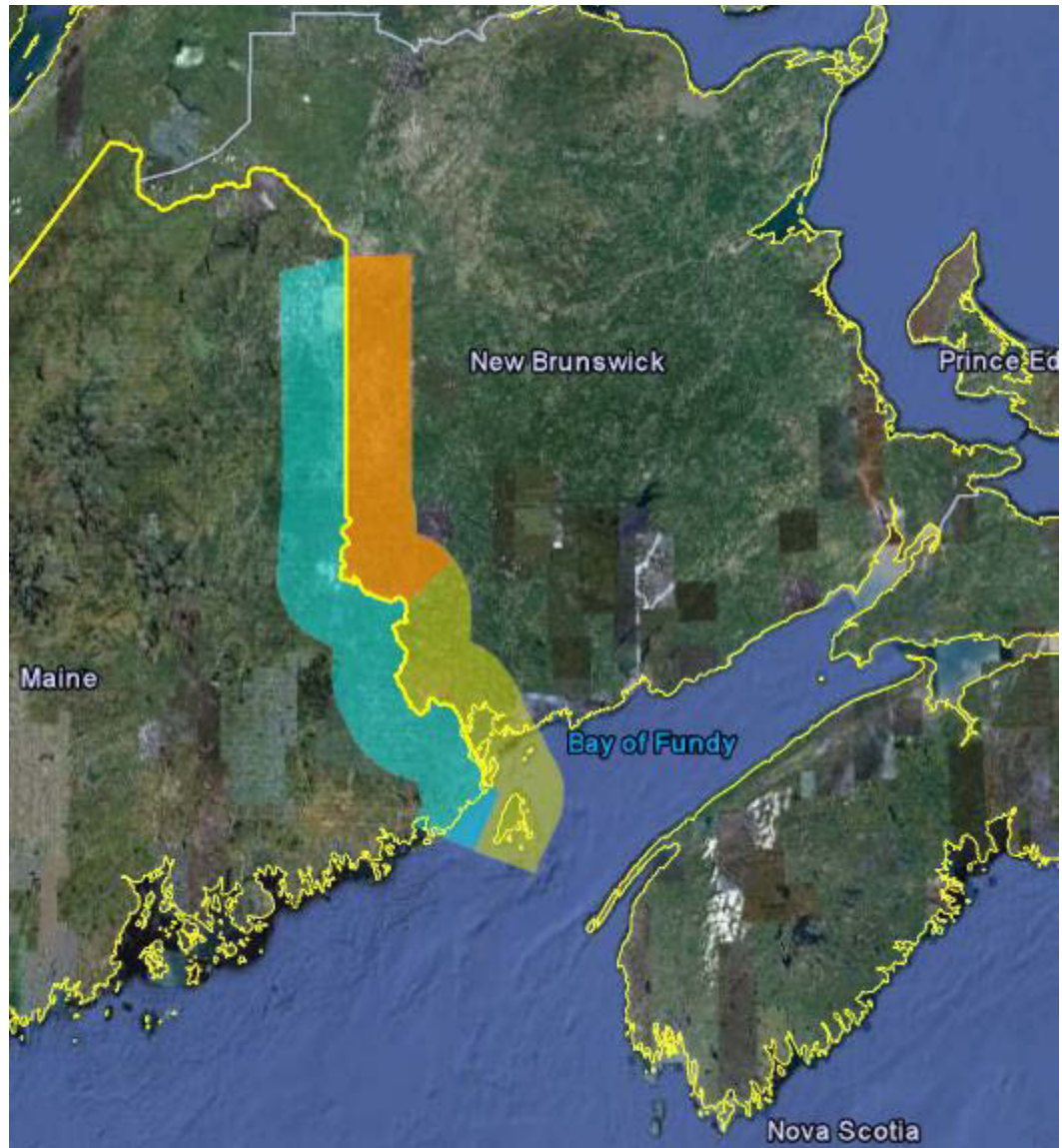


Figure 35 - ZoneCov Test 50% Canada in Zone 1 (orange section)

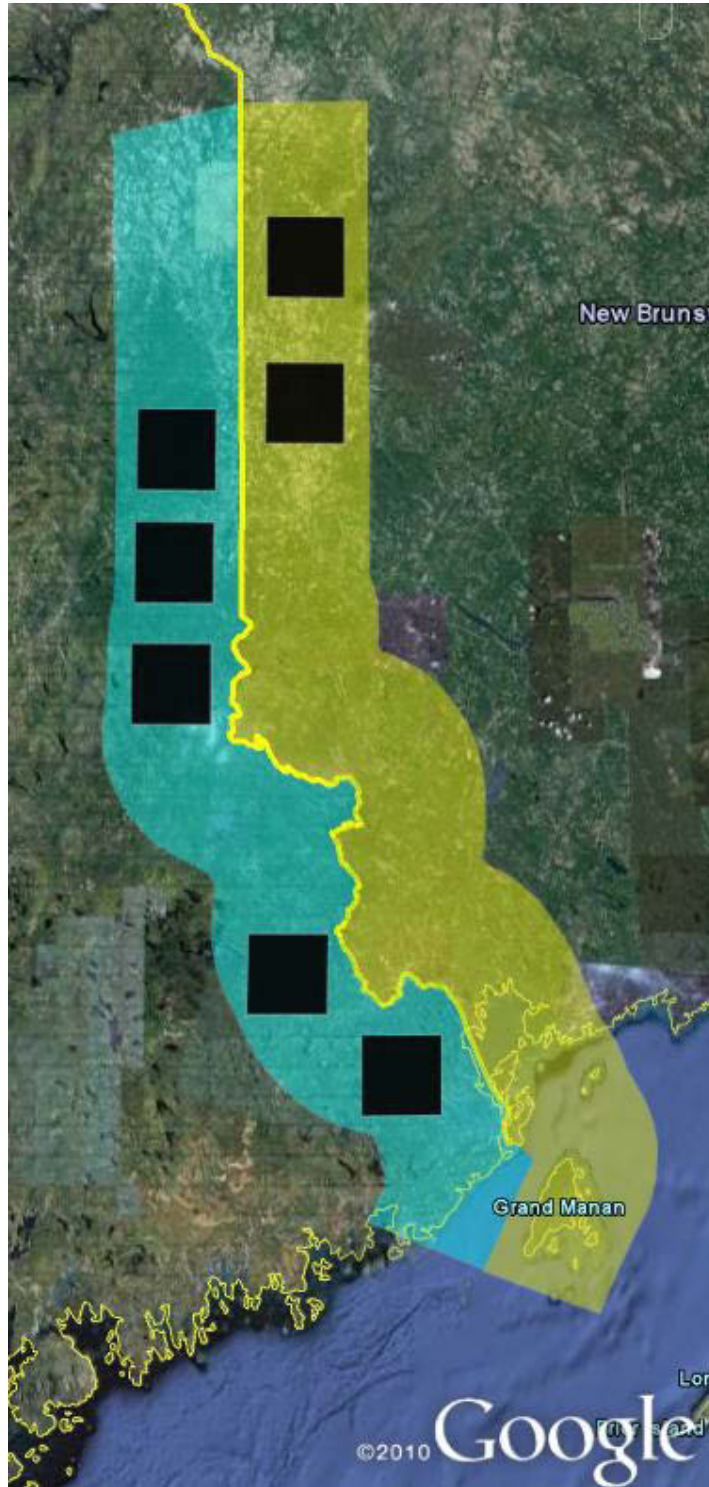


Figure 36 - Coverage Test Zone-01 2 x CAN 5 x US Into Zone 1
(Statistics show 2.5x more coverage in the US Zone for this test case)

3.2.4 Custom Zones

Users will have different metrics given their municipal, provincial / state or federal responsibilities and Areas of Interest. For example, your metrics can be community centric or road-specific as shown in the figure below.

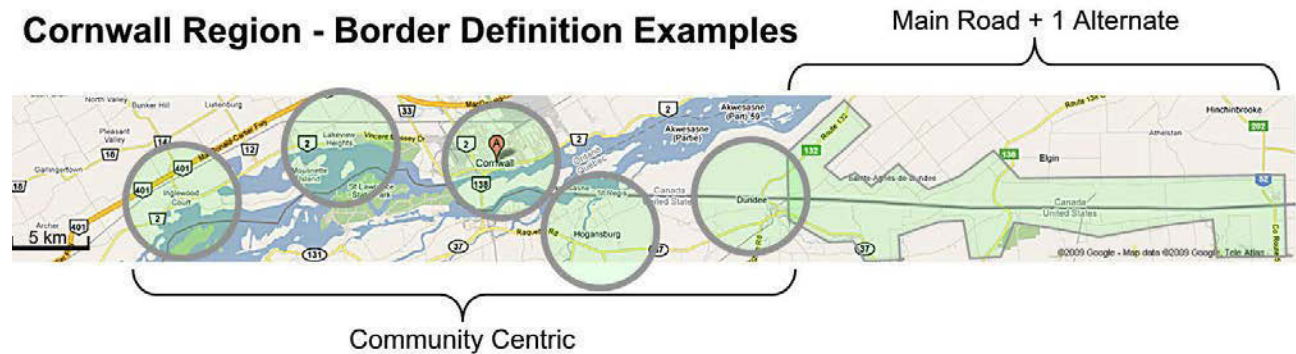


Figure 37 - Custom Zone Metrics

Customized zones can be created in any imaging software or in RMW, which if used to save the image will automatically create the required .dat and .kml files.

The four rules to follow are:

- 1) keep the original yellow and cyan colors for sub-zone definitions, they can be of any shape
- 2) save your images as .png files with white being transparent
- 3) zones have to be bound by a rectangle
- 4) change the geographic .dat (geographic coordinates of each corner of the image) and .kml (Google Earth) files corresponding to your zone's rectangle

A "Coverage Test Zone Custom" file is provided as an example of a dual colour zone and one radio coverage plot (red) over the island of Montreal, located top right in the figure below.

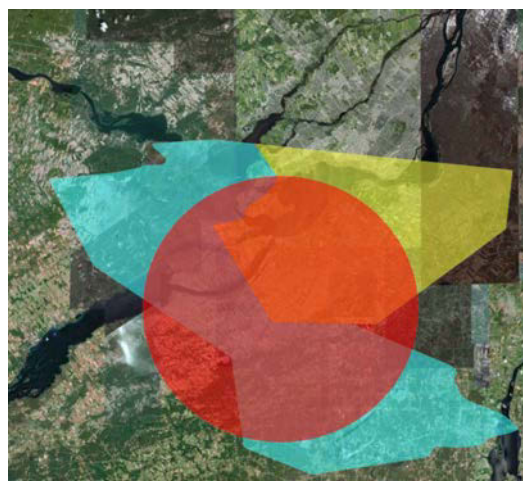


Figure 38 - Custom Zone Example

4. Attachments

ZoneCov.exe
Coverage Test Zone-01 2 CAN x 5 US.dat
Coverage Test Zone-01 2 x CAN 5 x US.jpg
Report_12_13_2010_13_34_02 2 X CAN 5 X US Zone 1.xls
Report_12_13_2010_14_19_14 Zone_Test.xls
Coverage Test Zone Custom.dat
Coverage Test Zone Custom.kml
Coverage Test Zone Custom.png
Zone Custom.dat
Zone Custom.kml
Zone Custom.png

5. Abbreviations

Mpixel	Mega (10^6) pixel
US	United States
WP	Work Package
ZoneCov	Zone Coverage

Project number: PSTP 02-302 EMSI

Range Calculation Error Budget Analysis

WP 2420

Document number: MDSC-ANA-0003 v02, 07 Mar 2011

Purpose

The purpose of this document is to provide an error budget, safety margin calculations and receiver sensitivity thresholds for the radio range calculation portion of the CANUS Border Radio Coverage project.

Scope

This document applies to all range calculations performed using the Radio Mobile for Windows software for this project, namely the results of presented in "WP 3100 Propagation Analysis". A similar methodology was considered for calculations performed with ICS Telecom from ATDI, the RF simulation/planning tool software use in "WP 3400 Validate with Field Measurements".

General Assumptions

- 1) The study focuses on radio equipment whose intended purpose/function is voice communications (as opposed to data or voice + data).
- 2) The study does not cover handheld radios; only vehicle-mounted radios are considered, which are referenced as "mobiles" in the document.
- 3) The study is missing public safety networks that are either unlisted in IC databases for security reasons or use commercial networks offered by Canadian carriers (Bell, Rogers, Telus, etc.), if such may be the case in the bands of interest.
- 4) All radios are considered to be operating on a non-interfering basis (ideal scenario)
- 5) With respect to Base Station (BS) parameters (Tx power, Tx line loss and Tx antenna gains), the "error budget" presents average typical values. For CANUS border coverage calculations, exact values of BS parameters were used generated from "batch script" analyses of IC/FCC databases. It is assumed that the IC/FCC databases are accurate.

- 6) With respect to mobile parameters (Rx sensitivity, Rx line loss and Rx Antenna gains), average typical values will be used as presented herein.
- 7) For this analysis, mobile antennas are assumed to be omnidirectional. In “WP 2300 Manage the Scope of the Coverage Analysis”, only four types of BS antennas are considered to manage the scope of this study; omnidirectional, yagi, ellipse and cardio. The test campaign of WP 3400 activities identified that the use of these default types may not always reflect actual antenna pattern and gain values of the equipment deployed in the field. This is especially true for BS omnidirectional antennas at VHF frequencies. Ideally, one would use the exact antenna patterns of each BS; this is the recommended approach for individual end-users.
- 8) The coverage analysis study is based solely on the downlink (BS to mobile) scenario i.e. on the transmit characteristics of base stations and the receiver characteristics of the mobiles. The asymmetry between uplink (mobiles to BS) and downlink communications will not be investigated due to the following hypothesis:

Operational requirements necessitate the ability of dispatch (BS) to communicate to mobiles at all times. Reverse (uplink) communications is not an operational requirement.

It is assumed that IC/FCC databases are accurate i.e. accounting for all line and component losses as well as exact antenna gains of a particular system. However, these databases cannot account for user errors or gain value differences which arise from antenna patterns variances (ideal vs. actual). WP 3400 activities verified through a limited number of field measurements (109 test points in the three RF bands of interest) that values originally presented in the error budget should be annotated with the following values:

- -3.4 dB in the 138-174 MHz band
- -3.0 dB in the 406-470 MHz band
- -4.5 dB in the 806-869 MHz band

These values stem from a combination of base station antenna gain, antenna pattern as well as additional line and component (filters, etc.) losses.

References

- A) TIA Telecommunications Systems Bulletin, Wireless Communications Systems Performance in Noise and Interference Limited Situations, Part 1: Recommended Methods for Technology Independent performance Modeling, TSB-88.1-C, February 2008
- B) Industry Canada Spectrum Direct on-line database: <http://www.ic.gc.ca/eic/site/sd-sd.nsf/eng/home>
- C) Radio Resource Guide Mission Critical Magazine, Jan 2010 Specs Guide
- D) Radio Mobile for Windows software version 10.7.9 www.ve2dbe.com

E) CRC-WASR Recommendations to "Range Calculation Error Budget Analysis,
MDSC-ANA-0003 v00 12 Nov 2010

Error Budget

The error budget has three contributors: system gain, link availability margin and Maximum Operational Range (MOR) threshold.

System Gain Budget

A system gain budget template was used to quantify least significant decimal error for each RF parameter. The absolute values used in Figure 39 are derived from averages of project relevant radios sampled in Ref. B and C.

Average Error Budget for First Responder Base Stations

System Type Description	138-174 Mhz			406-470 Mhz			806-869 Mhz		
	Band	Comment		Band	Comment		Band	Comment	
	Analog FM	(25 kHz Channel Spacing)		Analog FM	(25 kHz Channel Spacing)		Analog FM	(25 kHz Channel Spacing)	
	Average	Error (+/-)		Average	Error (+/-)		Average	Error (+/-)	
Frequency (MHz)	174		a	470		a	869		a
Bandwidth (kHz)	16			16			16		
Distance (km)	20		b	20		b	20		b
TX Power (dBm)	43.0	0.2	c	43.0	0.2	c	43.0	0.2	c
Tx Line Loss (dB) (negative)	-3.8	0.2	c	-3.3	0.2	c	-3.2	0.2	c
TX Antenna Gain (dBi)	7	0.2	d	6	0.2	d	5	0.2	j
Free Space Path Loss (dB) (calculated)	-103.3			-111.9			-117.2		
Mobile Rx Antenna Gain (dBi)	-1.25	1.3	e	-1.9	1.9	e	3	1.0	e
Mobile Rx Line Loss (dB)	-0.5	0.1	f,g	-3.3	0.1	f,g	-3.2	0.1	f,g
RX Reference Sensitivity Threshold [12 dB SINAD] (dBm)	-118	1.0	h	-118	1.0	h	-118	1.0	h
System Gain	162.5	2.9	k	158.5	3.5	k	162.6	2.6	k
RX Signal Level (dBm) (calculated)	-58.8			-71.4			-72.6		
MTR Margin [DAQ-2.0 or 12 dB SINAD] (dB) (calculated)	59.2			46.6			45.4		
Environmental & Man-made Noise (dB) (positive)	12.8	5.5	i	3.3	3.3	i	0.0	0.0	i
Link Availability Margin [DAQ-2.0] (dB)	4.0			4.0			4.0		
Link Availability Margin [DAQ-3.0] (dB)	17.0			17.0			17.0		
Link Availability Margin [DAQ-3.4] (dB)	20.0			20.0			20.0		
MOR Margin [DAQ-2.0] (dB) (Calculated)	46.4	8.4		43.3	6.8		45.4	2.6	
MOR Margin [DAQ-3.0] (dB) (Calculated)	33.4	8.4		30.3	6.8		32.4	2.6	
MOR Margin [DAQ-3.4] (dB) (Calculated)	30.4	8.4		27.3	6.8		29.4	2.6	
MOR DAQ-2.0 Design Threshold (dBm) (Calculated)	-105.2	8.4		-114.7	6.8		-118.0	2.6	
MOR DAQ-3.0 Design Threshold (dBm) (Calculated)	-92.2	8.4		-101.7	6.8		-105.0	2.6	
MOR DAQ-3.4 Design Threshold (dBm) (Calculated)	-89.2	8.4		-98.7	6.8		-102.0	2.6	

Comments

a) Upper band (Worst Case) value - Will use actual data from IC/FCC databases

b) Selected as reference point

c) Average based on Technical and Administrative Frequency List (TAFL-03) pruned for first responders - Will use actual data from IC/FCC databases

d) Average value based on TAFL-03 pruned for first responders, 30% of records use one decimal, 70% rounded-up to most significant integer - Will use actual data from IC/FCC databases

e) As per section 2.1.2.1 of "WP 2420 Range Calculation Error Budget Analysis"

f) most records use 1 decimal

g) must add duplexor loss if required

h) 12dB SINAD, from vendor datasheets, survey of 29 radios, source: Radio Resource Guide Mission Critical Magazine, Jan 2010 SpecsGuide

i) From CCIR Report 258-4 as per section 2.2 of "WP 2420 Range Calculation Error Budget Analysis"

j) Average calculated from TAFL-26 (not pruned for first responders) - Will use actual data from IC/FCC databases

k) Assumes IC/FCC databases are exact. Excludes corrections based on WP 3400 field measurement activities: -3.4 dB in 100MHz band, -3.0 dB in 400 MHz band, -4.5 dB in 800 MHz band

Figure 39 - Error Budget

"WP 3400 Validate with Field Measurements" identified that the above system gain values should be corrected to account for additional losses identified; the resulting MOR DAQ-3.4 design threshold values then become -85.8 dBm, -95.7 dBm and -97.5 dBm respectively. However, the RMW batch file used to produce the final radio coverage maps (see "WP 3100 Perform Propagation Analysis") is limited and only a single value change is possible across all bands of interest. A 3dB correction factor was chosen to account for the additional losses identified in WP 3400 activities.

