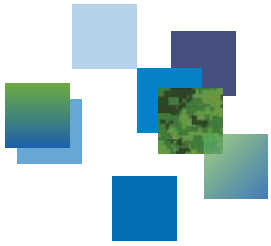
Defence Research and Development Canada
Recherche et développement pour la défense Canada

DRDC | RDDC



Optimal alignment of search and rescue response posture with historical incident occurrence

Bohdan L. Kaluzny
CJOC OR&A
DRDC – Centre for Operational Research and Analysis

Defence Research and Development Canada

Scientific Report
DRDC-RDDC-2014-R12
April 2014

Canada

Optimal alignment of search and rescue response posture with historical incident occurrence

Bohdan L. Kaluzny
CJOC OR&A
DRDC – Centre for Operational Research and Analysis

Defence Research and Development Canada
Scientific Report
DRDC-RDDC-2014-R12
April 2014

Abstract

The Canadian Armed Forces (CAF) maintain a response posture to Search and Rescue (SAR) operations 24 hours per day, seven days per week. Recently, SAR squadrons maintained a 30-minute response posture (RP30) for 40 hours (hrs) a week per resource (aircraft type): 0800-1600hrs, Monday to Friday, and a 2-hour response posture (RP2hrs) for remaining hours.

This report details the data, modelling and analysis for optimizing CAF SAR RP30 hours. Based on recent data, the report presents optimal RP30 schedules that maximize the alignment of CAF SAR response posture with the occurrence of distress or potential distress incidents.

Significance for defence and security

The primary goal of Canada's National SAR Program is to save lives at risk throughout Canada's SAR area of responsibility. The CAF are one of several contributing entities. The primary SAR responsibility of the CAF is the provision of aeronautical SAR and the coordination of the aeronautical and maritime SAR system.

In response to a Canadian Joint Operations Command (CJOC) J3 SAR request, CJOC Operational Research & Analysis undertook a study to determine optimal RP30 schedules maximizing the alignment with the occurrence of distress or potential distress incidents based on recent data (last five years), focusing in the busy summer SAR season.

The results provided Commander (Comd) CJOC with quantitative evidence to base response posture direction in the 2013 and 2014 CJOC SAR Directives. The recommended optimal RP30 schedules were trialled in the Trenton SAR region (SRR) between May and September 2013. The 2013 trial validated anticipated gains in the number of distress or potential distress incidents for which optimized CAF RP30 schedules aligned with. A post-analysis of the trial informed CJOC and 1 CAD decision makers and was used as input to the 2014 CJOC SAR Directive. This report also documents the optimization of RP30 schedules in the Victoria and Halifax SRRs as reference for future CJOC SAR Directives.

Facts confirmed include:

- Summer months collectively represent the period with higher SAR activity;
- The occurrence of distress or potential distress incidents are most prevalent on weekends and afternoons/evenings, but to different degrees per SRR.

Key findings include:

- 0800-1600hrs, Monday to Friday, RP30 schedules align with approximately 25-30% of distress or potential distress incidents. There is no statistical evidence to suggest that these schedules were chosen to align with the occurrence of SAR incidents;
- Optimal "Best 5×8" RP30 schedules (8 hours a day for 5 consecutive days a week, with consistent start times) are anticipated to align with 40-50% of distress or potential distress incidents;

- The variation in effectiveness between good (near-optimal) schedules is small—other criteria other than number of incidents can be used to select the preferred schedule from the menu of choices provided;
- Study results are consistent with those of a 1987 study—the near-optimal schedules determined herein align with schedules determined therein. This is a strong indication that the occurrence and pattern of SAR incidents has not changed much in the last 20-30 years.

Résumé

Les Forces armées canadiennes (FAC) doivent maintenir une capacité d'intervention dans le cadre des opérations de recherche et de sauvetage (SAR) 24 heures sur 24, et ce 7 jours sur 7. Récemment, les escadrons de SAR ont maintenu une posture d'intervention de 30 minutes pour 40 heures par semaine par ressource (type d'aéronef), soit de 8 h à 16 h du lundi au vendredi et de 2 heures en dehors de cet horaire.

Le présent rapport explique de façon détaillée les données, la modélisation et l'analyse visant à optimiser les heures où les ressources de SAR des FAC maintiennent une posture d'intervention de 30 minutes. En se fondant sur des données récentes, il présente des horaires optimaux qui maximisent la concordance entre la posture d'intervention des FAC en matière de SAR et l'occurrence de cas de détresse ou de détresse potentielle.

Importance pour la défense et la sécurité

L'objectif principal du Programme national de SAR du Canada est de sauver des vies humaines en danger dans l'ensemble de la zone de responsabilité de SAR du Canada. Les FAC sont l'une des nombreuses organisations participantes. La principale responsabilité des FAC dans le domaine est d'assurer des services aéronautiques de SAR et de coordonner le système aéronautique et maritime de SAR.

En réponse à une demande du J3 SAR du Commandement des opérations interarmées du Canada (COIC), l'équipe d'analyse et de recherche opérationnelle du COIC a entrepris une étude visant à établir un horaire optimal lié a la posture d'intervention de 30 minutes. L' étude a été produite en maximisant la concordance avec l'occurrence de cas de détresse ou de détresse potentielle en se basant sur des données récentes (cinq dernières années) et en se concentrant sur la saison estivale de SAR - la saison la plus occupée.

Les résultats ont fourni au commandant du COIC des données quantitatives sur lesquelles il s'est appuyé pour élaborer l'orientation en matière de disponibilité opérationnelle dans les directives de SAR 2013 et 2014 du COIC. Les horaires optimaux recommandés ont été mis à l'essai de mai à septembre 2013, dans la région de recherche et sauvetage (RRS) de Trenton. L'essai de 2013 a validé l'augmentation prévue du nombre d'incidents de détresse ou de détresse potentielle en tenant compte de la posture d'intervention de 30 minutes des FAC. Une analyse ultérieure a permis d'informer les décideurs de la 1 DAC et du COIC. Elle a également servi à orienter la directive de SAR 2014 du COIC. Ce rapport décrit également l'optimisation des horaires liés à la posture d'intervention de 30 minutes dans les RRS de Victoria et Halifax comme références pour les directives de SAR du COIC à venir.