The resulting DAQ-3.4 threshold values used in the final analysis are:

-86.2 dBm (100MHz band), -95.7 dBm (400MHz band) and -99 dBm (800MHz band)

Radio Receiver Sensitivity Survey

A survey of Ref. C was performed to obtain the radio receive sensitivity.

source: Radio Resource Guide Mission Critical Magazine, Jan 2010 SpecsGuide

radio #	Manufacturer	Model	Published Sensitivity (uV)	Published Sensitivity (dBm)	Sensitivity (dBm)
1	Alligator	1800		-120	-120
2	Bridge Comm	CS-540U	0.25		-119
3	Bridge Comm	CS-540V	0.25		-119
4	Connect Systems	CS7000	0.25		-119
5	Daniels Electronics			-118	-118
6	EF Johnson	2600	0.25		-119
7	EF Johnson	3800	0.25		-119
8	Harris	Master V		-119	-119
9	Harris	Skymaster		-112	-112
10	ICOM	FR3000/4000	0.25		-119
11	Kenwood	P-25	0.28		-118
12	Kenwood	NXR-700/800	0.27		-118
13	Midland	Analog	0.3		-117
14	Midland	P-25	0.3		-117
15	Power Trunk	TR-1000		-119	-119
16	Power Trunk	Trunk 25		-119	-119
17	Relm Wireless	V series		-118	-118
18	Sonic Messaging	WMBS	0.3		-117
19	Spectra Engineering	MX800		-117	-117
20	Spectra Engineering	MX920		-117	-117
21	Tait	TB7100		-117	-117
22	Tait	TB9100		-119.5	-119.5
23	Telsate	450	0.3		-117
24	Vertex	VXR-7000	0.35		-116
25	Westel	Irukanji		-118	-118
26	Westel	DBR25		-118	-118
27	WiPath			-118	-118
				average	-118

Figure 40 - Radio Receive Sensitivity Survey

Survey Study Limitations

While the front end of both type of radios (BS and mobile) may be similar, this survey (based on current equipment offerings) is not necessarily representative of mobiles used by all first responders along the CANUS border. However, it is a reasonable approximation for the scope of work and level of funding of this study. It is assumed that the radio receive sensitivity is the same for all bands of interest in the study.

The receiver sensitivities presented in Figure 40 are not absolute values but “static threshold” or “reference sensitivity” values as defined in the TSB-88.1 document. These values are typically referenced to a standard performance metric:

- Analog systems: 12dB static signal-to-noise and distortion ratio (SINAD);
- Digital systems: 5% bit error rate ratio (BER).

For those manufacturer receiver sensitivities presented in voltage, the analysis assumes a typical 50 ohms systems in reference to 1mW. For example 0.25 μ V sensitivity becomes:

$$0.25 \mu\text{V} = 20 \log_{10} (0.25) = -12 \text{ dB}\mu\text{V} \text{ and}$$

$$\text{dBm} = \text{dB}\mu\text{V} - 107 \text{ dB}$$

Thus,
 $-12 \text{ dB}\mu\text{V} = -119 \text{ dBm}$

Resulting Recommendations for follow-on study work:

- Survey should be done for mobile equipment
- Survey should reference the actual equipment, including mobile antennas, used by 1st responders, details to be obtained via IC database or similar.

Mobile Antenna Gain Survey

A survey of Ref. C was performed to obtain the radio mobile antenna gain.

source: Radio Resource Guide Mission Critical Magazine, Jan 2010 SpecsGuide

note 1: only band-specific antennas retained i.e. no broadband antennas

note 2: special hidden or small form factor antennas not retained, only standard

Antenna #	Manufacturer	Model	Mid VHF Gain (dBi)	Low UHF Gain (dBi)	Mid UHF Gain (dBi)
1	Comprod	577-75	2		
2	Comprod	583-75		5.15	
3	Comtelco	A1641B		0	
4	Comtelco	A1145A		3.5	
5	Comtelco	A1843A		3	
6	EM Wave	EM-M11003			3
7	EM Wave	EM-M10003		5.15	
8	Larsen	LM700			5.6
9	Larsen	B150	2.1		
10	Larsen	B450		5.5	
11	Pasternak	PE51013			3
12	PC Tel	1322HDS	2.4		
13	Polar	315UC		0	
14	Polar	214W	0		
15	Sinclair	SVB-1482	4.1		
16	Telstate	MTA 443	0		
17	Telstate	DA6			3
18	Telstate	ATF104	6		
19	WEH	CR2ARD	0		
20	WEH	CR4ARD		0	
average (dBi)			2	3	4

Figure 41 - Mobile Antenna Gain Survey

Mobile Antenna Detailed Considerations

Values presented in Figure 41 reference both $\frac{1}{2}\lambda$ and $\frac{1}{4}\lambda$ antennas. In the case of $\frac{1}{4}\lambda$ antennas, the gain values presented assumes that a proper ground plane is present, which may not be the case for actual deployments. When considering operation in the 138-174 MHz band, first responder vehicles are most likely to use $\frac{1}{4}\lambda$ antennas ($\frac{1}{4}\lambda=0.5\text{m}$) as opposed to $\frac{1}{2}\lambda$ antennas ($\frac{1}{2}\lambda=1\text{m}$) due to their smaller footprint and as such, 0 dBi gain for mobile equipment should be assumed in the analysis. However, this is optimistic as actual antenna performance may differ.

The use of $\frac{1}{4}\lambda$ antennas is also mentioned in 'Section D.3.8' (p.164) of the TS-88.1 document, albeit the referenced average gain for $\frac{1}{4}\lambda$ antennas is 1.15 dBi. This value is not band specific, but the average value for all equipment operating below 1 GHz. The use of $\frac{1}{4}\lambda$ antennas on mobile vehicles most likely applies for system deployments in the 400 MHz band as well. Further research is needed for system deployments in the 800 MHz, however $\frac{1}{2}\lambda$ mobile antennas will be assumed for the scope of this analysis.

Furthermore, the radiation pattern of the mobile antenna will be affected by its placement on the vehicle, thereby reducing its overall effective gain (from specification). This is also alluded to in TS-88.1; 'Table D-3' (p.165) which presents various correction factors that should be applied to the

average $\frac{1}{4}\lambda$ antenna gain given its location. Note that the 1.15 dBi (-1 dBd) value represents no change in gain, as per 'Table D-2' (p.164). This table presents that gain correction factors of up to -2.5 dB can be applied to $\frac{1}{4}\lambda$ mobile antennas mounted on vehicles (at the reference frequency of 155 MHz). As such, mobile Rx antenna gains mounted on vehicles can be approximated by:

-1.25 dBi (± 1.25 dB error) [155 MHz ref.]

-1.9 dBi (± 1.9 dB error) [455 MHz ref.]

The TS-88.1 reference document does not provide a correction factor for the mid UHF band (800 MHz) for $\frac{1}{2}\lambda$ mobile antennas therefore the $\frac{1}{4}\lambda$ antenna gain of Figure 41 is used:

3.0 dBi (± 1.0 dB error) [mid UHF, 800 MHz band]

Link Availability Margin

A link availability margin was derived to provide radio operators with a high degree confidence radio range limit. This range is defined as the Maximum Operational Range. The MOR takes into account Delivered Audio Quality (DAQ) of 3.4: ***"Speech understandable with repetition only rarely needed. Some Noise/Distortion"***, defined in Table 2 of Ref. A. The MOR has a large safety margin and shall be used for first responder's area of interest (AOI) planning.

Table 2 Delivered Audio Quality

DAQ Delivered Audio Quality	Faded Subjective Performance Description	Static SINAD equivalent intelligibility ^{1,2}
1	Unusable, Speech present but unreadable	<8 dB
2	Understandable with considerable effort. Frequent repetition due to Noise/Distortion	12 ± 4 dB
3	Speech understandable with slight effort. Occasional repetition necessary due to Noise/Distortion	17 ± 5 dB
3.4	Speech understandable with repetition only rarely needed. Some Noise/Distortion	20 ± 5 dB ³
4	Speech easily understood. Occasional Noise/Distortion	25 ± 5 dB
4.5	Speech easily understood. Infrequent Noise/Distortion	30 ± 5 dB
5	Speech easily understood.	>33 dB
¹ The VCPC is set to the midpoint of the range. ² Measurement of SINAD values is not recommended for analog system performance assessment. ³ The 20 dBS equivalency necessitates a DAQ of approximately 3.4. This value can then be used for linear interpolation of the existing criteria. Non public safety CPC specifications would normally request a DAQ of 3, while Federal Government agencies commonly use a DAQ of 3.4 at the boundary of a protected service area. Note that regulatory limitations could preclude providing a high probability of achieving this level of CPC for portable in-building coverage. In addition, higher infrastructure costs could be needed with potential lessened frequency reuse.		

Figure 42 - TSB-88.1-C Table 2

As explained in TSB-88.1, DAQ was developed to facilitate the mapping of analog and digital voice system performance to Circuit Merit and Static SINAD equivalent intelligibility when subjected to multipath fading. TS-88.1 further explains that typical systems may be designed with link availability margins derived from a DAQ value of 3.0 (eq. to Static SINAD value of 17 dB) while Federal Government agencies (in the US) use a DAQ value of 3.4 (eq. to static SINAD of 20 dB) to define the boundary of a protected first responder service area.

A Maximum Technical Range (MTR) is also defined: it represents what radio range would be based on equipment data sheets threshold levels in a best-case situation for radio transmission which **excludes** DAQ-3.4. The MTR is too optimistic and shall not be used for first responder AOI planning.

In this project the MOR, which **includes** DAQ-3.4, will be used to represent radio coverage. If the first responder's area of interest radio coverage is green there is a high probability that the radio will work at that given geographic point. If it does not work, then the local technical responsible person for that area should be challenged as to why the radios do not work in the field.

Degradation Due to Environmental and Man-Made Noise

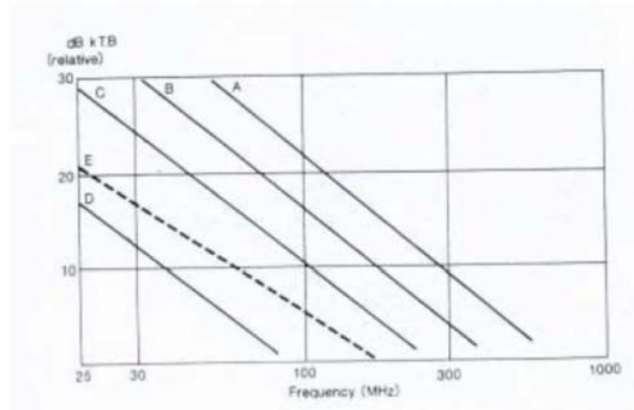
While link availability margins can be calculated from DAQ values, it is important to note that:

- DAQ values and Static SINAD equivalent of 'Table 2' in TSB-88.1 do not take into account any adjustments due to environmental or man-made noise and interference;
- The same can be said for the methodology presented in TSB-88.1.

In fact, TSB-88.1 makes note on several occasions to reference TSB documents 88.2 and 88.3 for such adjustments. The TSB-88.1 document nevertheless makes reference ('Section D3.11', p.166) to an additional 6 dB average '*derating value*' of ambient RF noise in the 132-174 MHz band (3dB in 406-512 MHz band). However, no reference is made on how this average value was obtained.

A more rigorous approach would be to use mean values of man-made noise relative to Land Mobile Services from CCIR Report 258-4, presented in Figure 43.

NOISE POWER ON TYPICAL RADIO SITES



Mean values of man-made noise for a short vertical lossless grounded monopole antenna

Environmental category:

- A: Business
- B: residential
- C: rural
- D: quiet rural
- E: galactic

The above graphs have been taken from CCIR Report 258-4, and have been expanded from 25 to 1000MHz for ease of reference to the Land Mobile Services.

Figure 43- Noise Power on Typical Radio Sites from CCIR Report 258-4

From the above figure, the following average man-made noise desensitization values on radio sites can be extrapolated in the 150-175 MHz range for specific environmental categories; 18.3 dB for 'Business',

12.5 dB for 'Residential' and 7.2 dB for 'Rural'. A similar process is used to extrapolate values for the 406-470 MHz band. Noise adjustments in the 800 MHz bands are likely negligible. As such, environmental and man-made noise degradation values can be approximated by:

138-174 MHz: 12.8 dB (± 5.5 dB error)

406-470 MHz: 3.3 dB (± 3.3 dB error)

These values are taken into account when calculating MOR design threshold levels used to represent the final radio coverage maps.

Recommendations for Post-Study Work

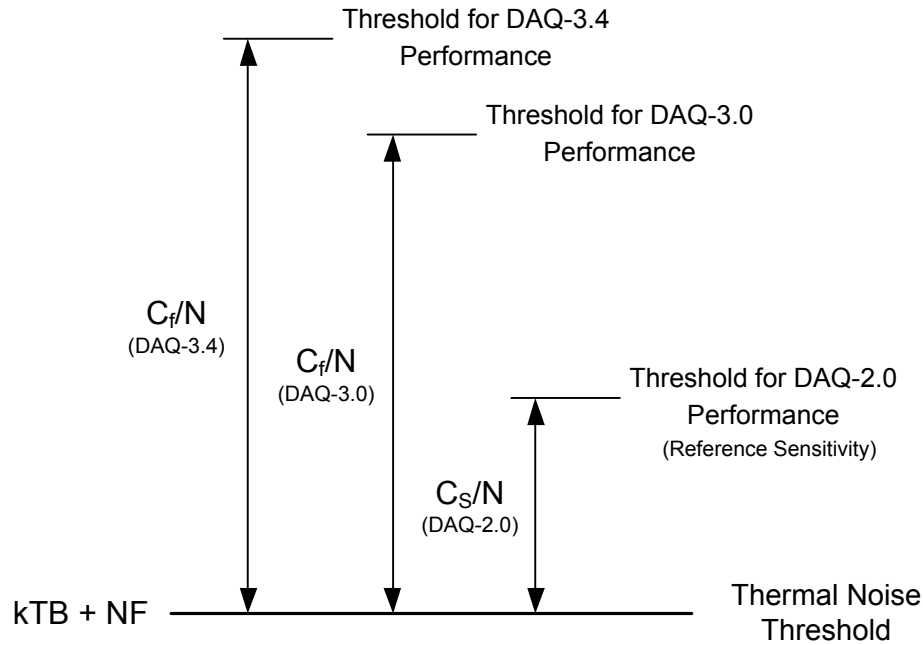
CCIR report 258-4 is an old reference. It is highly recommended that a more up to date reference be found for environmental and man-made noise values. Suggestions include the use of ITU-R 722 document.

Link Availability Margin - Additional Considerations

As mentioned in TSB-88.1 (i.e. note 2 of Figure 42), analogue (or digital) performance testing and evaluation using static SINAD values is not recommended as performance measurements occur in a fading environment which differs dramatically from a static environment. TSB-88.1 further explains that the goal of DAQ is to determine the median Faded Carrier to Interference plus Noise ratio [$C_f/(I+N)$] that is needed to produce a subjective audio quality metric under Rayleigh multipath fading. The reference is to a static FM analogue audio SINAD equivalent intelligibility, thus providing a cross reference between faded DAQ and static SINAD intelligibility values.

Since interference is the subject of TSB-88.3, the TSB-88.1 document actually presents median Faded Carrier to Noise ratio [C_f/N] values, where the only noise considered is that of the thermal threshold. C_f/N values vary quite drastically as they are dependent on the type of equipment used as well as the target DAQ value.