Parmi les faits confirmés :

- Les mois estivaux représentent, collectivement, la période d'activité de SAR la plus élevée ;
- L'occurrence de cas de détresse ou de détresse potentielle est plus élevée les fins de semaines et en après-midi/soirée, mais à différents degrés par RRS.

Parmi les principales conclusions :

- Un horaire de 8 h à 16 h du lundi au vendredi pour la posture d'intervention de 30 minutes englobe avec environ 25 à 30 % des cas de détresse ou de détresse potentielle. Toutefois, aucune preuve statistique ne laisse croire que ces horaires ont été choisis pour concorder avec l'occurrence des incidents de SAR ;
- Les horaires optimaux 8 heures/5 jours liés a la posture d'intervention de 30 minutes (8 heures par jour pendant 5 jours consécutifs, avec la même heure de début) devraient concorder avec 40 à 50 % des incidents de détresse ou de détresse potentielle ;
- La variation de l'efficacité dans les bons horaires (quasi-optimaux) est faible - des critères autres que le nombre d'incidents peuvent être utilisés pour choisir l'horaire privilégié à partir du menu des options fournies ;
- Les résultats de l'étude correspondent à ceux de 1987 - les horaires quasi-optimaux actuels concordent avec ceux de l'époque. Cela indique que la distribution d'incidents de SAR a peu changé au cours des 20 à 30 dernières années.

Acknowledgements

The author thanks Dr. John Steele, Mr. Charles Hunter, and Mr. Sean Bourdon for useful discussions and insight on previous DRDC CORA studies on Search and Rescue (SAR) response posture optimization and on SAR data sources. Mr. Raman Pall provided timely suggestions for data and result presentation and the appropriate selection of statistical tests. Dr. Patrick Dooley reviewed initial drafts and provided excellent suggestions.

The author thanks LCol Chris Denko (CJOC J3 SAR until February 2013), LCol Craig Weir (CJOC J3 SAR February 2013 - March 2014) and their superb staff (MWO Greg Smit, Maj Kevin Grieves) for timely input, direction, and for fostering an integrated approach to the analysis.

Capt David Burneau (19 Wing 442 Transport and Rescue Squadron) was instrumental in extracting and forwarding data in a timely fashion.

This page intentionally left blank.

Table of contents

List of figures

This page intentionally left blank.

1 Introduction

1.1 Background

The National Search and Rescue Secretariat, an independent agency of the Government of Canada, administers the National Search and Rescue Program (NSP), coordinating public policy for the provision of Search and Rescue (SAR) services. The primary goal of the NSP is to save lives at risk throughout Canada's SAR area of responsibility (AOR). Figure 1 depicts the entirety of the Canadian AOR. The area encompasses over 18,000,000 km^2 and includes all of Canada's land mass as well as areas of the Atlantic, Pacific and Arctic oceans as designated by the International Maritime Organization and International Civil Aviation Organization.

For command and control purposes, the Canadian AOR is subdivided into three smaller search and rescue regions (SRRs), each with its own Joint Rescue Coordination Centre (JRCC): the Victoria SRR, Trenton SRR, and Halifax SRR.

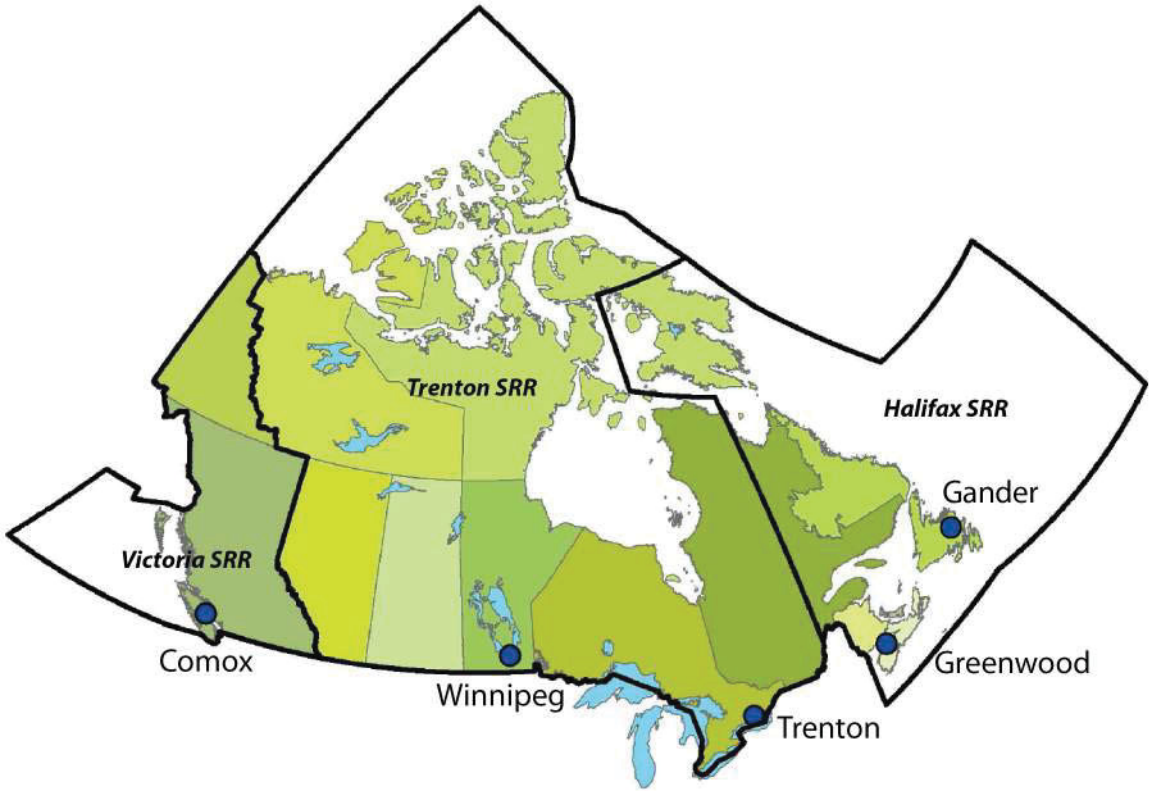


Figure 1: *Canadian AOR and the Victoria SRR, Trenton SRR, and Halifax SRR subdivisions.*