The link availability margin is referred to as the "*Voice Channel Performance Criterion (VCPC)*" (p.29) in TSB-88.1, a value that can be calculated from the reference sensitivity value of the equipment plus the difference between C_f/N (for a specific DAQ value) and the Static Carrier to Noise ratio (C_s/N) value for radio equipment. In fact, C_s/N is the SNR value required above the thermal noise threshold of a receiver (correcting for equivalent noise bandwidth [ENBW] and noise figure [NF]) such that system performance associated with this operational threshold (or "*Faded Performance Criteria*" value from 'Figure 5' (p34) in TSB-88.1) is comparable to a DAQ-2.0 value (static SINAD value of 12 dB). Reference sensitivity values specified in manufacturer specifications already include a link availability margin, specified by the C_s/N values of the TS-88.1 document. **Error! Reference source not found.** presents link availability margins based on several DAQ values and how they relate to various system design thresholds.



Note: Additional adjustments for environmental and man-made noise may be required

Figure 44- Link Availability Margins Using DAQ Values

Average (typical) values for C_S/N and C_f/N are presented in 'Table A-1' (p.75) in the TSB-88.1 and as previously mentioned, these values are **equipment specific**. Several link availability margins (and equivalent design thresholds) can be derived from these values. Examples for two analog FM systems as well as a digital P.25 (C4FM) system are given below based on the reference sensitivity value of value of -118 dBm presented in Section 2.1.1 and theoretical ENBW values from 'Table 5' (p.43) in TSB-88.1.

i. Analog FM (12.5 KHz Channel Spacing)

DAQ-2.0 Link availability margin: $C_S/N = 7$ dB (SINAD of 12 dB)

DAQ-3.0 Link availability margin: $C_f/N = 23$ dB (SINAD of 17dB)

DAQ-3.4 Link availability margin: $C_f/N = 26$ dB (SINAD of 20dB)

Thermal Noise Threshold: $-174 + 10 \log [\text{ENBW}] + \text{NF} = -125$ dBm
where, ENBW = 7.8 kHz and NF = 10 dB

DAQ-2.0 Design Threshold (Reference Sensitivity) = $-125 + 7 = -118$ dBm

DAQ-3.0 Design Threshold = $-125 + 23 = -102$ dBm

DAQ-3.4 Design Threshold = $-125 + 26 = -99$ dBm

ii. Analog FM (25 KHz Channel Spacing)

DAQ-2.0 Link availability margin: $C_S/N = 4$ dB (SINAD of 12 dB)

DAQ-3.0 Link availability margin: $C_f/N = 17$ dB (SINAD of 17dB)
DAQ-3.4 Link availability margin: $C_f/N = 20$ dB (SINAD of 20dB)

Thermal Noise Threshold: $-174 + 10 \log [ENBW] + NF = -122$ dBm
where, ENBW = 16 kHz and NF = 10 dB

DAQ-2.0 Design Threshold (Reference Sensitivity) = $-122 + 4 = -118$ dBm
DAQ-3.0 Design Threshold = $-122 + 17 = -105$ dBm
DAQ-3.4 Design Threshold = $-122 + 20 = -102$ dBm

iii. Digital C4FM (12.5 KHz Channel Spacing)

DAQ-2.0 Link availability margin: $C_S/N = 5.4$ dB (BER of 5%)
DAQ-3.0 Link availability margin: $C_f/N = 15.2$ dB (BER of 2.6%)
DAQ-3.4 Link availability margin: $C_f/N = 16.2$ dB (BER of 2.0%)

Thermal Noise Threshold: $-174 + 10 \log [ENBW] + NF = -123.6$ dBm
where, ENBW = 5.5 kHz and NF = 13.2 dB

DAQ-2.0 Design Threshold (Reference Sensitivity) = $-123.4 + 5.4 = -118$ dBm
DAQ-3.0 Design Threshold = $-123.4 + 15.2 = -108.2$ dBm
DAQ-3.4 Design Threshold = $-123.4 + 16.2 = -107.2$ dBm

Recommendations for Post-Study Work

Take into account all three (DAQ-2.0 to 3.4) link availability margins. The various design thresholds (dictated by the link availability margins) will yield different operational distances or service area boundaries which can be associated to the various MORs given specific operational requirements.

Link availability margin values are equipment and type specific (analog vs. digital, etc.). Equipment types must be derived from IC database and cross-referenced to TSB-88.1 documents on a case-per-case basis.

Link Availability Margin Assumptions

For this analysis, it is assumed that all (voice only) radios have the same bandwidth and emission class as type F3EJN, which refers to:

F: Frequency modulation
3: Single analog channel
E: Telephony incl. voice broadcast
J: Sound of commercial quality
N: No multiplexing

The IC database has several ENBW associated to this emission class. While the most popular are 11, 13, 16 and 25 kHz, also included are 32, 40, 54 and 60 kHz. For example, if first responders have gone narrow band in the US (ENBW ~5 to 8 kHz) as hinted by FCC at the Windsor Workshop, then link

availability margins metric can differ significantly from the one considered in study (25 kHz channel vs. 12 kHz channel) as shown in Section 2.2.2 above.

The analysis assumes all emitters to be analog voice FM systems only; systems with **16 kHz ENBW** only (25 kHz channel spacing).

Interpretation of Error Budget in terms of Range Performance

What is important and well understood by end users is range. The boundary of the protected service area for first responders is the Maximum Operational Range defined previously.

To represent this MOR, the values of Figure 39 - Error Budget were entered in the Radio Mobile for Windows software and a radio coverage calculation example is performed with values derived from the Public Safety pool in the IC database:

BS Tx antenna gain: 3 dBi
Tx Frequency: 468 MHz
Mobile antenna gain: -1.9 dBi
Line loss: 3.2 dB
Tx power: 43dBm (20W)
Tx antenna height: 26m

Note: Individual radio coverage maps produced in "WP 3100 Propagation Analysis" will use actual values specific for each Base Station from the IC database and not the above mentioned averages.

The RMW input (for the purpose of this example) is:

The screenshot shows the 'Networks properties' dialog box with the 'Parameters' tab selected. The 'List of all systems' on the left includes 'Average', 'Average Mobile', and 'System 3' through 'System 10'. The 'Parameters' tab contains the following fields and values:

Field	Value	Unit / Note
System name	Average	
Transmit power (Watt)	20	(dBm) 43
Receiver threshold (µV)	3.6728	(dBm) -95.7
Line loss (dB)	3.2	(Cable+cavities+connectors)
Antenna type	omni.ant	View
Antenna gain (dBi)	3	(dBd) 0.85
Antenna height (m)	26	(Above ground)
Additional cable loss (dB/m)	0	(If antenna height differs)

Buttons at the bottom: 'Add to Radiosys.dat' and 'Remove from Radiosys.dat'.

Figure 45 – Representative base station values entered in RMW

For the mobile unit, the IC database is not used and the average parameters (frequency specific) presented in the error budget will be used in "WP 3100 Propagation Analysis" as a generic mobile unit template for all calculations. This will allow for an evenly balanced comparison of all Base Station radio coverage maps.

Networks properties

Default parameters Copy Net Paste Net Cancel OK

List of all systems

- Average
- Average Mobile
- System 3
- System 4
- System 5
- System 6
- System 7
- System 8
- System 9
- System 10

Parameters Topology Membership **Systems** Style

00 Select from VHF ... UHF ...

System name Average Mobile

Transmit power (Watt) 25 (dBm) 44

Receiver threshold (μV) 3.6728 (dBm) -95.7

Line loss (dB) 0 (Cable+cavities+connectors)

Antenna type omni.ant View

Antenna gain (dBi) -1.9 (dBd) -4.05

Antenna height (m) 2 (Above ground)

Additional cable loss (dB/m) 0 (If antenna height differs)

Add to Radiosys.dat Remove from Radiosys.dat

Figure 46 - Representative mobile values entered in RMW

Inputting the various receiver thresholds (MTR and MOR) derived in the error budget into the RMW tool allows it to compute and assess radio coverage in terms of range (Figure 47 below).

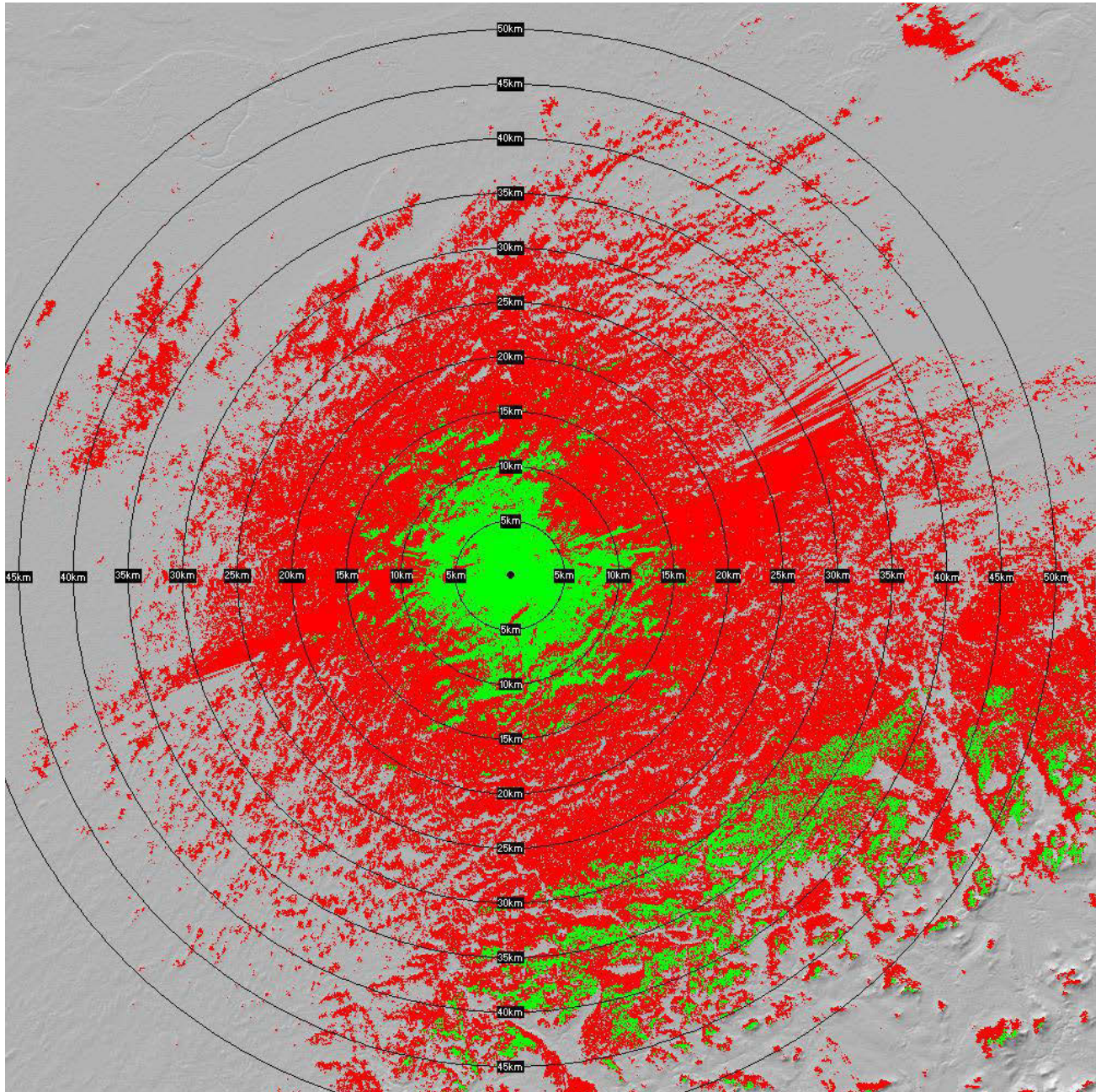


Figure 47 – Maximum Technical Range vs. Maximum Operational Range

An MTR threshold of -118 dBm (red) is used above, equivalent to manufacturer specifications (no noise, no specified audio quality). As per the error budget, the MOR threshold of -95.7 dBm (green) takes into account both environmental and man-made noise and DAQ-3.4 audio quality.

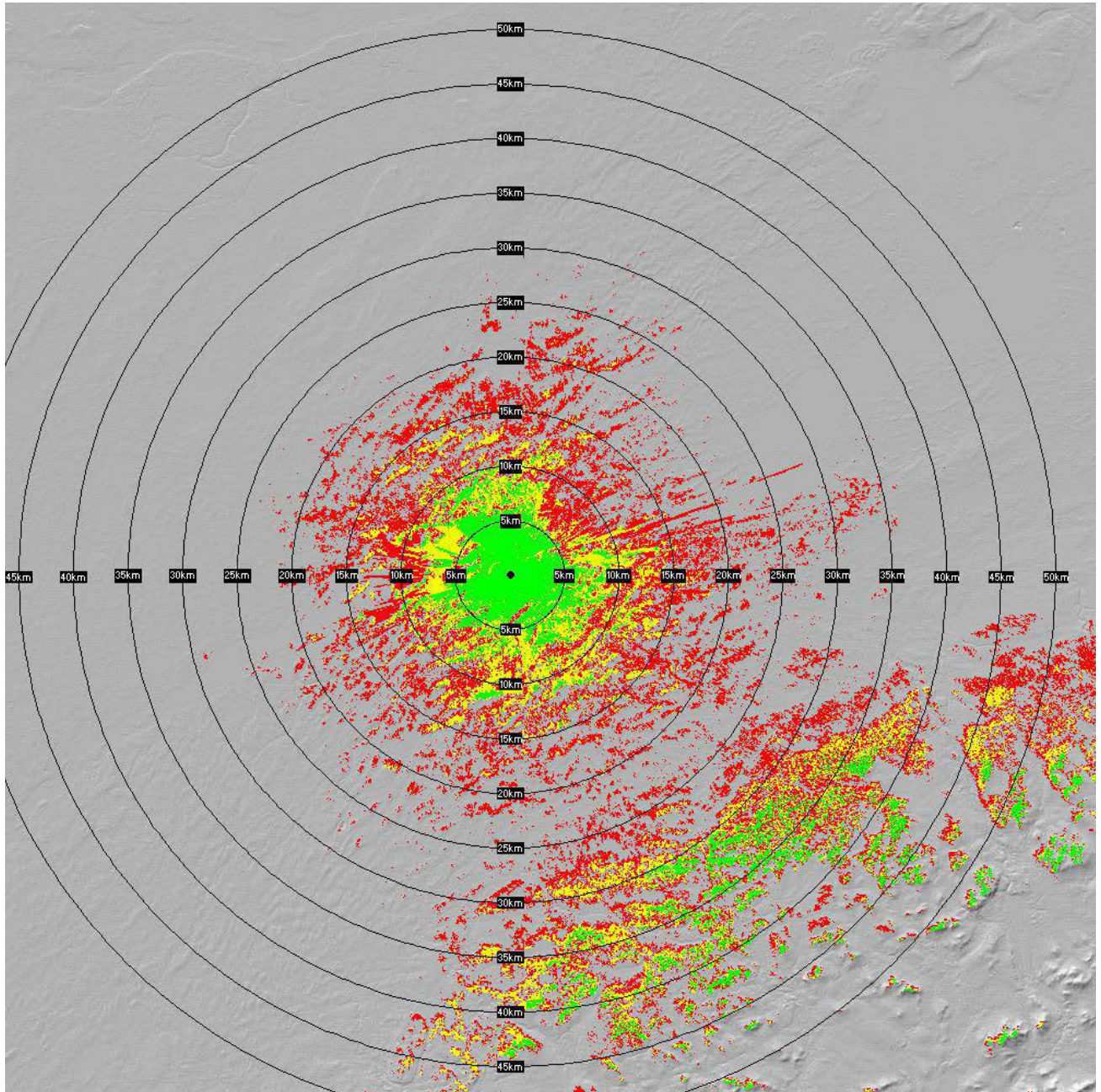


Figure 48 – Low UHF MOR (DAQ-3.4) Design Threshold Accounting for All Errors Presented In the Budget
 Conservative MOR (green), Average MOR (yellow), Optimistic MOR (red)

Conservative MOR DAQ-3.4 Design Threshold:	-88.9 dBm (-95.7dBm + 6.8dB)
Average MOR DAQ-3.4 Design Threshold:	-95.7 dBm
Optimistic MOR DAQ-3.4 Design Threshold:	-102.5 dBm (-95.7dBm -6.8dB)

Range performance conclusion:

The receiver thresholds values for this project will use the Average MOR DAQ-3.4 Design Threshold values defined in the error budget and further corrected (limited to 3dB due to RMW batch script limitations) to take into account the additional losses identified in WP 3400 activities. The values used in the final analysis are therefore:

-86.2 dBm (mid VHF), -95.7 dBm (low UHF) and -99.0 dBm (mid UHF)

Note: The above assumes analog systems using 25 kHz channel spacing with a high level delivered audio quality (equivalent to DAQ 3.4). It does not mean that there will be no radio coverage beyond the simulation, just that the level of service quality cannot be defined.

Attachments

The following files are included with this report:

- IC Public Safety Pool 100km from Border v01 with Histogram and Averages.xls
- Radio Resource Mission Critical Magazine.pdf
- Error Budget v01.net
- net1.map
- Path Loss Error Budget v04-WASR Review.xls

Abbreviations

ATDI	brand name (see: www.ATDI.com)
AOI	Area Of Interest
BER	Bit Error Rate
BS	Base Station
CANUS	CANada United States
CCIR	Comité Consultatif International des Radio Communications
CRC	Communication Research Center
DAQ	Delivered Audio Quality
ENBW	Equivalent Noise Bandwidth
FM	Frequency Modulation
IC	Industry Canada (see: http://www.ic.gc.ca)
ie	id est, that is
MOR	Maximum Operational Range
MTR	Maximum Technical Range
Ref.	Reference
RF	Radio Frequency
RMW	Radio Mobile for Windows
Rx	Receive
SINAD	Signal, Noise and Distortion
SNR	Signal to Noise Ratio
TIA	Telecommunications Industries Association
Tx	Transmit
UHF	Ultra High Frequency
VHF	Very High Frequency
WASR	Wireless Applications and System Research group (part of CRC)

Project number: PSTP 02-302 EMSI

Propagation Analysis

WP 3100

Document number: MDSC-PM-0008 v03, 07 Mar 2011

Purpose

The purpose of this document is to provide the methodology used by Martello Defence Security Consultants Inc. (MDSC) and to provide the results of the Work package (WP) 3100 Propagation Analysis for the Canada-United States (CANUS) Border Radio Coverage project.

For this task, MDSC has awarded a subcontract to Rheinmetall Defence Canada Inc. for the engineering support services of Mr. Roger Coudé for the use of the Radio Mobile for Windows (RMW) software. MDSC has also arranged a subcontract with the Réseau Québécois de Calcul de Haute Performance (RQCHP) Université de Montréal for the use of a supercomputer.

Scope

This document uses results from:

WP 2100 Document Survey and Context Definition,
WP 2300 Manage the Scope of the Coverage Analysis,
WP 2420 Error Budget Range Calculation Error Budget Analysis, and
WP 3400 Validate with Field Measurements

to produce an all-inclusive radio coverage map for “WP 3200 Produce Coverage Visualization Maps”.

The coverage map will then be used for the operational task “WP 3300 Assess Severity of Coverage Gaps”.

References

- A) NTIA Report 82-100 A guide to the use of the ITS Model, Hufford, Longley and Kissik, U.S. Department of Commerce, April 1982
- B) Radio Mobile for Windows: www.ve2dbe.com

Radio Mobile for Windows (RMW)

The program used to perform the coverage calculations is RMW v 10.7.9.

It was selected because:

- it is a mature and reliable coverage prediction software
- it is utilizable as a freeware,
- it uses free to use geomatics data (terrain elevation, land cover), and
- it can be used to overlay geographic-referenced imagery and maps.

RMW can be downloaded from: www.ve2dbe.com where the installation and system configuration parameters are provided.

RMW Configuration of Radio Frequency Parameters

The following screen shots define the configuration used for RMW:

Figure 49 - Map Properties

Networks properties

List of all nets

- UHF Low
- Net 2
- Net 3
- Net 4
- Net 5
- Net 6
- Net 7
- Net 8
- Net 9
- Net 10

Parameters | Topology | Membership | Systems | Style

Net name: UHF Low

Minimum frequency (MHz): 138

Maximum frequency (MHz): 869

Polarization: ☒ Vertical ☐ Horizontal

Mode of variability: ☒ Spot (% of time: 50) ☐ Accidental (% of locations: 50) ☐ Mobile (% of situations: 70) ☐ Broadcast

Surface refractivity (N-Units): 301

Ground conductivity (S/m): 0.005

Relative ground permittivity: 15

Climate: ☐ Equatorial ☐ Continental sub-tropical ☐ Maritime sub-tropical ☐ Desert ☒ Continental temperate ☐ Maritime temperate over land ☐ Maritime temperate over sea

Figure 50 - Network Properties

The use of the default value (Spot - 70% of situations) for the 'Mode of variability' parameter was selected in accordance to the field tests performed by the author of RMW, Mr. Roger Coudé as documented on the RMW website. Recommended modifications to this default value are addressed in Section 4.1.2 below.

Note: It is assumed that the rain effect is negligible for the frequency bands considered in this study.

Networks properties

Default parameters | Copy Net | Paste Net | Cancel | OK

Parameters | Topology | Membership | Systems | **Style**

Propagation mode: ☒ Use "Two Rays" for Line-Of-Sight ☐ Normal ☐ Interference

☒ Draw a green line if RX relative signal (dB) is >= -3

☒ Else draw a yellow line if RX relative signal (dB) is >= -16

☐ Else draw a red line

☒ Draw lines with dark background

Note that if the net topology is type cluster and number of hops > 0, then the color yellow is not used and the threshold is set to 0 both for green and red

Figure 51 - Two Ray Propagation Mode

Data options

Elevation data | Land cover | Cancel | OK

Elevation data extraction method for Radio Link and Network performance

☒ Use elevation data in memory generated by Map Properties

☐ Extract elevation data directly from database

Profile extraction

Maximum number of records to use with propagation model: 1000

Performance test

Figure 52 - Elevation Data Options

Data options

Elevation data | **Land cover** | Cancel | OK

landheight.dat

☒ Include land cover height

	Height (m)	Density (%)
00 Water	0	0
01 Evergreen Needleleaf Forest	15	100
02 Evergreen Broadleaf Forest	25	60
03 Deciduous Needleleaf Forest	15	100
04 Deciduous Broadleaf Forest	15	60
05 Mixed Forest	15	70
06 Woodland	10	70
07 Wooded Grassland	5	10
08 Closed Shrubland	1	10
09 Open Shrubland	1	10
10 Grassland	1	5
11 Cropland	1	5
12 Bare Ground	0	0
13 Urban and Built-up	10	100

Default

Load

Save

☒ Icon

☒ LCV

☐ IMG

Land Cover File

F:\Geodata\Landcover\W45W075.lcv

Browse...

Figure 53 - Land Cover Options

The use of the default Land Cover values presented above and recommended modifications to these default values are addressed in Section 4.1.2 below.

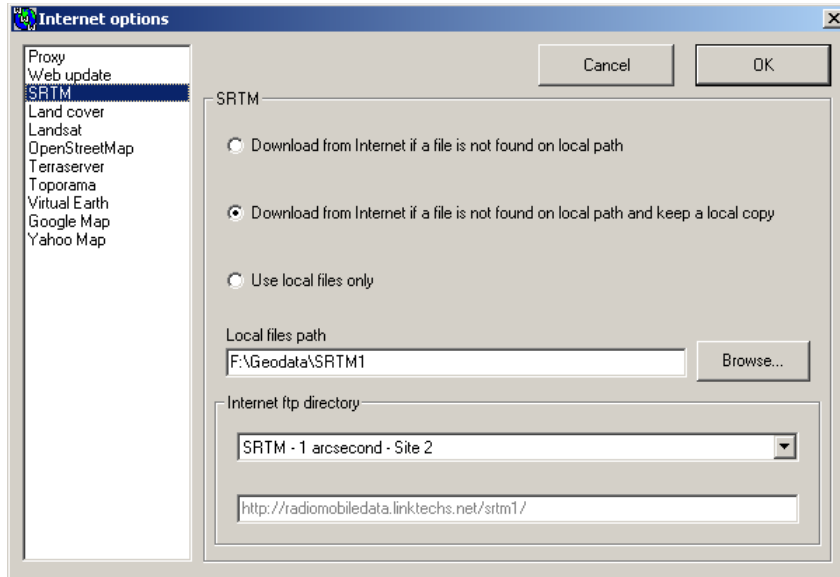


Figure 54 - Internet Option for SRTM1

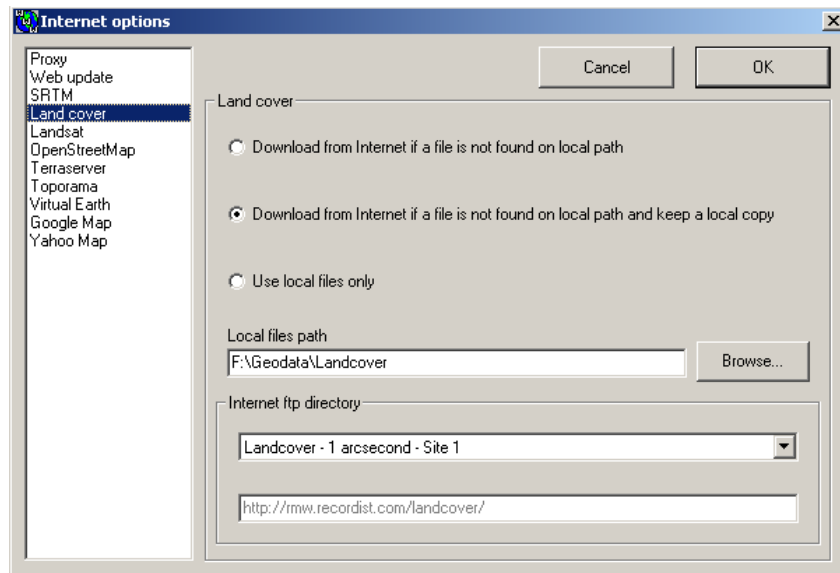


Figure 55 - Internet Options for Land Cover

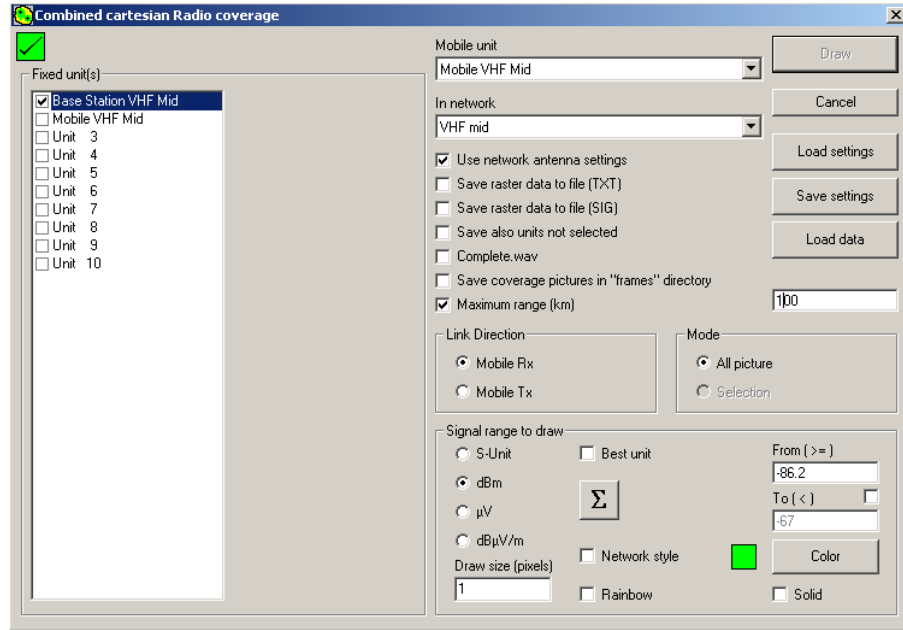


Figure 56 - Cartesian Coverage Settings Example

From Figure 56, it is important to note that:

- 'Maximum range' metric is based on the center of map, thus 100km radial gives a 200km x 200km map.
- The 'Signal range to draw' metric uses the Average MOR Design Threshold values defined in "WP 2420 Range Calculation Error Budget Analysis".
- The green square (upper left with a checkmark) indicates that Land Cover option is used in the radio coverage calculations.

Default Parameters for Mobile Unit

If RMW is used with a mobile unit to visualize the radio links, the parameters to be used (frequency specific) are those presented in the error budget. Refer to "WP 2420" for detailed system gain parameters.

RMW Modifications

As mentioned in “WP 2200 Define Radio Coverage Area of Interest”, the DEM used in this analysis (digital terrain model format) only presents the bare ground surface elevation data. In an attempt to account for physical objects located on the surface, land cover data is also used to produce the radio coverage maps. Land cover modifies simulated results obtained using terrain data only by introducing a rough concept clutter (several categories of vegetation and building data is defined) into the analysis such that the simulated radio paths account for physical objects. RMW then computes additional path loss, based on statistics and the category of land cover encountered. While using land cover data in coverage simulations does take into account some of the effects of physical objects in the radio paths, parameter values must be carefully chosen such that they more accurately reflect the specific areas of interest and resulting radio paths.

As part of the deliverables of “WP 3400 Validate with Field Measurements” was to validate radio coverage maps produced using the default parameter values of RMW with a limited number of field measurements to see if any modifications were required for the scope of this analysis. A limited number of field measurements in the three frequency bands of interests were conducted and analysed; the receive signal levels (RSLs) of 109 test points from four different emitter test sites. Radio coverage maps and detailed point-to-point path analyses were then performed in RMW, validated with ICS Telecom (ATDI) and the coverage results were compared to the field measurements.

The following is a summary of the recommended modifications to the default parameters, both ‘Mode of variability – Spot %’ and ‘Land Cover’ values, used in RMW and presented Section 4.1. Two sets of values for each case are presented, an average and a pessimistic (worst case) adjustment. In order to manage the scope, only two radio path environments are considered per frequency band; rural and urban.

It is important to note that the following modifications apply to radio coverage maps produced for the scope of this particular analysis only and may not reflect individual first responder AOI environments.

100MHz – Rural

- Average Adjustment: Spot 65% + “100MHz_Rural Land Cover”
{All “Forest” codes (01 to 05) changed to 25m height **and** 120% density, “Urban” code (13) changed to 120% density}
- Pessimistic Adjustment: Spot 85% + “100MHz_Rural Land Cover”
{All forests codes changed to 25m height **and** 120% density, urban code changed to 120% density}

100MHz – Urban

- Average Adjustment: Spot 65% + “100MHz_Urban Land Cover”
{Urban changed to 25m height **and** 130% density, all other codes to default values}
- Pessimistic Adjustment: Spot 80% + “100MHz_Urban_2 Land Cover”
{Urban changed to 25m height **and** 120% density, all other codes to default values}

400MHz – Rural

- Average Adjustment: Spot 60% + “400MHz_Rural Land Cover”
{All forests codes changed to 25m height **and** 140% density, urban code changed to 120% density}
- Pessimistic Adjustment: Spot 80% + “400MHz_Rural_2 Land Cover”
{All forests codes changed to 25m height **and** 130% density, urban code changed to 120% density}

400MHz – Urban

- Average Adjustment: Spot 60% + “400MHz_Urban Land Cover”
{Urban changed to 25m height **and** 150% density, all other codes to default values}
- Pessimistic Adjustment: Spot 80% + “400MHz_Urban Land Cover”
{Urban changed to 25m height **and** 150% density, all other codes to default values}

800MHz – Rural

- Average Adjustment: Spot 65% + “800MHz_Rural Land Cover”
{All forests codes changed to 25m height **and** 140% density, urban code changed to 120% density}
- Pessimistic Adjustment: Spot 80% + “800MHz_Rural_2 Land Cover”
{All forests codes changed to 25m height **and** 150% density, urban code changed to 120% density}

800MHz – Urban

- Average Adjustment: Spot 65% + “800MHz_Urban Land Cover”
{Urban changed to 25m height **and** 150% density, all other codes to default values}
- Pessimistic Adjustment: Spot 80 + “800MHz_Urban_2 Land Cover”
{Urban changed to 25m height **and** 165% density, all other codes to default values}

While the use of the above values will yield more statistically accurate calculations, the RMW batch file used to produce the final radio coverage maps (see Section 4.3 below) was limited and could not account for all the modifications presented herein. Furthermore, the AOI environment type (rural vs. urban) for each emitter considered in the analysis would need to be identified. It is therefore important to note that in order to manage the scope of the analysis, the above recommended modifications **were not** used in the final analysis; **the default RMW parameter values were used to perform all radio coverage maps**. The use of the RMW modifications presented herein is recommended for any follow-on study.

RMW Batch File

A batch version of RMW "rmweng.exe v 10.8.7" dated 04 Jan 11 was used to circumvent all the manual entries that would have to be performed in the various menus of RMW described in section 4.1.

System and unit properties are defined in “WP 2100 Document Survey and Context Definition” and more specifically by:

- WP 2110 - List of Emitters from IC (for Canada)
- WP 2120 - List of Emitters from FCC (for the U.S.)

Search Query Language (SQL) query scripts applied to the Industry Canada (IC) and Federal Communications Commission (FCC) were used to convert units of measure and to prepare and format the data as a tab-delimited .txt file for automatic calculation of thousands of radio coverage maps using

a batch version of RMW. This batch version supports multiple instances of RMW and was specifically configured for running on a multi-CPU supercomputer.