The NSP involves federal departments, provincial and territorial governments, municipalities, non-profit organizations, and volunteers working together to provide search and rescue in Canada. The Department of National Defence (DND) is the lead ministry responsible for providing and coordi-

nating SAR response for incidents involving aircraft, and incidents involving vessels in federal or international waters. Canadian Joint Operations Command (CJOC) is responsible for the Canadian Armed Forces (CAF) contribution to aeronautical and maritime SAR services throughout Canada. The Commander (Comd) CJOC is the responsible authority for CAF operational SAR policy and force employment, the operation of the JRCCs[1], and operational command of all assigned aeronautical SAR assets at designated Canadian Forces Bases (CFBs):

- Victoria SRR serviced by 442 Transport and Rescue Squadron (19 Wing CFB Comox),
- Trenton SRR serviced by 435 Transport and Rescue Squadron (17 Wing CFB Winnipeg) and 424 Transport and Rescue Squadron (8 Wing CFB Trenton),
- Halifax SRR serviced by 413 Transport and Rescue Squadron (14 Wing CFB Greenwood) and 103 Search and Rescue Squadron (9 Wing CFB Gander).

The CAF maintain a response posture to SAR operations 24 hours per day, seven days per week. The SAR squadrons fly two types of fixed-wing aircraft, the CC-130 Hercules (435, 424, and 413 Squadrons) and the CC-115 Buffalo (442 Squadron), and two types of helicopters, the CH-146 Griffon (424 Squadron) and the CH-149 Cormorant (442, 413, and 103 Squadrons). SAR aircraft are used to respond to incidents within the SRR they are based in. In each SRR the SAR squadrons maintain a response posture defined as the ability to be airborne within a stated time period:

- RP30 (30 minutes): the aircrew are on base and the aircraft is available and ready to fly; and
- RP2hrs (2 hours): the aircrew may not be on base and the aircraft may require pre-flight checks.

Defence Research and Development Canada (DRDC) Centre for Operational Research and Analysis (CORA) studies [1, 2] have shown that in reality the *average difference* between the two response postures is platform (aircraft) specific, ranging from 30 to 50 minutes.[2]

1.2 Issue

Recently, squadrons maintained RP30 for 40 hours (hrs) a week per resource (aircraft type): eight hours a day, Monday (Mon) to Friday (Fri) (five days/week, excluding holidays), 0800-1600hrs local time and RP2hrs for remaining hours. As will be shown in Section 2, there is no statistcal evidence to suggest that this schedule was chosen to align with the occurrence of SAR incidents.

Intuitively, one expects that a quicker response to situations where people are in distress or potential distress will make a positive difference in the outcome of the SAR cases, even potentially saving more lives. Steele [2] provided evidence supporting this intuition. Response posture impacts the reaction time from SAR resource tasking by a JRCC to an aircraft being airborne. It has also been shown to impact decision time: the time between JRCC controllers being notified and tasking a SAR resource. Analysis by Shurson and Fitch [1] on 1983-1986 data showed that JRCC controllers tasked crews an

[1] Although CAF is responsible for the operation of JRCCs, JRCCs also organize the response of non-CAF resources.

[2] Steele [2] compiled the median reaction time per CAF aircraft type. He found the median reaction time to range between 30-40 minutes when on RP30 and between 60-90 minutes when on RP2hrs.

average of ten minutes earlier when they are already on base on RP30. In Section 2 it is shown that this is SRR-specific and exceeding half an hour in the Trenton SRR.

Decision and reaction time are a subset of the SAR incident timeline which includes aware time (incident occurrence to notification of responsible agency), contact time (alerting post notified), alert time (JRCC notified), **decision time** (SAR resource tasked), **reaction time** (SAR resource departs), transit time (SAR resource reaches initial search location), search time, deploy time, assistance time, and evacuation transit time. The SAR incident timeline is depicted in Figure 2, highlighting the times where response posture may have impact. Shurson and Fitch found that decision and reaction time constituted 65% of the total time from notification to reaching the search site.