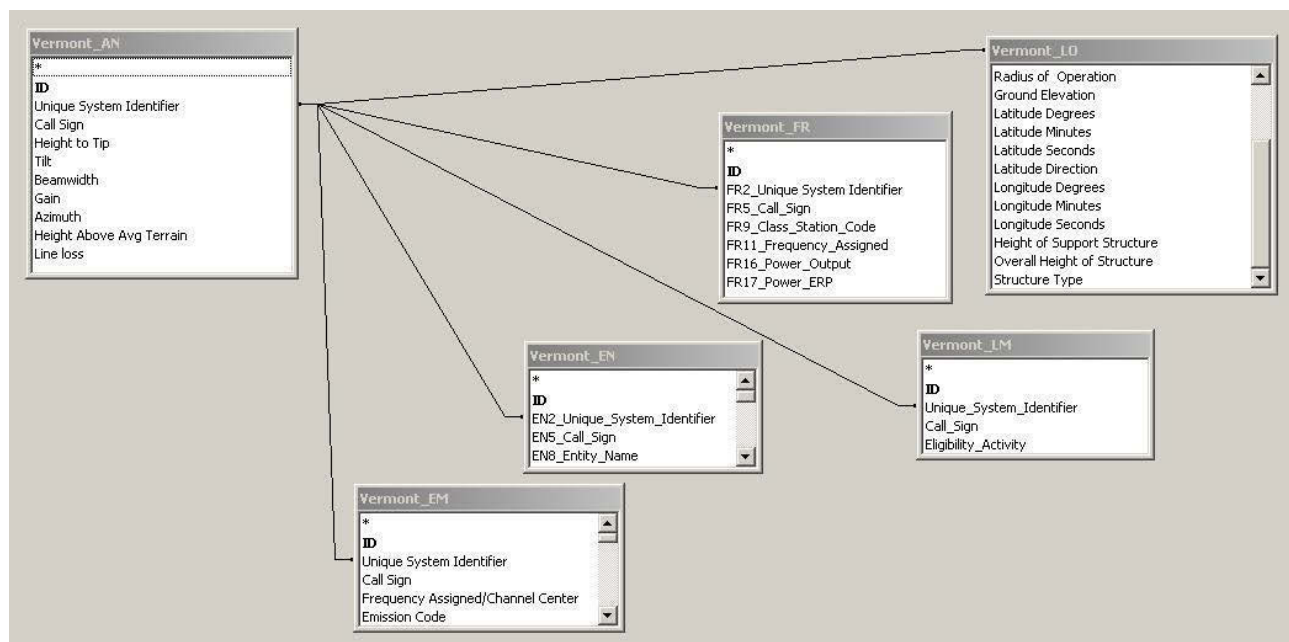


Figure 57 - FCC Field Relationships

B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Picture file	System gain (dB)	Antenna file	Antenna azimuth (m)	Antenn a tilt (deg)	Antenna height (m)	Elevation ASL (m) (insert 0 if not used)	Mobile antenna height (m)	Frequency (MHz)	Latitude (dec)	Longitude (dec)	Map resolution (m/pixel)	Maximum range (km)	Color	SRTM path	Lancover path (insert 0 if not used)

Figure 58 - RMW Batch Input File Field Description and Layout

The batch program stores the results in folders defined by the "Picture file" record as four file types:

- The **.log** file that describes the processing time:


```

BEGIN 68      12-24-2010      09:35:23
SRTM path    z:\RQMNT\exec4\guests\guest002\Radio_Mobile\geodata\srtm1\
Lancover path z:\RQMNT\exec4\guests\guest002\Radio_Mobile\geodata\lancover\*.lcv
\
ELEVATION    File= 267 SRTM= 255      Used= 267
Lancover test Urban and Built-up
COMPUTE_COV  68      12-24-2010      09:45:05
SAVE_PIC     68      12-24-2010      11:10:20
END 68      12-24-2010      11:10:20
      
```
- The **.dat** file that describes the coverage image coordinates for use in RMW and in ZoneCov defined in "WP 2410 Define Operational Availability Metrics". Note the .inf and .geo files produced by RMW provide the same information in another format and are not required.


```

1
-85.65636,47.4185
-83.04086,47.4185
      
```

- The **.kml** for Google Earth


```
<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://www.opengis.net/kml/2.2">
<GroundOverlay><name>XJJ24-821.475.0.png</name><color>88ffffff</color><Icon
<href>XJJ24-821.475.0.png</href>
<viewBoundScale>0.75</viewBoundScale></Icon><LatLonBox>
<north> 44.34017</north>
<south> 42.54039</south>
<east>-79.26814</east>
<west>-81.74686</west>
</LatLonBox></GroundOverlay></kml>
```
- The **.png** image file that shows the coverage. Note the size of the image is determined by the selection of the maximum range and map resolution parameters of the batch input file of Figure 58. The following table can be used as a guide for determining the desired image size:

		Maximum Range (km)											
note: radial range from center of map		30	40	50	60	70	80	90	100	150	200	300	500
Map resolution	(m/pixel)												
	25	2400	3200	4000	4800	5600	6400	7200	8000	12000	16000	24000	40000
	30	2000	2667	3333	4000	4667	5333	6000	6667	10000	13333	20000	33333
	50	1200	1600	2000	2400	2800	3200	3600	4000	6000	8000	12000	20000
	100	600	800	1000	1200	1400	1600	1800	2000	3000	4000	6000	10000
	200	300	400	500	600	700	800	900	1000	1500	2000	3000	5000
	400	150	200	250	300	350	400	450	500	750	1000	1500	2500

In Figure 59, a 2000 x 2000 pixel image is produced for each radio station in the batch file when the map resolution is set to 100m/pixel and the maximum range is set to 100 km; these values are the default values used for the project (shown in green). Note that the computing time increases geometrically as image size is increases so values in red are not recommended as they may exceed the memory capacity or the of the computer and take a very long time to compute (the 2000 x 2000 pixel image takes approximately 1.5 hour to process on a single 2 GHz 32 bit Xeon CPU).

RMW Batch on a Supercomputer



<https://rqchp.ca/>

MDSC arranged a subcontract with the Réseau Québécois de Calcul de Haute Performance (RQCHP) Université de Montréal (refer to "WP 2300 Manage the Scope of the Coverage Analysis") where RMW was executed on Wine Windows emulator (see: <http://www.winehq.org>) over Linux on a supercomputer using simultaneously 1024 cores of a 3 GHz CPU.

The computing time for each radio system was also approximately 1.5 hour in the 3GHz (same as 2GHz machine) because of the overhead of the Windows 32 bit emulator. See attached file "Run1_Files.txt" as an example of the first full scale computing time benchmark test performed on the supercomputer.

A test run performed at RQCHP from 22 to 27 Dec 2010 used 5000 CPU hours to produce some 3160 radio coverage maps at 100m/pixel resolution and for a map size of 200 x 200 km. This would have taken 208 days on a single processor desktop PC but took 30 hours on the supercomputer.

SQL Script for FCC

The following SQL script was developed by MDSC and used for the U.S. data which was provided as separate files which required relational database processing as shown in Figure 57. Note that the values in **bold** correspond to input values for the RMW Batch program as defined in Figure 58:

```
SELECT DISTINCT
```

```
FCC_EN.Unique_System_Identifier AS Sys_ID,
```

```
FCC_EN.Entity_Name & FCC_LM.Eligibility_Activity AS Resp_Class,
```

```
    If([Resp_Class] Like "**FIRE**"), "FIRE", If([Resp_Class] Like "**POLICE**"), "POLICE", If([Resp_Class] Like  
    "**SHERIFF**"), "POLICE", If([Resp_Class] Like "**RED CROSS**"), "EMS", If([Resp_Class] Like  
    "**AMBULANCE**"), "EMS", If([Resp_Class] Like "**RESCUE**"), "EMS", If([Resp_Class] Like "**911**"), "EMS", If([Resp_Class]  
    Like "**PUBLIC SAFETY**"), "EMS", If([Resp_Class] Like "**EMERG**"), "EMS", If([Resp_Class] Like  
    "**hosp**"), "EMS", If([Resp_Class] Like "**CUSTOMS**"), "POLICE", If([Resp_Class] Like "**EMS**"), "EMS", "other") AS  
Expr3,
```

```
"c:\temp\" & [Expr3] & "\" & FCC_AN.Call_Sign & "-" & FCC_FR.Frequency_Assigned & ".png" AS Picture_File,
```

```
If((FCC_AN.Gain Is Null), 0, FCC_AN.Gain) AS Gain_Cor,
```

```
10*(Log(FCC_FR.Power_Output/0.001)/Log(10)) AS Tx_PW,
```

```
If((FCC_AN.Line_Loss Is Null), 0, [Line_Loss]) AS Line_Loss_Cor,
```

```
If((FCC_FR.Frequency_Assigned<200), -1.25, If((FCC_FR.Frequency_Assigned<700), -1.9, 3)) AS Cor_Mob_Ant_Gain,
```

```
If((FCC_FR.Frequency_Assigned<200), 86.2, If((FCC_FR.Frequency_Assigned<700), 95.7, 99)) AS Cor_Rx_Th,
```

Round(((Tx_PW]-[Line_Loss_Cor])+[Gain_Cor]+[Cor_Mob_Ant_Gain]+Cor_Rx_Th),2) AS **Sys_Gain**,
 If((FCC_AN.Beamwidth Is Null),0,FCC_AN.Beamwidth) AS Cor_BW,
 If((Cor_BW=0,"omni.ant",If((Cor_BW=360,"omni.ant",If((Cor_BW>100,"cardio.ant",If((Cor_BW<100,"yagi.ant","other"))))) AS **Ant_File**,
 If((FCC_AN.Azimuth Is Null),0,FCC_AN.Azimuth) AS Cor_Ant_Az,
 If((Cor_Ant_Az=360),0,Cor_Ant_Az) AS **Ant_Az**,
 If((FCC_AN.Tilt Is Null),0,FCC_AN.Tilt) AS **Ant_Tilt**,
 If((FCC_LO.Overall_Height_of_Structure Is Null),0,FCC_LO.Overall_Height_of_Structure) AS **Ant_Height**,
 FCC_LO.Ground_Elevation AS **Elev_ASL**,
 2 AS **Mob_Ant_Height**,
 FCC_FR.Frequency_Assigned AS **Frequency**,
 Round(FCC_LO.Latitude_Degrees+(FCC_LO.Latitude_Minutes/60)+(FCC_LO.Latitude_Seconds/3600),5) AS **Latitude_dec**,
 Round(-1*(FCC_LO.Longitude_Degrees+(FCC_LO.Longitude_Minutes/60)+(FCC_LO.Longitude_Seconds/3600),5) AS **Longitude_dec**,
 1000 AS **Map_Res**,
 100 AS **Max_Range**,
 If((([Expr3]="EMS"),"0000FF",If((([Expr3]="FIRE"),"0099FF",If((([Expr3]="CCG"),"FF9900",If((([Expr3]="POLICE"),"00FF00",If((Expr3="other"),"00FFFF","FFFFFF")))))))) AS **Color**,
 "f:\geodata\srtm1" AS **SRTM_Path**,
 "f:\geodata\landcover*.lc" AS **LCV_Path**
 FROM (((FCC_AN INNER JOIN FCC_FR ON FCC_AN.Unique_System_Identifier = FCC_FR.Unique_System_Identifier)
 INNER JOIN FCC_LM ON FCC_AN.Unique_System_Identifier = FCC_LM.Unique_System_Identifier) INNER JOIN FCC_LO
 ON FCC_AN.Unique_System_Identifier = FCC_LO.Unique_System_Identifier) INNER JOIN FCC_EN ON
 FCC_AN.Unique_System_Identifier = FCC_EN.Unique_System_Identifier;

Notes:

- SRTM= Shuttle Radar Topography Mission (SRTM1 v2) terrain elevation data
- LCV= Land Cover Data
- Antenna patterns were approximated as three types for FCC and four types for IC.

SQL Output File

A sample of the SQL output file is as follows:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
16	c:\temp\FIRE\VP\FC\415-8510875.png	151.77 omni.ant	0	0	18	672		2	851.0375	44.71863	-73.89958	1000	100	0099FF	F:\geodata\src\tml	F:\geodata\src\tml	F:\geodata\src\tml	F:\geodata\src\tml
17	c:\temp\FIRE\VP\VB\322-853.0375.png	151.77 omni.ant	0	0	18	232		2	853.0375	44.46539	-73.67389	1000	100	0099FF	F:\geodata\src\tml	F:\geodata\src\tml	F:\geodata\src\tml	F:\geodata\src\tml
18	c:\temp\FIRE\VP\QE\A779-460.95.png	151.55 omni.ant	0	0	46	178		2	460.95	43.022	-78.96114	1000	100	0099FF	F:\geodata\src\tml	F:\geodata\src\tml	F:\geodata\src\tml	F:\geodata\src\tml
19	c:\temp\EMS\K\K\385-460.6375.png	150.8 gagi.ant	45	0	43	174		2	460.6375	43.04917	-77.65444	1000	100	0000FF	F:\geodata\src\tml	F:\geodata\src\tml	F:\geodata\src\tml	F:\geodata\src\tml
20	c:\temp\EMS\K\K\Q\A\343-460.6375.png	150.8 omni.ant	135	0	43	127.5		2	460.6375	43.02444	-76.66944	1000	100	0000FF	F:\geodata\src\tml	F:\geodata\src\tml	F:\geodata\src\tml	F:\geodata\src\tml
21	c:\temp\FIRE\VP\GC\Y\617-460.975.png	150.73 omni.ant	0	0	53.4	189		2	460.975	42.37533	-78.85836	1000	100	0099FF	F:\geodata\src\tml	F:\geodata\src\tml	F:\geodata\src\tml	F:\geodata\src\tml
22	c:\temp\FIRE\VP\NR\300-807.8375.png	150.75 omni.ant	0	0	186			2	807.8375	43.2185	-78.21803	1000	100	0099FF	F:\geodata\src\tml	F:\geodata\src\tml	F:\geodata\src\tml	F:\geodata\src\tml

Figure 60 - SQL Output File Example

The actual output files are provided as an attachment as .txt files:

- IC PS Pool for RMW Batch v13.txt (Canada, PS stands for Public Safety)
- FCC for RMW Batch v06.txt (U.S)

Note: for multiple occurrences of call signs only the highest antenna and largest system gain for that call sign was kept as a project scope management measure. Refer to "WP 2300 Manage the Scope of the Coverage Analysis" for more details.

RMW Output

The output of RMW is an image file in .png format showing where radio coverage is good associated with its geographic coordinates in .dat and .kml file formats.

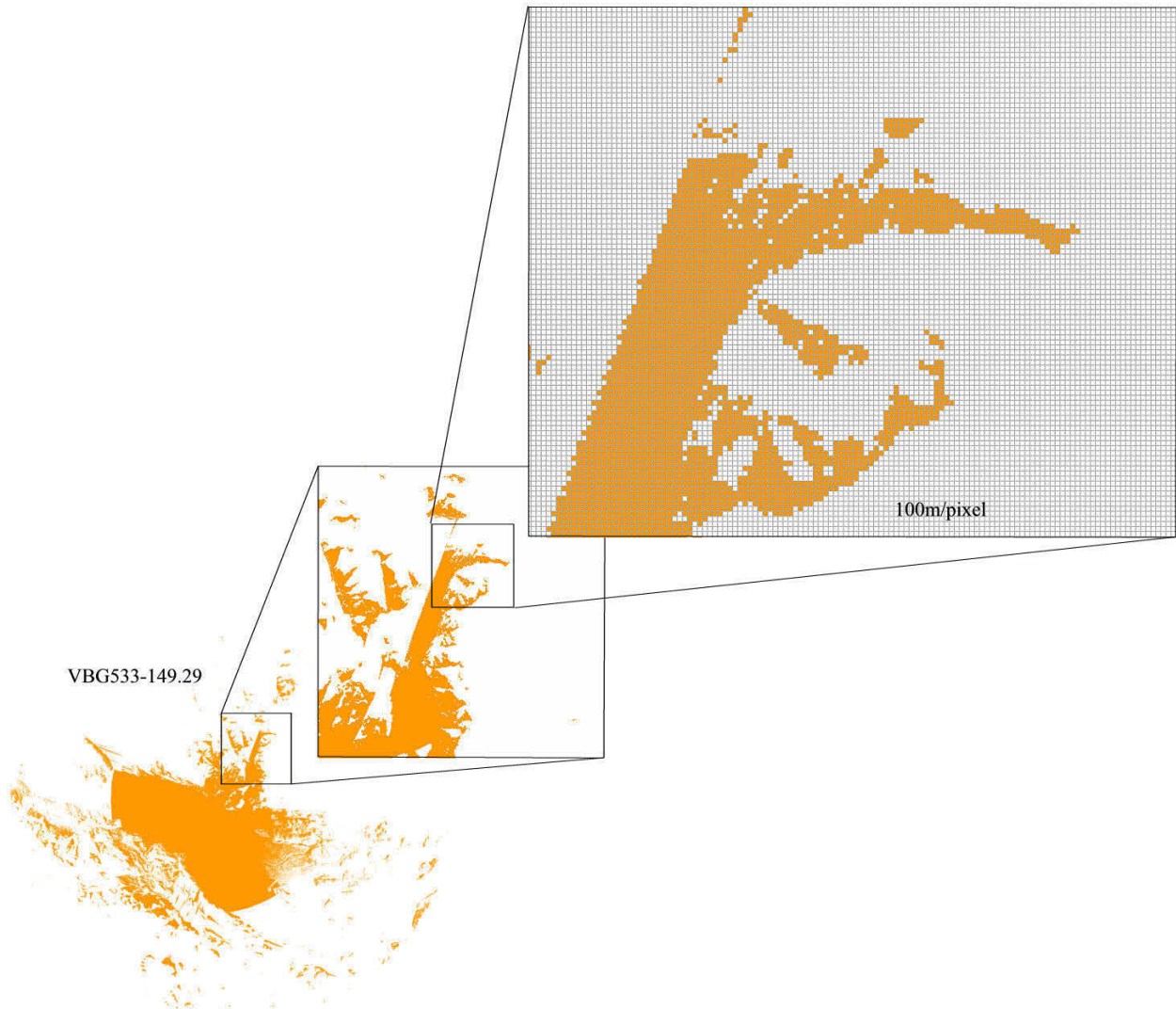


Figure 61 - RMW Output Example for 100m/pixel and 200 x 200 km map size

Note: a resolution of 100 m/pixel makes placement of antennas relative to mountain peaks very important. If there is an error in the position of the antennas the peak may cast a shadow which is very significant with respect to the global coverage.

Coverage Results

In order to produce global coverage maps that could be processed as a single image combining over 7000 images on a desktop workstation, all radio records were processed in RMW batch in low resolution at 4km/pixel and 100 x 100 km to produce 50 x 50 pixel thumbnails.

Methods and processing equipment needed to display the coverage in high resolution are presented in "WP 3200 Produce Coverage Visualization Maps".

The coverage results are stored in a tree structure as shown in Figure 62.