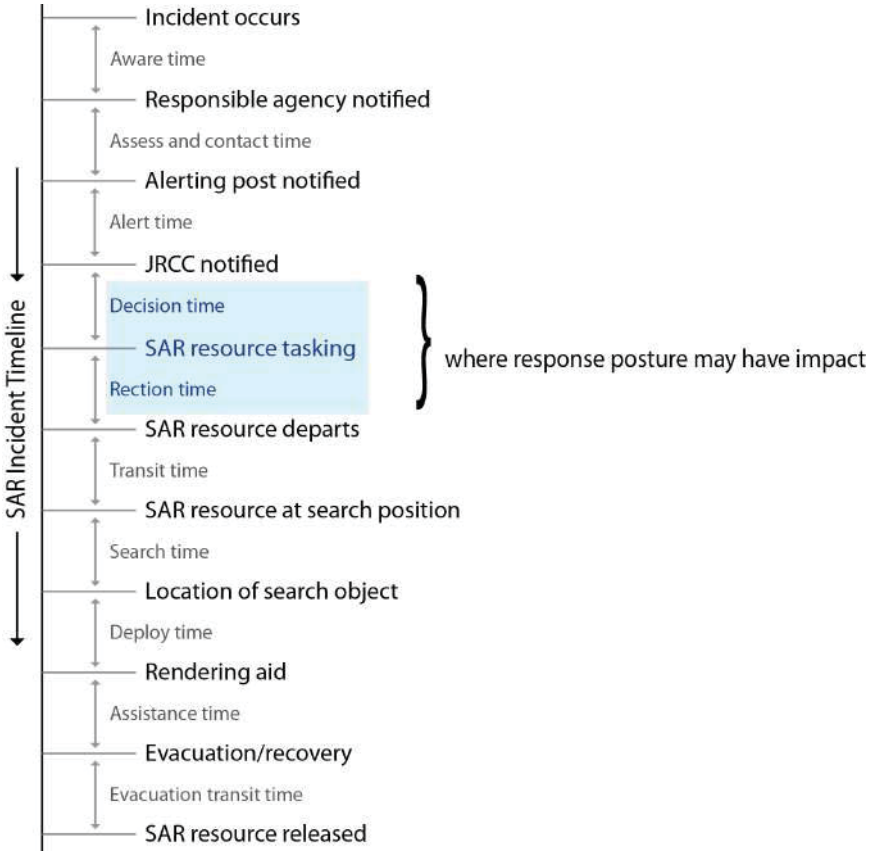


Figure 2: *SAR incident timeline.*

In December 2012 CJOC J3 SAR tasked the CJOC Operational Research and Analysis (OR&A) team [3] to determine optimal RP30 schedules maximizing the alignment with the occurrence of distress or potential distress incidents based on recent data (last five years).[3]

[3]The Canadian Search and Rescue Manual [4] defines and details the categorization of incidents.

1.3 Previous work

DRDC CORA studies have previously analyzed response posture. Shurson and Fitch [1] examined 1983-1986 data for the Halifax, Victoria, Trenton and Edmonton SRRs (435 Transport and Rescue Squadron was based at CFB Edmonton until 1994 when it was moved to Winnipeg). In particular, the study analyzed the difference between RP30 and RP2hrs reaction time, the peak hours and days for aeronautical and maritime Category (Cat) 1 (distress) and 2 (potential distress) SAR incidents—segregating summer (May-October) and winter months. Findings included identification of seasonality (higher number of incidents occurring during summer months) and recommending adjusted RP30 schedules (five consecutive days of eight hours per day) per SRR covering the peak SAR incident occurrence times.

Innes, Corbett and Nguyen [5] developed the SAR Location Evaluation Program (SARLEP), initially developed to analyze the location of CAF SAR bases, but later augmented to determine optimal RP30 schedules (based on hard-coded constraints). In 2005 Bourdon and Rempel [6], when analyzing the capabilities required for new fixed-wing SAR aircraft, looked at 1998-2001 data and optimized RP30 hours constrained to a common start time nationally (Universal Coordinated Time) and between Monday and Friday.

In 2006 Grenkow and Julien [7] studied the occurrence of SAR incidents in the Victoria SRR between 1994 and 2005. They considered the subset of incidents responded to by the CAF (regardless of category/classification). Summer months were determined to be twice as busy as winter months and found no evidence that CAF responds to more incidents on any particular day of the week in the summer. Grenkow and Julien also found that when standby posture is relaxed (to RP2hrs), the number of CAF taskings decrease.

Stemming from a request by 1 Canadian Air Division (CAD) Headquarters, Steele [2] analyzed how often the number of lives saved in SAR incidents was directly affected by the response posture of the responding SAR unit. The study was part of a Director Air Force Readiness initiative to determine the cost-benefit of increasing the RP30 hours allotment (from 40 to 168 hours per week) [8]. Steele also proposed optimal schedules of alloted (40) weekly RP30 hours based on 2000-2004 data. Grenkow and Julien [7] and Steele [2] also summarize the history of the CAF experience with modified RP30 schedules, noting that adjustments began after the United Fisherman and Allied Workers Union expressed safety concerns on the West Coast to the Prime Minister in 1993. Sections 4, 6 and 7 compare recent results to the findings of the above mentioned studies.

In comparison to the previous response posture studies listed, this study is most comparable to the work of Shurson and Fitch—both consider Cat 1 and 2 SAR incidents, regardless of actual responder, and segregated peak summer months.

Various other studies of note on SAR have been undertaken within DRDC CORA. Many of the studies can be clustered as follows: studies on asset positioning and base location [9, 10, 11, 12, 13, 14], asset performance/availability [15, 16, 17, 18, 19], training [20, 21], sensors, search patterns and communications [22, 23, 24, 25].

The reader will also note that parts of the present paper were previously published as DRDC CORA Letter Reports [26, 27].

1.4 Objective

This scientific report details the modelling and analysis for optimizing RP30 hours for the summer SAR season. The objective was to provide Comd CJOC with quantitative evidence to base his direction for summer SAR seasons (2013 and beyond). To that end, the report documents CJOC OR&A results [26] that were included in the 2013 and 2014 Comd CJOC SAR Directives [28, 29, 30] (the recommended optimal RP30 schedules were trialled in the Trenton SRR between May and September 2013, and refinements were trialled in the Trenton and Victoria SRRs between May and September 2014). The report also documents the optimization of RP30 schedules in the Victoria and Halifax SRRs as reference for future Comd CJOC SAR Directives.

1.5 Scope and limitations

This study quantifies the potential increase in the number of Cat 1 and 2 incidents that optimized RP30 schedules would align with. It does not quantify the impact of the outcome of SAR cases responded to on RP30 versus RP2hrs. By request of CJOC J3 SAR, recent historical data (2008-2012) was used to determine optimal RP30 schedules. When calculating the historical alignment of legacy CAF RP30 hours with Cat 1 and 2 incidents, only the time of SAR incidents occurrence was considered. The study does not analyze potential trends—it assumes that observed patterns (seasonal/weekly/daily) in recent years will continue in the near future. All Cat 1 and 2 incidents, and only Cat 1 and 2 incidents, were considered. Historically, the CAF responds to less than a quarter of Cat 1 and 2 incidents, and in addition responds to many incidents that are categorized post hoc as Cat 3 (no distress) and 4 (false alarm) incidents. Upon reviewing data (to be presented in Section 2) CJOC HQ and 1 CAD stakeholders agreed that optimization should align CAF resources with the occurrence of the maximal number of Cat 1 and 2 incidents, regardless of type (aeronautical, maritime, and humanitarian).

By request of CJOC J3 SAR, the study only considers the optimization of 40 hours of RP30 per week (per resource/CFB). This constraint is mainly driven by force generation issues (resource flying hours, number of crews, etc.). This study focuses on determining the alignment of RP30 hours with the occurrence of SAR incidents, and does not consider the optimization of crew shift schedules to correspond to the RP30 hour sequences, including the ability to respond to multiple SAR incidents concurrently.

With respect to data, the study shares many of the same limitations and assumptions as predecessor DRDC CORA research. To be elaborated in Section 2, the data used for analysis is imperfect. While SRR-specific analyses excluded periods of identified inconsistencies, it was still assumed that data censoring (inconsistency/omission) is homogeneous with respect to time and day: For example, it is assumed that the number of inconsistent data entries for incidents that occurred on a Monday between 1200-1300hrs is not significantly different than the number of inconsistent data entries for incidents that occurred on a Thursday between 0900-1000hrs. In certain cases median values are presented instead of mean values: the median is the numerical value separating the higher half of a data sample from the lower half; it is more robust than the mean with respect to the effect of outliers.

Retroactively determining the number of SAR incidents that may have benefited from revised RP30 schedules is problematic since it is unclear if the number of CAF taskings would change (e.g., increase) when squadrons are on RP30 during times of higher incident occurrence.

RP30 schedules were optimized per squadron at CFBs Comox, Winnipeg, Trenton, Greenwood, and Gander.

1.6 Outline

Section 2 examines the data available for analysis and confirms the peak SAR season. The section subsequently analyzes the suitability of the data per SRR. Section 3 documents the methodology, providing an overview of the optimization approach and high-level results. Section 4 details the optimization of RP30 in the Trenton SRR and provides a menu of near-optimal RP30 schedules.The results therein were included in the 2013 CJOC SAR Directive and the recommended optimal RP30 schedules were trialled in the Trenton SRR in 2013. Section 5 follows with post-analysis of the 2013 Trenton SRR trial. Sections 6 and 7 present the optimization of RP30 in the Victoria and Halifax SRRs respectively.

Parts of Section 2, and 4-7 are purposely structured to present data and results per SRR, facilitating an in-depth look at each SRR at the expense of some repetitiveness in wording. In particular, Sections 4-7 are written in a fashion enabling the reader to skip data/technical/model details presented in Sections 2 and 3, with limited loss of understanding.

Section 8 summarizes the results and proposes areas for follow-on work. Annex A details the mathematical formulation of the optimization model and Annex B lists the 2013 SAR cases which were affected by the revised RP30 schedule trialled in the Trenton SRR.

2 Data

2.1 Sources and assumptions

Information for each SAR incident is recorded in SAR databases. The Canadian Coast Guard (CCG) maintains the System of Information for Search and Rescue (SISAR) that resides on the Department of Fisheries and Oceans' network. For this study data from 1993 to 2012 were available from CCG's SISAR database. In the early 2000s, the SAR Mission Management System (SMMS)[31] was developed to provide integrated and comprehensive means for JRCCs and Marine Rescue Sub Centres to effectively and efficiently process aeronautical and maritime distress cases. The SMMS database spans 2003-present, however it is potentially inconsistent for 2003-2006, when the system was still in its testing phase [32]. With the development of SMMS, the SISAR database transitioned to having data pulled from the SMMS database before undergoing validation (sometimes resulting in several months of lag) [33]. As pointed out in [2], beginning in 2005 SRR-specific data inconsistencies may be observable in SISAR largely because of regional policies on data entry associated with the incremental transition from paper-based to the SMMS software.

As a result, neither SMMS or SISAR are fully authoritative for SAR incident details—the database offering the most complete and valid set of incidents depends on the year. SRR-specific inconsistencies in the SISAR dataset are observable and pointed out in the following subsections. To mitigate against the impact of omitted or erroneous data, select years deemed to be representative spatially and temporally (per SRR) were chosen for analysis, and median values (rather than means) were used to dampen the effect of outliers. Furthermore, with respect to time of incident occurrence, the study assumed that any data inconsistencies were homogeneous with respect to time and day (e.g., it is unlikely that the data omits or errs on significantly more incidents on a particular hour of the week than any other hour of the week).

Table 1 breaks down the set of 2010-2012 SAR incidents by SRR[4] and indicates the percentage responded to by the CAF. Cat 1 and 2 incidents (distress and potential distress) are broken down further into aeronautical (A), maritime (M), and humanitarian (H) categories. Within Canada, SAR activities span a multitude of jurisdictions:[5]

- The CAF are responsible for aeronautical incidents;
- The CCG is responsible for marine incidents;
- Parks Canada is responsible within national parks; and,
- Provincial and territorial governments are responsible for searches for missing persons including those who are lost or overdue on land or inland waters - commonly known as Ground Search and Rescue (GSAR), and often delegated to the police service of jurisdiction.

Although the primary SAR responsibility of the CAF is the provision of aeronautical SAR, the information provided in the table supports the inclusion of maritime and humanitarian SAR incidents in the analysis of optimal RP30 schedules.

[4] SAR incidents occurring outside the AOR and not attributed to a JRCC are not included.

[5] Source: www.nss-snrs.gc.ca.