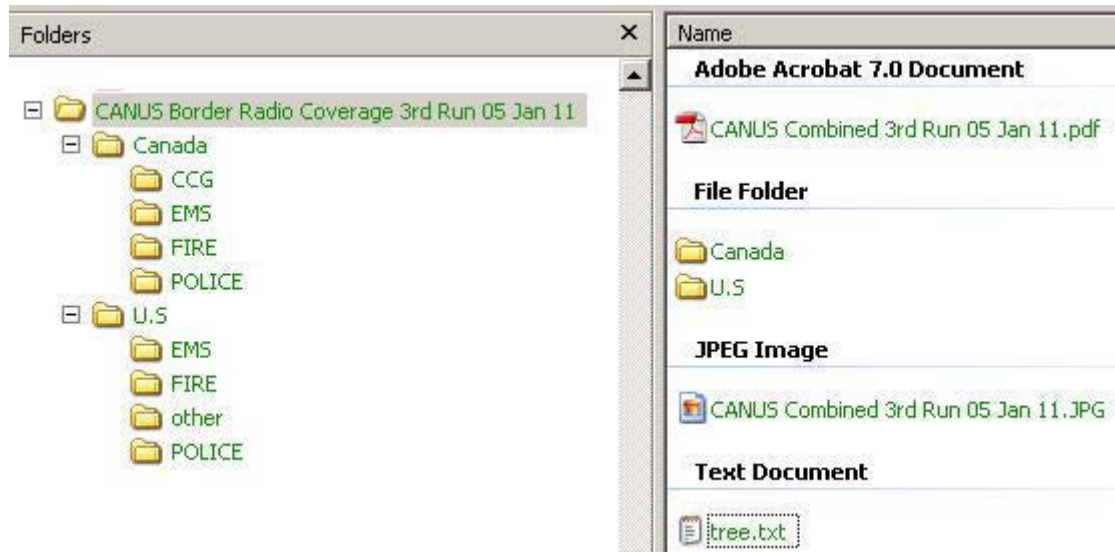


Figure 62 - Folder Tree Structure for Coverage Results

The list of files and the tree structure of these results is also included in attachment as "tree.txt".

The assessment of the high resolution images is performed in "WP 3200 Produce Coverage Visualization Maps".

The operational impact analysis is performed in "WP 3300 Assess Severity of Coverage Gaps".

Canada Coverage Results

The global Canada coverage results are shown in Figure 63.

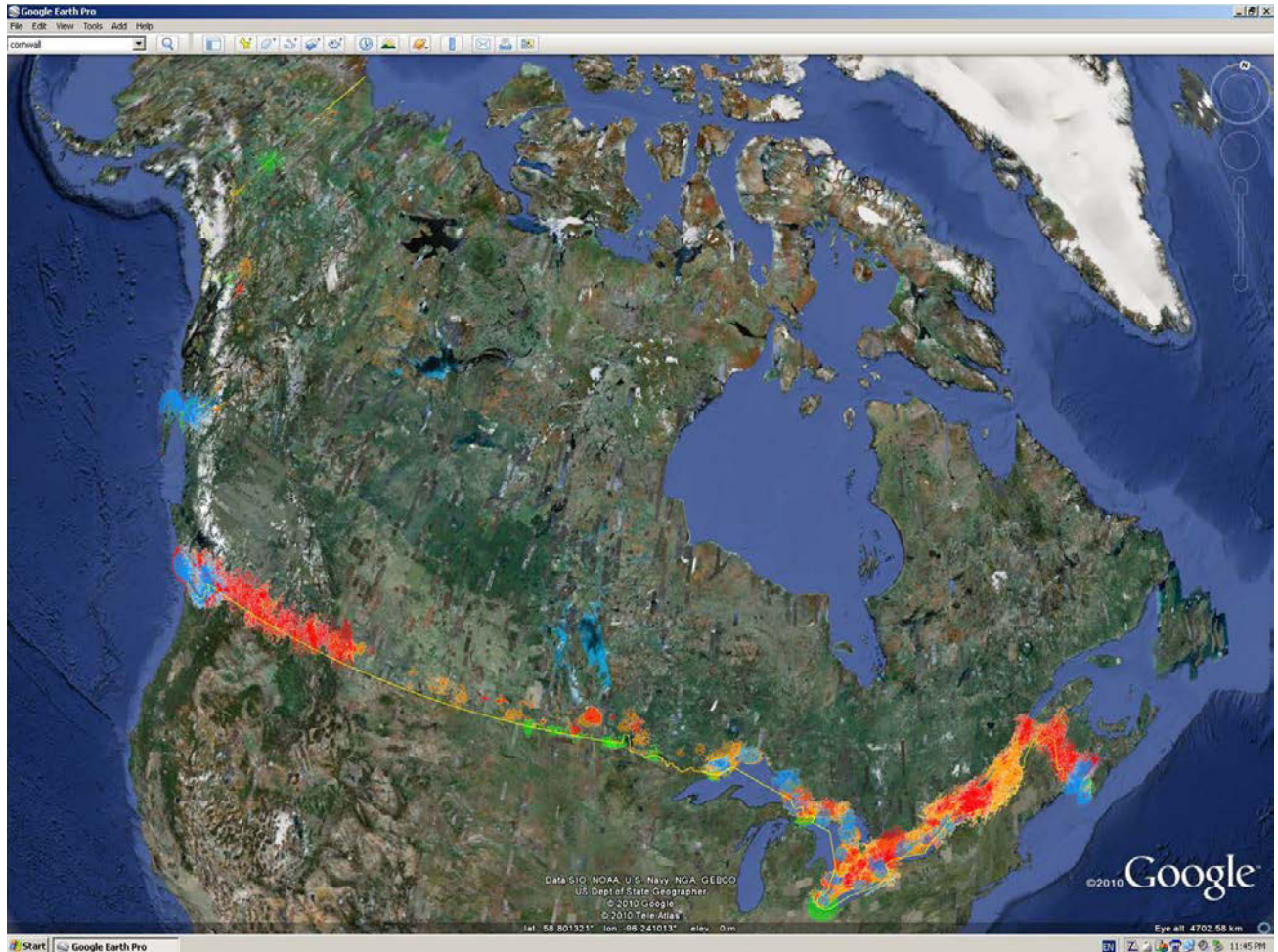


Figure 63 - Global Canada Coverage 05 Jan 11 Run

A high resolution of this map is provided in attachment to this report as "Canada 05 Jan 11 Run.pdf"

Unites States (U.S.) Coverage Results

The global U.S. coverage results are shown in Figure 64.

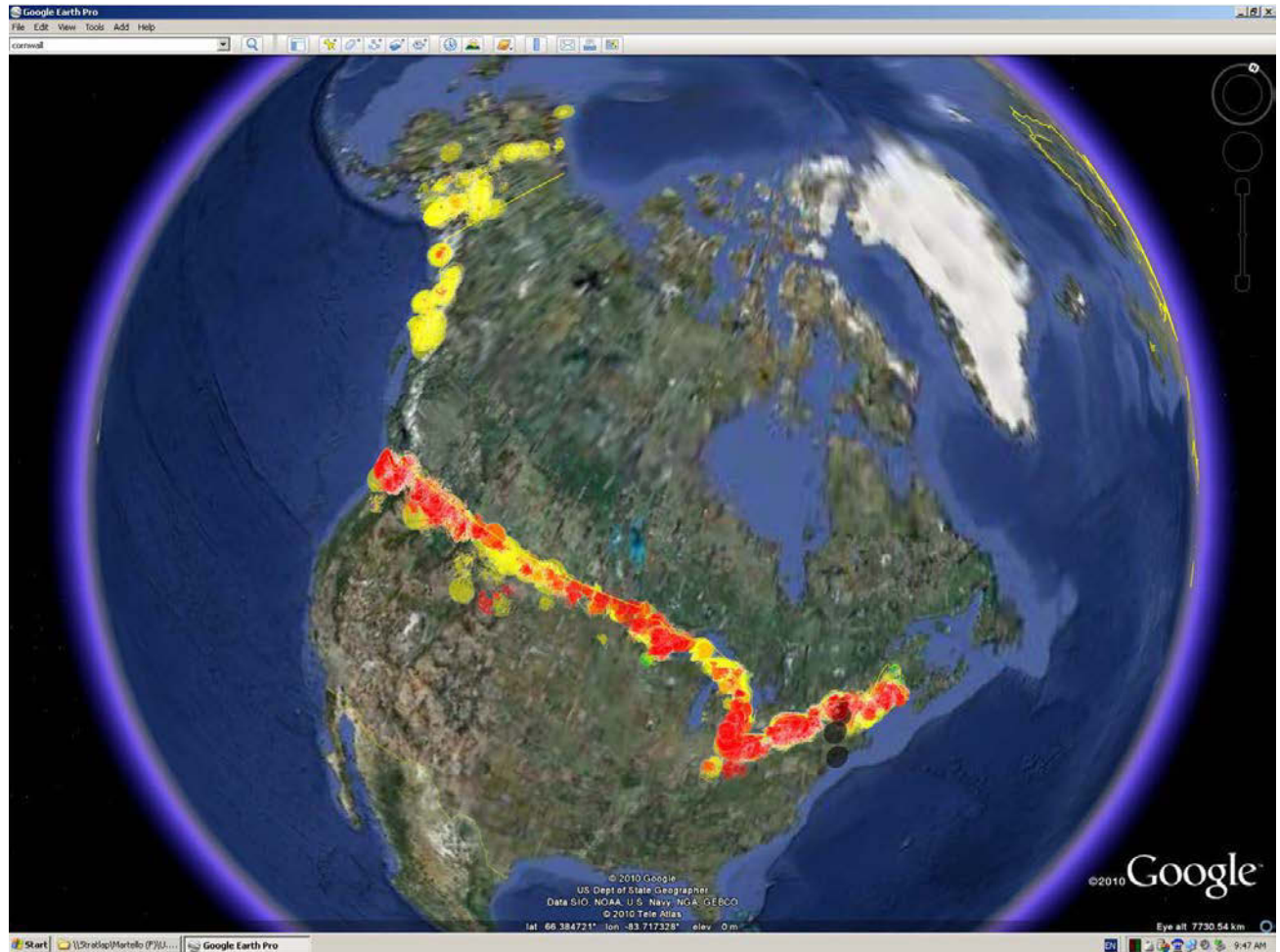


Figure 64 - Global U.S Coverage 05 Jan 11 Run

A high resolution of this map is provided in attachment to this report as "U.S. 05 Jan 11 Run.pdf".

Combined Canada and United States Results

The combined Canada and U.S. coverage results are shown in Figure 65.

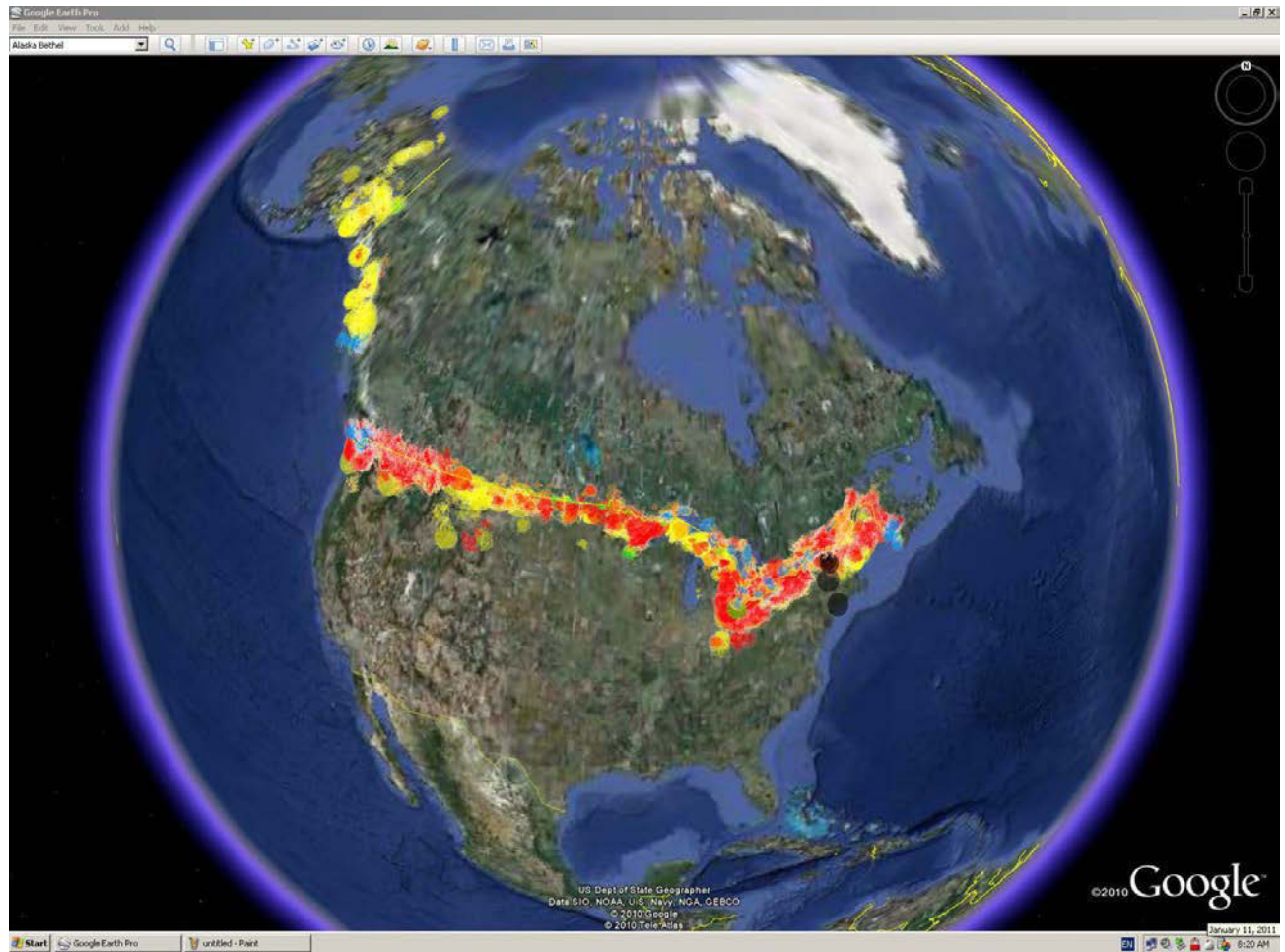


Figure 65 - Combined Canada and U.S. Coverage 05 Jan 11 Run

A high resolution of this map is provided in attachment to this report as "CANUS Combined 3rd Run 05 Jan 11.jpg".

Attachments

The following files are included with this report:

- rmweng v 10.6.7 23 Dec 10.exe
- IC PS Pool for RMW Batch v13.txt (Canada, PS stands for Public Safety)
- FCC for RMW Batch v06.txt (U.S)
- Run1_Files.txt
- tree.txt
- Canada 05 Jan 11 Run.pdf
- U.S. 05 Jan 11 Run.pdf
- CANUS Combined 3rd Run 05 Jan 11.jpg

Abbreviations

CANUS	Canada United States
CPU	Central Processing Unit
CRC	Communications Research Center
CSS	Center for Security Science
FCC	Federal Communications Commission
IC	Industry Canada
LCV	Land Cover
MDSC	Martello Defence Security Consultants inc.
NTIA	National Telecommunications and Information Administration
PS	Public Safety
RQHCP	Réseau Québécois de Calcul de Haute Performance
RMW	Radio Mobile for Windows
SQL	Search Query Language
SRTM	Shuttle Radar Topography Mission
U.S.	United States
WP	Work Package
ZoneCov	Zone Coverage – name of an executable computer program

Project number: PSTP 02-302 EMSI

Coverage Visualization Maps

WP 3200

Document number: MDSC-ANA-0009 v01, TBD Mar 2011

Purpose

The purpose of this document is to provide the methodology used by Martello Defence Security Consultants inc. (MDSC), and examples of the radio coverage maps. The analysis shows how to reproduce and visualize in 'plan', 'perspective' and 'stereo' view terrain maps textured with radio coverage plots.

For this task, MDSC has used:

- Radio Mobile for Windows (www.ve2dbe.com),
- Google Earth Pro (<http://www.google.com/earth/businesses/>),
- Earth Plot (<http://www.earthplotsoftware.com>), and
- Rhinoceros 3D software (www.rhino3d.com).

Scope

This document uses the results from:

WP2200 Define Radio Coverage Area of Interest
WP3100 Propagation Analysis

The coverage maps and techniques will be used for the operational task "WP3300 Assess Severity of Coverage Gaps".

Visualization Metadata

Visualization Tools

Visualization with Radio Mobile for Windows

Radio Mobile for Windows (RMW) has many views; the most useful ones being planar, perspective and stereoscopic.

It can be seen in Figure 66 that the wedges without coverage are due to obstructions from the mountain top. The antenna is not located at the top of the mountain as seen in the elevation grid as there are elevations higher than the 210m position of Unit 6. In practice, such obstructions may be voluntary to avoid interference with other sites. The views offered by RMW are useful to understand global coverage issues for a particular transmitter site.