Table 1: *2010-2012 SAR incident categorization and percentage of CAF responses.*

SAR Incidents	Victoria SRR	Trenton SRR	Halifax SRR	Total
All Incidents	9162	11335	8156	28643
CAF Responses	474 (5%)	798 (7%)	624 (8%)	1896 (7%)
Cat 1 and 2s	2204	1601	1029	4834
CAF Responses	240 (11%)	323 (20%)	362 (35%)	925 (19%)
Aeronautical Cat 1 and 2s	181	301	55	537
CAF Responses	54 (30%)	84 (28%)	17 (31%)	155 (29%)
Maritime Cat 1 and 2s	1216	871	719	2806
CAF Responses	104 (9%)	118 (14%)	221 (31%)	443 (16%)
Humanitarian Cat 1 and 2s	807	429	255	1491
CAF Responses	82 (10%)	121 (28%)	124 (49%)	327 (22%)

The analysis presented in this paper considers aeronautical, maritime, and humanitarian SAR Cat 1 and 2 incidents (i.e., incidents with final classification of A1, A1P, A2, M1, M1P, M2, H1, or H2).[6] The corresponding SAR records listing an incident record identifier, date of occurrence, and coordinates (latitudinal and longitudinal) were used in the analysis. Duplicate entries were removed. JRCC incident identification numbers or geographic location (via polygon inclusion tests) were used to allocate incidents to one of the three SRRs. To separate the analysis of incidents that may be responded to by the CAF from CFB Winnipeg and CFB Trenton, CJOC J3 SAR requested that incidents that occurred in the Trenton SRR be partitioned into two subdivisions divided by a north-south line at 87.4°W (approximate mid-point longitude between CFB Winnipeg and CFB Trenton). It is stressed that this division is completely artificial and not necessarily representative, however it was selected by CJOC J3 SAR to facilitate analysis. The subdivisions are herein referred to as Trenton SRR 435 Squadron Area (CFB Winnipeg) and Trenton SRR 424 Squadron Area (CFB Trenton). Incidents in the Halifax SRR were not separated based on proximity to CAF bases. Time of incident occurrence was used for data analysis (appropriately converted to local time at CFBs from Universal Coordinated Time taking into account Daylight Savings Time).

2.2 Temporal analysis of an example year

Figure 3 shows the distribution of Cat 1 and 2 SAR incidents in 2011 across the Canadian SRR. The 2011 data is deemed to be representative of the most recent years [4]. 2011 data records indicate that there were 9128 incidents, 1518 (17%) of which were Cat 1 or 2 (depicted in figure). Spatially, it is clear that most incidents occur within close proximity to the current SAR bases.

There is a clear annual seasonality in the occurrence of Cat 1 and 2 incidents. Figure 4 depicts the seasonality of incidents occurring in 2011. According to records, in 2011, 1027 (68%) of Cat 1 and 2 incidents occurred between the months of May and September (392 in the Victoria SRR, 413 in the

[6] Incidents classified as "1P" are defined as previously unreported cases of distress that are Cat 1 incidents (potentially resolved prior to the SAR system being alerted).

Figure 3: *Cat 1 and 2 incidents in 2011 and the Victoria, Trenton, and Halifax SRRs.*

Trenton SRR, and 222 in the Halifax). In 2011 the CAF responded to 713 incidents, 344 of these were Cat 1 or 2 (23% of all Cat 1 or 2 incidents nationally[7]) for which the CAF was the primary responder. Of the 344 Cat 1 or 2 incidents responded to by the CAF, 198 (58%) occurred between May and September (inclusive). The count of incidents responded to by the CAF are highlighted in darker blue in the figure. The figure also highlights holidays and holiday long weekends.

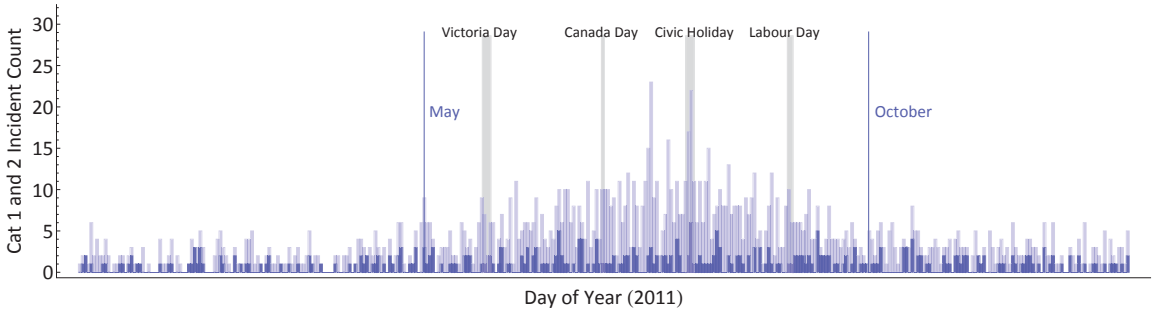


Figure 4: *Seasonality of Cat 1 and 2 incidents in 2011.*

There is also a clear weekly pattern for SAR incidents.[8] Figure 5 shows that Cat 1 and 2 incidents have

[7] The CAF responded to 90 Cat 1 and 2 incidents in the Victoria SRR (14% of all in the SRR), 114 in the Trenton SRR (21% of all in the SRR), 140 in the Halifax SRR (41% of all in the SRR).

[8] Data for 30 April was included to yield an integer number of weeks (22) between 30 April and 30 September.

a higher likelihood of occurrence on weekends. The count of incidents responded to by the CAF are highlighted in darker blue in the figure.

There is also a clear hourly, or "time-of-day", pattern for SAR incidents. In Figure 6 Cat 1 and 2 incidents are binned by hour of week (168 hours). The gray bars highlight the 40 hours of an RP30 schedule of 0800 to 1600 hours Monday-Friday. Of the 1020 Cat 1 and 2 incidents that occurred between May and September 2011, 300 (29%) occurred during the CAF RP30 and 720 (71%) occurred during the CAF RP2hrs. Of the 198 incidents responded to by the CAF occurred between May and September, 62 (31%) occurred during RP30, 136 (69%) occurred during RP2hrs. The count of incidents responded to by the CAF are highlighted in darker blue in the figure.

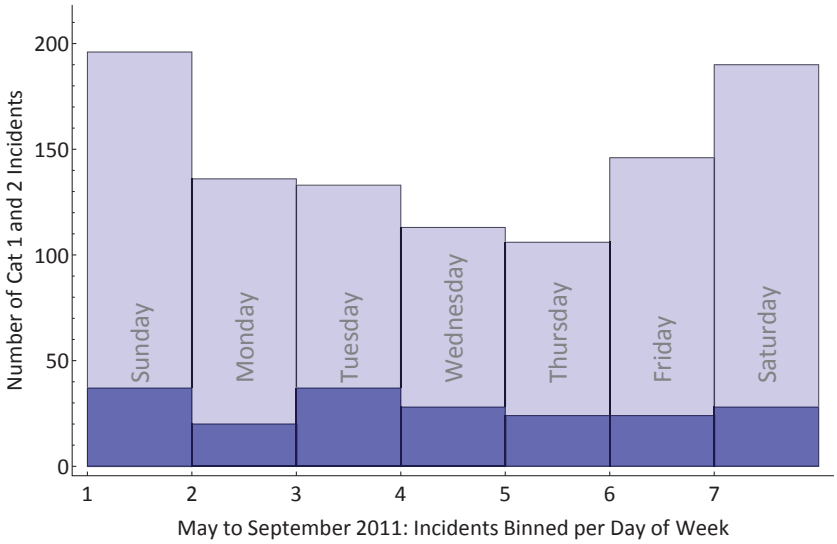


Figure 5: *Cat 1 and 2 incidents in 2011 binned by day of week.*

Analysis of 2011 data supports findings by Shurson and Fitch [1] that showed that JRCC controllers (based on 1983-1986 data) tasked CAF crews an average of ten minutes earlier when they were on RP30 vice RP2hrs. 2011 data shows a median decision time difference of 5 to 31 minutes between notification time and tasking time depending on the SRR. Table 2 details the decision time difference per SRR.

Table 2: *Decision time difference to task the CAF when on RP30 versus RP2hrs.*

	CAF on RP30	CAF on RP2hrs	Difference
Victoria SRR	23 minutes	28 minutes	5 minutes
Trenton SRR	31 minutes	65 minutes	31 minutes
Halifax SRR	18 minutes	30 minutes	12 minutes

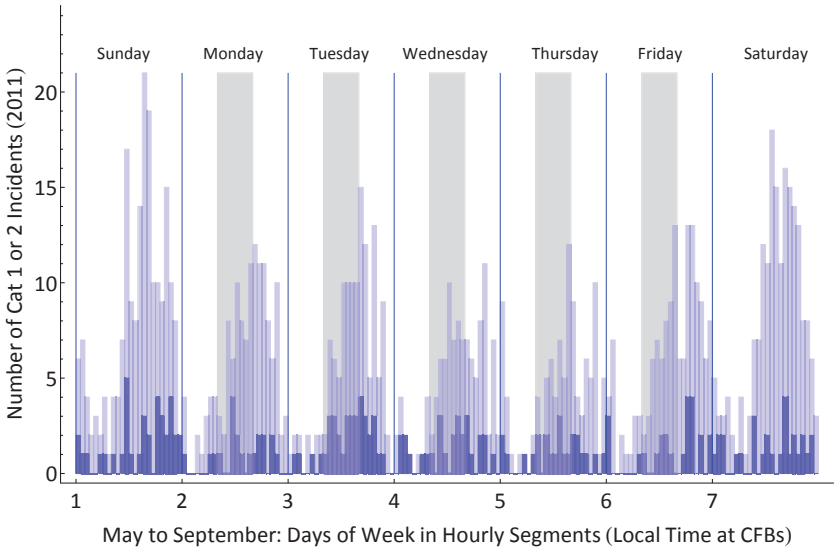


Figure 6: *Cat 1 and 2 incidents in 2011 binned by hour of week.*

The effect on CAF response posture on JRCC decision (whether to task CAF or not) and the corresponding decision time may merit further research including detailed data analysis and interviews with JRCC dispatchers.

2.3 1993-2012 Victoria SRR data

There is a clear seasonality in the occurrence of Cat 1 and 2 incidents in the Victoria SRR. Figure 7 depicts the annual seasonality of incidents occurring between 1993 and 2012. The figure provides temporal-based evidence that the SISAR database is potentially missing records (e.g., 2006-2008). Combining the years and binning the data into 365 days, Figure 8 depicts the seasonality of incidents occurring in the Victoria SRR between 1993 and 2012 for which 442 Transport and Rescue Squadron (CFB Comox) could have been tasked. 62% of all Cat 1 and 2 incidents occurred between May and September (1993-2012). The figure also highlights holidays and long weekends.[9]

Binning the incidents that occurred May-September into the seven days of a week, Figure 9 depicts the weekly pattern of incident occurrence in the Victoria SRR between 1993 and 2012 for which 442 Transport and Rescue Squadron (CFB Comox) could have been tasked. The gray bars highlight the 40 hours of an RP30 schedule of 0800 to 1600 hours Monday-Friday. Monday to Friday 0800-1600 RP30 schedules (40 of 168 hours per week) aligned with 27% of Cat 1 and 2 incidents. There is variation in the percentage of Cat 1 and 2 incidents that CAF RP30 hours are aligned with each year: between 1993 and 2012 the alignment percentage ranged from 21% to 30% with a mean percentage of 27% and a standard deviation of 2.4%.

[9] Because of leap years and holidays occurring on particular Mondays of a month, there is variability in the specific day from year to year.