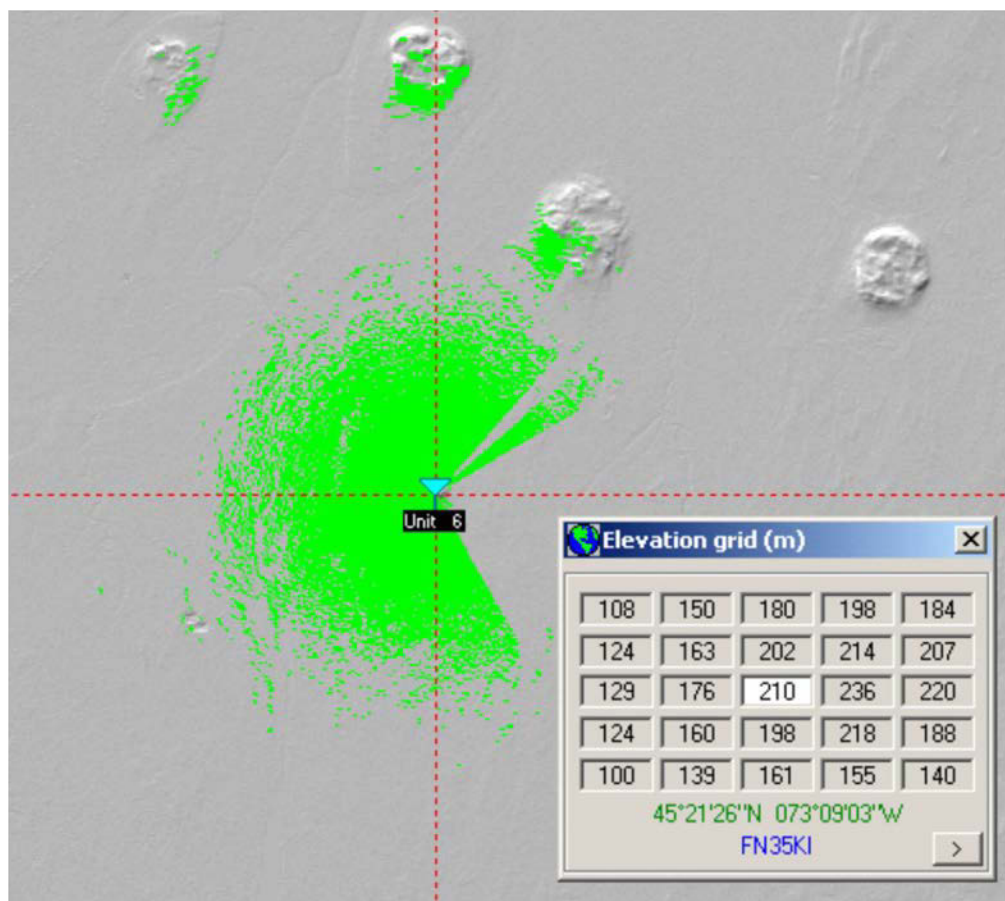


Figure 66 – Mont St-Grégoire RMW Planar View

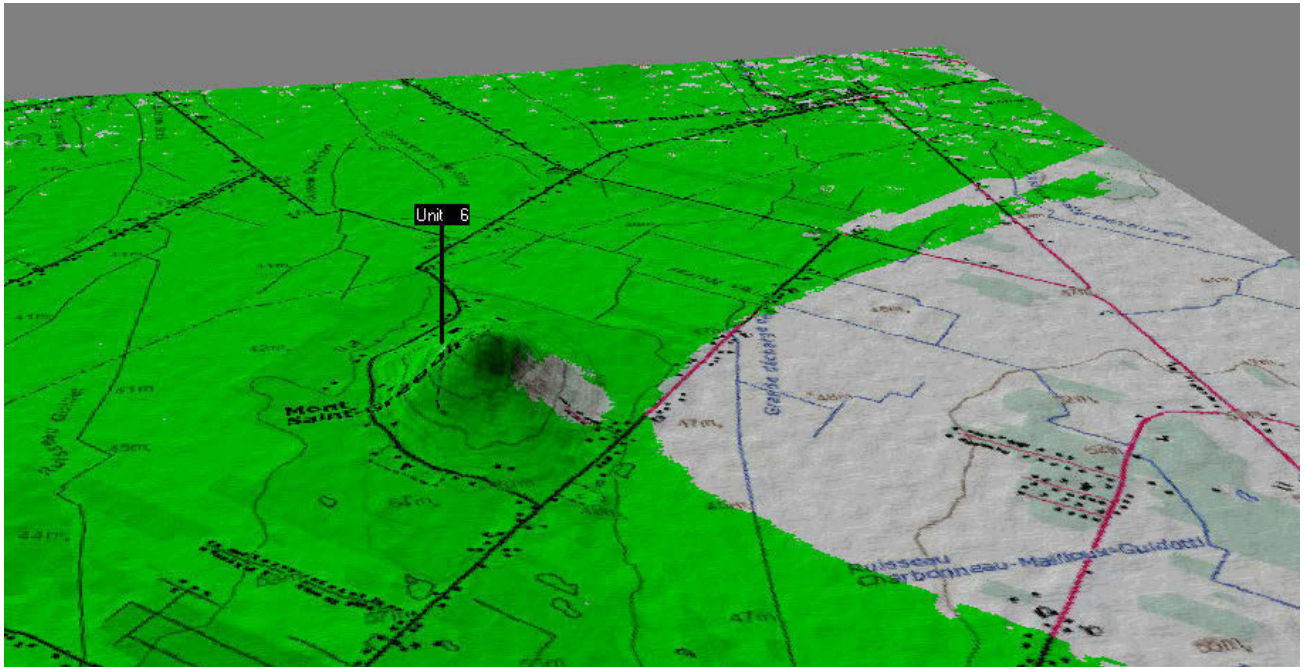


Figure 67 - Mont St-Grégoire RMW 3D View

Using Figure 67, it is clear that the mast is not on top of the mountain; the shadow is well understood. The stereo view of Figure 68 can help as well.

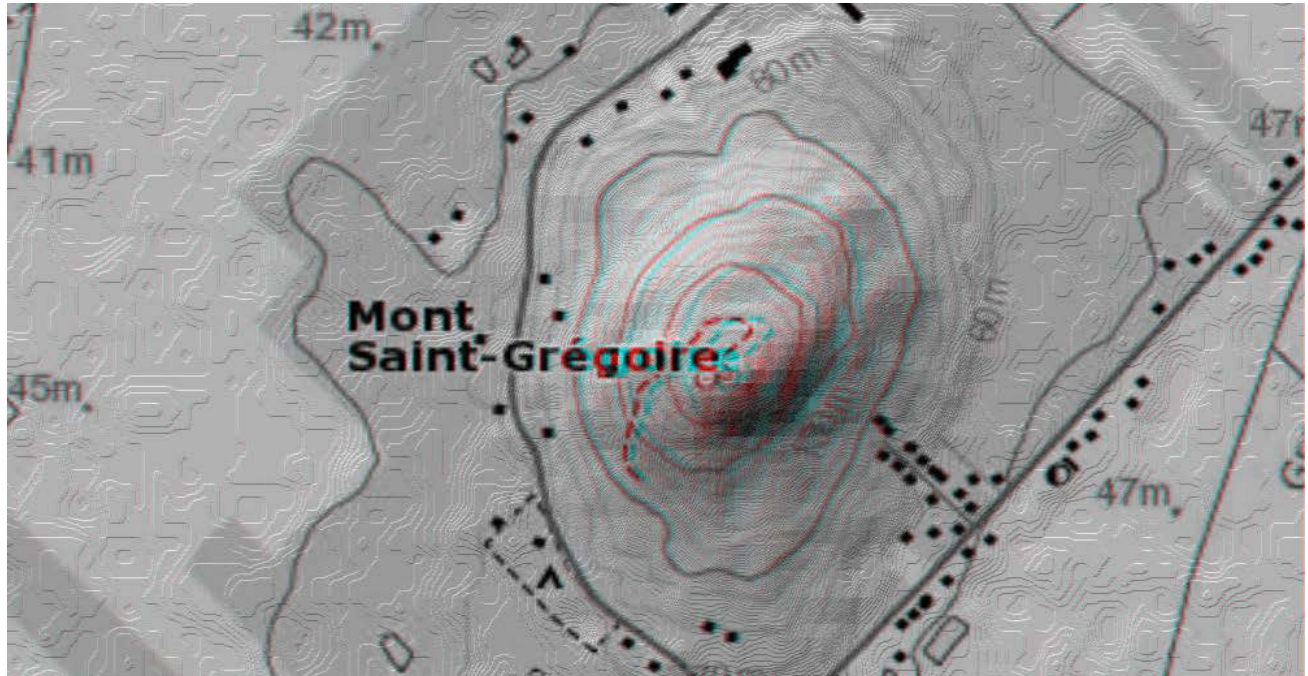


Figure 68 - Mont St-Grégoire RMW Anaglyph Stereo (Red-Blue) View

RMW to Google Earth

Saving pictures in RMW also automatically saves a .kml file and associated geomatics metadata .dat .geo and .inf files. For importing files into Google Earth, save the coverage as a picture with a white background using the .png image file format. For a white background, merge with operation "copy" an image with brightness set to max. and contrast set to min. as shown in Figure 69.

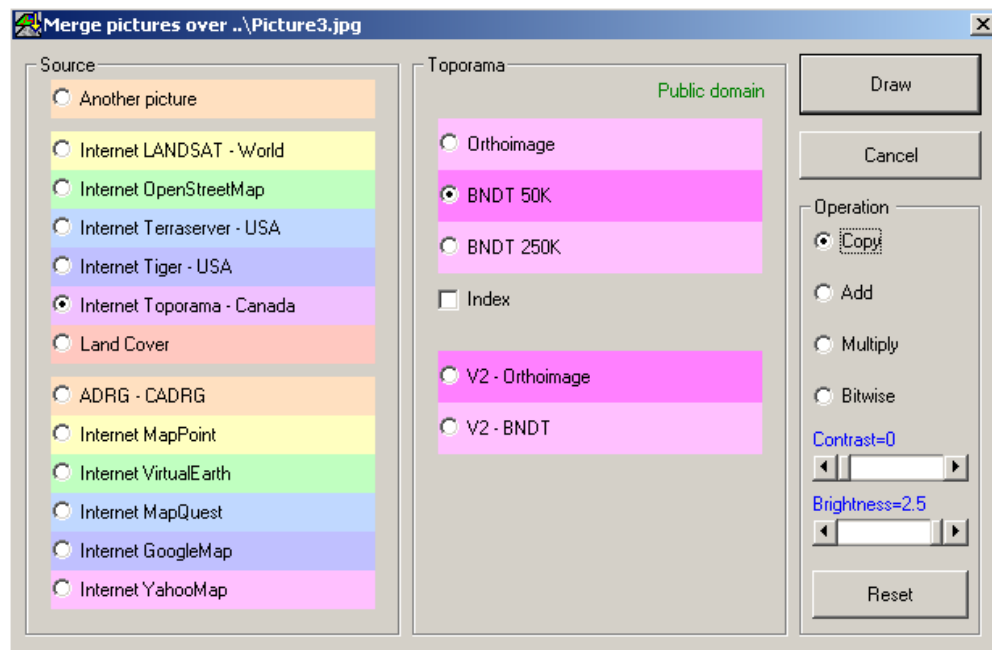


Figure 69 - Setting white background in RMW

For best view in Google Earth, set white as transparent as shown in Figure 70 when saving a RMW picture.

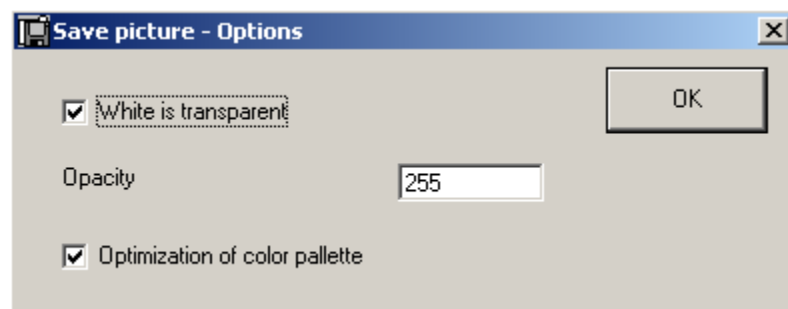


Figure 70 - Setting white as transparent in RMW

Visualization with Google Earth

Graphics Processing Limitations

Loading all the radio coverage images at once is a very demanding task for a desktop PC. Do not attempt to load all the high resolution 2000x2000 pixel radio coverage maps at once on any machine.

The following benchmarks were performed for loading 2222 .kml files of the 50 x 50 pixel Canadian coverage:

- Nvidia Quadro 4 256 MB AGP4 card and 2GHz Xeon CPU, 2GB RDRAM: > than 3 hours
- Nvidia GeForce GTX 460M 1.5GB and Intel i7-Q740 CPU, 8GB DDR3 (in Open GL): ~ 2 min

To efficiently use Google Earth with a large number of coverage maps, the use of a very powerful gaming PC is recommended.

Graphics Processing Limitation Mitigation

As a mitigation technique for viewing a large number of files at once, MDSC used the Earth Plot software to generate post maps for Google Earth where the call sign of the unit is visible. Post maps are not a significant computing load for the PC. This allows the user to visualize all the radio emitters in a given region by zooming-in with Google Earth and then enabling the .kml file only for those stations for which the coverage is to be seen. An example of Post Map is provided in Figure 72.

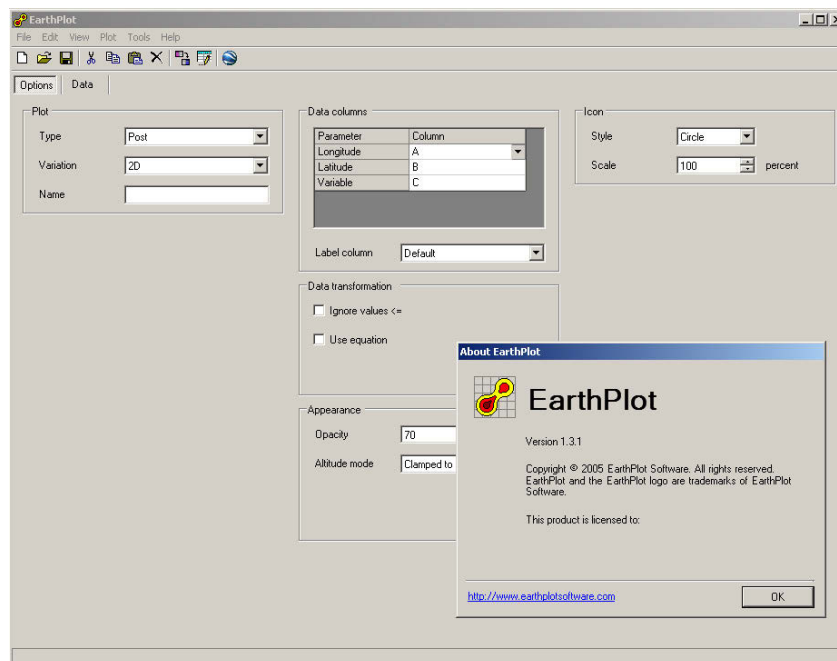


Figure 71 - Earth Plot Post Map Options

See attached files "Canada Post Map.kmz" and "U.S. Post Map.kmz".

Another advantage of Post Maps is that it allows the user to be aware of overlapping radio coverage maps, for co-located transmitters on the same mast. In Figure 72, it can be seen that there are three transmitters at site VBA3.

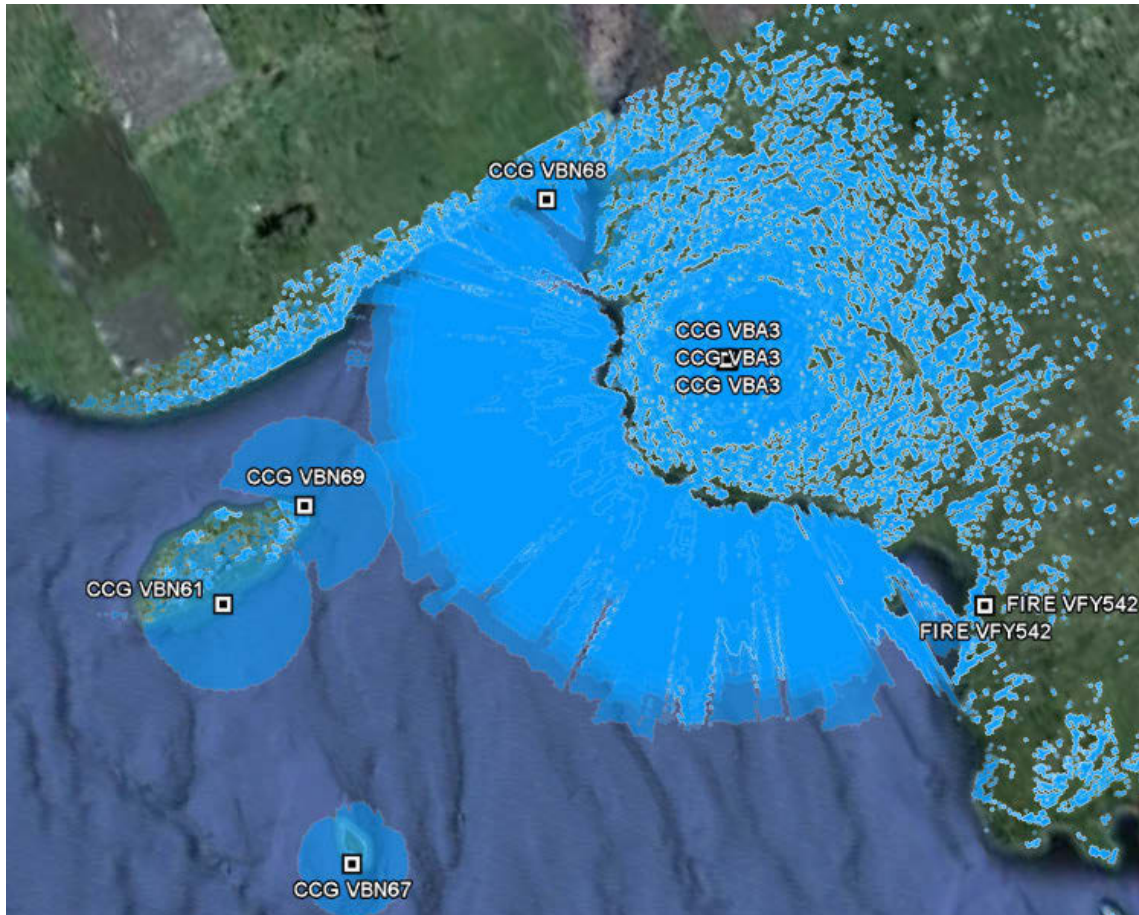


Figure 72 - Planar view of Canadian Coast Guard Coverage in Google Earth with Post Map Overlay

Views in Google Earth

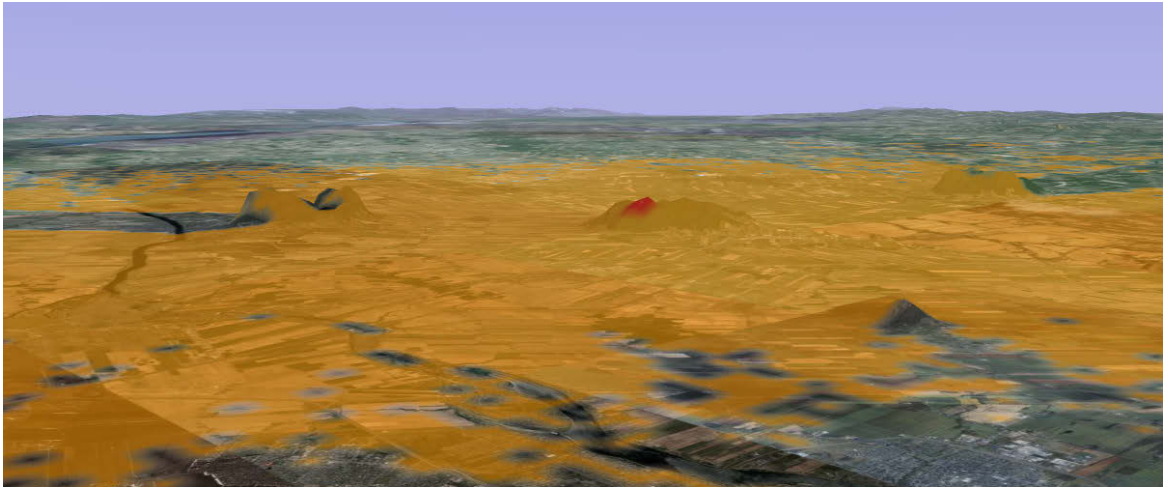


Figure 73 - Rougemont Area Mont Saint Hilaire (left) and Mont St-Grégoire (right) Shadows

With the views in Google Earth, the coverage can be validated while showing a perspective view and terrain relief. In the example of Figure 73 the transmitter antenna location is depicted by a shaded red area and the radio coverage in orange; it is clearly seen that mountains are creating radio propagation obstructions. This observable fact is a good way to understand why the specific radio coverage plot is not round.

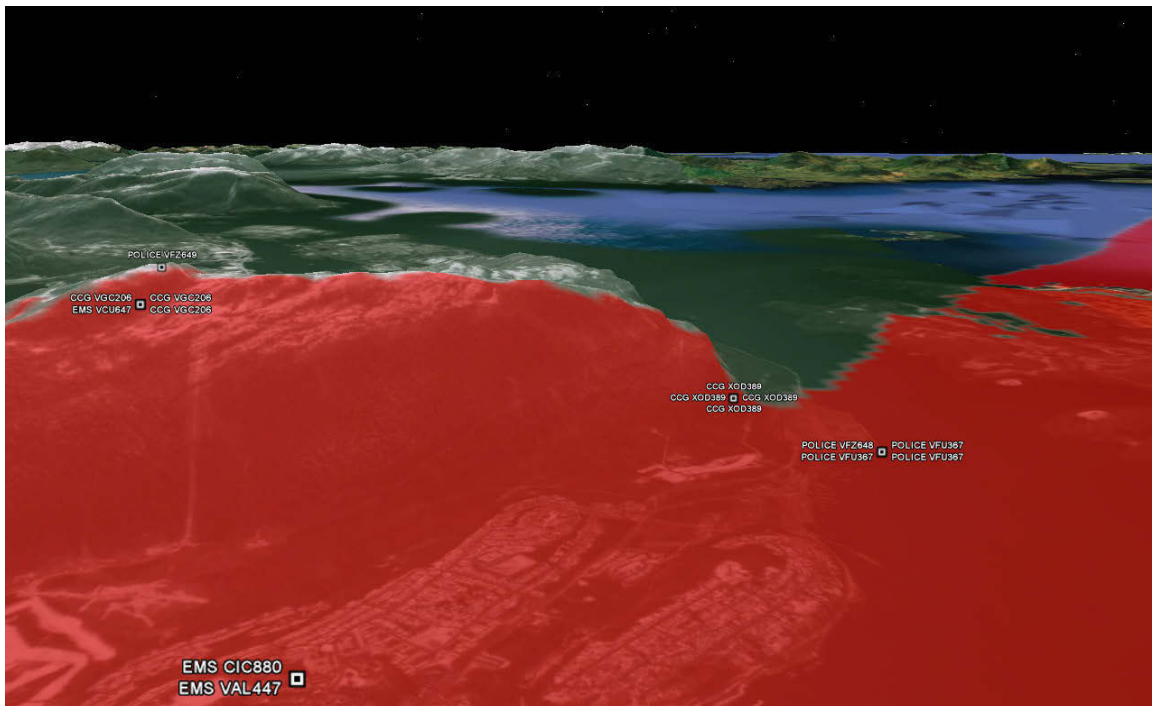


Figure 74 - Obstruction by Mountain Ridge for VAL447

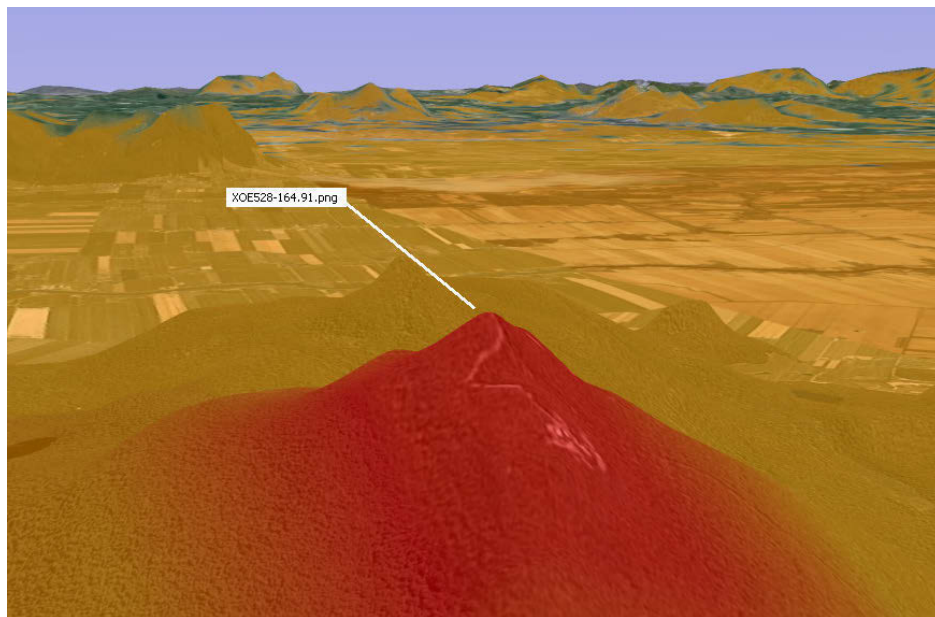


Figure 75 - Mont Rougemont Antenna Site

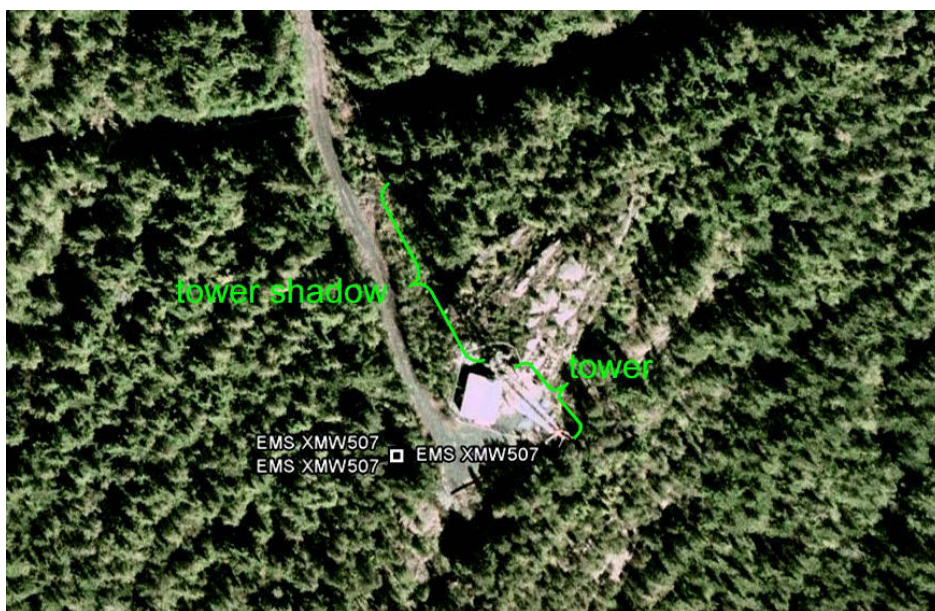


Figure 76 - XMW507 Tower

In Figure 75, the service road for the antenna is visible and in Figure 76 the tower itself is visible. When interpreting and producing high resolution coverage, small errors in the position of the antenna with respect to the mountain peak can cause significant coverage differences. If an error is to be corrected, it is suggested that RMW be used to relocate that transmitting unit based on high resolution GPS data or Toporama 50K overlays.

Video produced by Google Earth

See attached file "CANUS Border Radio Coverage Visualization Demo.wmv"

The following describes the video:

The demo shows the land border vector received from NRCAN/International Boundary Commission and the territorial sea limits received from the Canadian Hydrographic Service.

The view zooms-in on the Vaudreuil-Kingston Zone 4 (total of 28 Zones for the border for the project).

A 60 km wide strip was created to define two sub-strips Canada (yellow) and US (cyan). Four color codes were assigned to different responder types which will allow specific coverage reports to be created using an image analysis software; (note: the example does not use real radio data and police is not shown).

The video zooms-in to show roads demonstrating that the coverage resolution is 100m/pixel.

A "combined" green coverage in square brackets is shown at the end of the video to illustrate the coverage of all first responders combined i.e. assuming they are fully interoperable.



Fire



EMS



Coast Guard



Police

entire

very

A 1080 x 720 High Definition (HD) video named "Flight over CANUS Border HD v01.wmv" is provided as an attachment. This video represents the data from "WP 3100 Perform Propagation Analysis".

Note: for the U.S. color yellow was assigned to "other government agencies" which were included as records under the public safety pool.

Visualization with Rhino3D

Google Earth's terrain database is limited in resolution while the terrain resolution viewable with RMW is SRTM1 v2 at ~30m resolution between elevation points. If there is a need to visualize terrain and overlays in very high resolution, RMW images saved as X-ray inverted can be used in conjunction with the "heightfield" command of Rhino3D to produce a 3D mesh in .3ds or .dxf formats which are then useable by most Computer Aided Design (CAD) software.

The texture for the mesh can be any image, in Figure 77 a Canadian Toporama orthoimage was used.

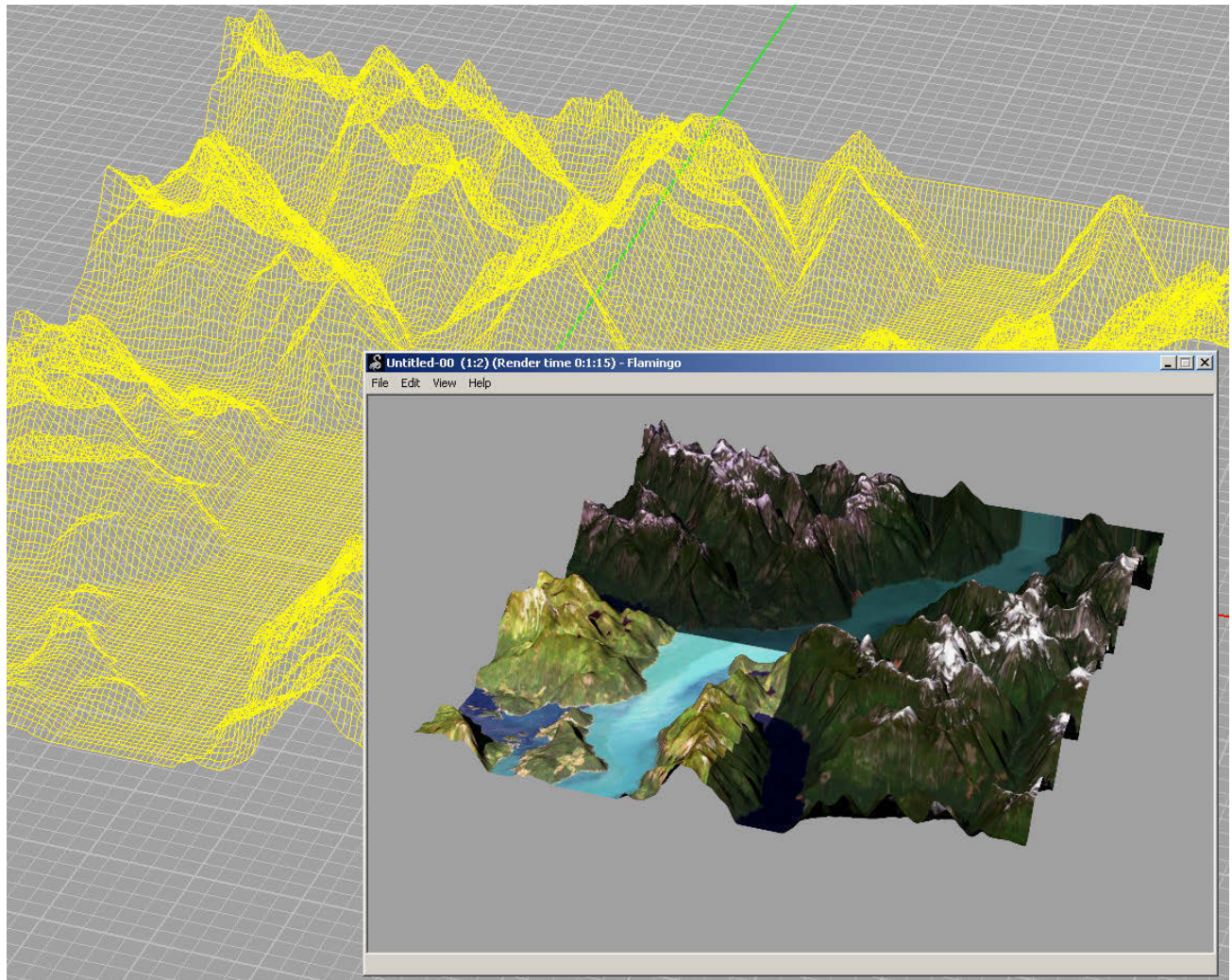


Figure 77 - Terrain Mesh and Texture Overlay

The terrain mesh is very useful for predicting satellite coverage in mountainous areas using ray tracing techniques.

Attachments

The following files are included with this report:

- Canada Post Map.kmz
- U.S. Post Map.kmz
- CANUS Border Radio Coverage Visualization Demo.wmv
- Flight over CANUS Border HD v01.wmv
- RQCHP Final Run 01 Mar 11 (7397 Radio coverage Plots at 100m/pixel)
- CCG-All Final Hi Res (100m per pixel).kmz
- CANUS v02 05 Jan 11 Run (4km per pixel 100km max range).kmz
- 2011 03 01 YARA Coverage Plots.kmz
- CANUS for RMW Batch v05.txt

Abbreviations

5.1

CAD	Computer Aided Design
CANUS	Canada - United States
CPU	Central Processing Unit
CRC	Communications Research Center
CSS	Center for Security Science
DDR	Double Data Rate
GPS	Global Positioning System
HD	High Definition
i.e.	id est (Latin), that is
MDSC	Martello Defence Security Consultants inc.
OpenGL	Open Graphics Library
PC	Personal Computer
RDRAM	RAMBUS Dynamic Random Access Memory
RMW	Radio Mobile for Windows
SRTM	Shuttle Radar Topography Mission
U.S.	United States
WP	Work Package

Project number: PSTP 02-302 EMSI

Assess Severity of Coverage Gaps

WP 3300

Document number: MDSC-ANA-0010 v02, 09 Mar 2011

Purpose

The purpose of this document is to present the radio coverage gaps for the Canadian-United States (CANUS) border region. The analysis provides an overview of all gaps on a continental scale as well as high resolution radio coverage images of each gap region associated with a brief observation.

Scope

This document uses results from:

- WP 2410 Define Operational Availability Metrics
- WP 3100 Propagation Analysis
- WP 3200 Produce Coverage Visualization Maps
- WP 4300 Coverage Analysis Training

Note: This document will be revised to include comments from first responders based on 5 regional debriefings which will be conducted from 14 Feb to 01 Mar 2011 which is an element of "WP 4300 Coverage Analysis and Training". Also, comments from the Canadian Coast Guard and the Canadian Border Services Agency will be added to complete the review process.

The following documents will use information from this report:

- WP 4100 Identify Technology Solution Options
- WP 4200 Produce Capability Roadmap

Annex H contains sensitive information; in order to make this report widely available details have been removed. For further information please consult the Scientific Authority.