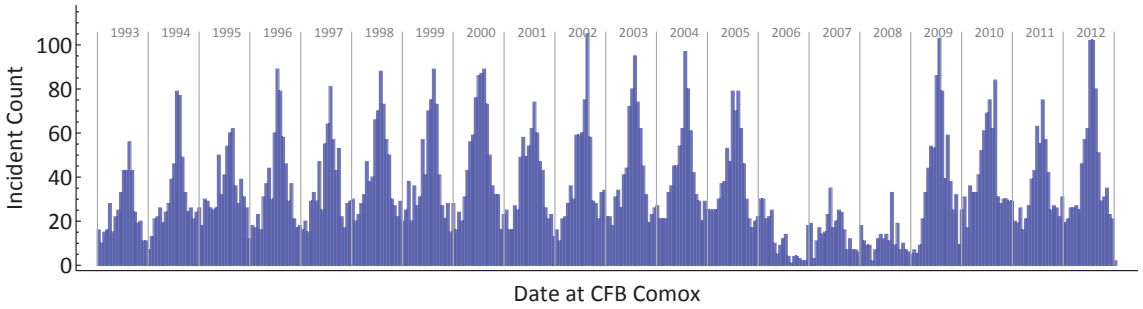


Figure 7: *Seasonality of Cat 1 and 2 incidents between 1993 and 2012 that could have prompted a response from 442 Squadron.*

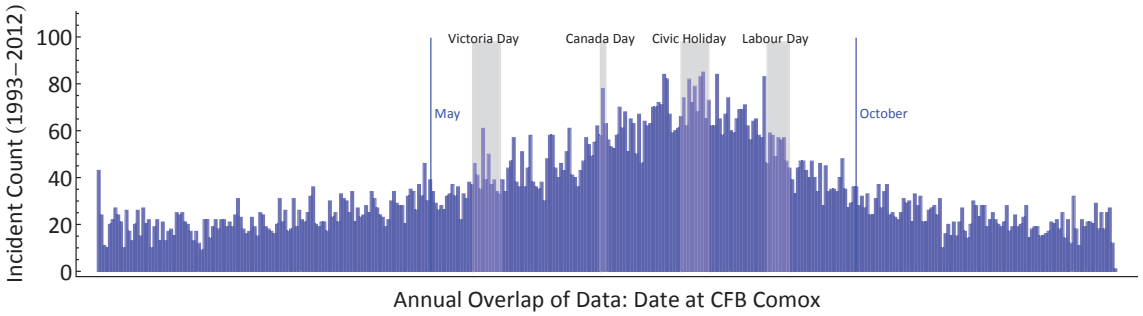


Figure 8: *Cat 1 and 2 incidents occurring between May and September (1993-2012) that could have prompted a response from 442 Squadron.*

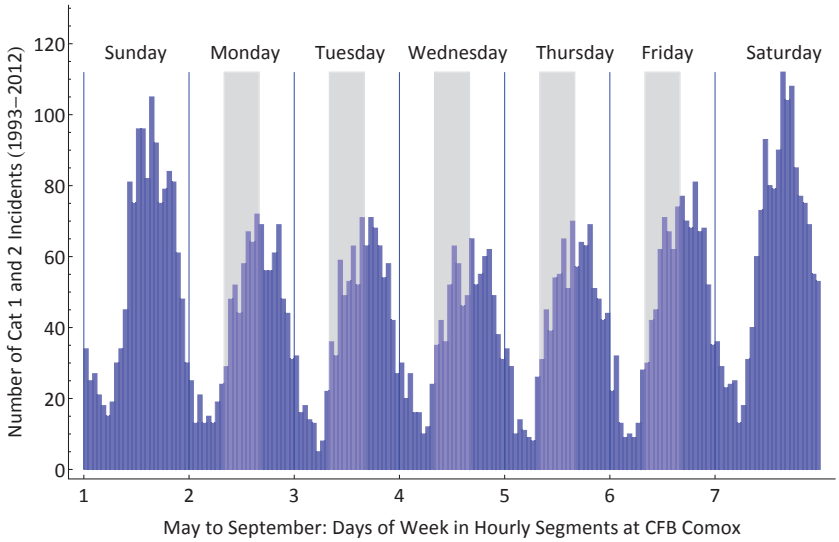


Figure 9: *Weekly pattern by hour at CFB Comox.*

2.4 1993-2012 Trenton SRR data

2.4.1 Trenton SRR 435 Squadron area

Figure 10 depicts the annual seasonality of incidents occurring between 1993 and 2012. The figure provides temporal-based evidence that the SISAR database is potentially missing records (e.g., 2005-2007). Combining the years and binning the data into 365 days, Figure 11 depicts the seasonality of incidents occurring in the Trenton SRR 435 Squadron Area between 1993 and 2012 for which 435 Transport and Rescue Squadron (17 Wing CFB Winnipeg) could have been tasked. 68% of all Cat 1 and 2 incidents occurred between May and September (1993-2012).

Figure 12 depicts the weekly pattern of incident occurrence in the Trenton SRR 435 Squadron Area between 1993 and 2012 (between May and September) for which 435 Transport and Rescue Squadron could have been tasked. Monday to Friday 0800-1600 RP30 schedules aligned with 28% of Cat 1 and 2 incidents. Between 1993 and 2012 the RP30 alignment percentage ranged from 0%[10] to 40% with a mean percentage of 26% and a standard deviation of 9.4%.

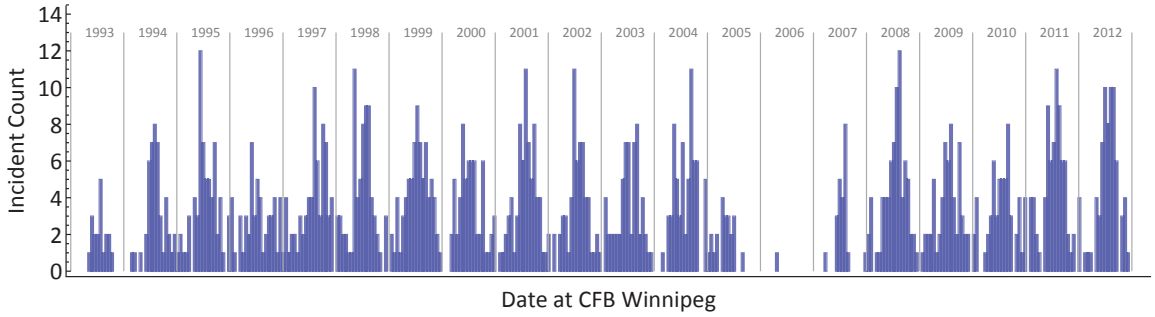


Figure 10: *Seasonality of Cat 1 and 2 incidents between 1993 and 2012 that could have prompted a response from 435 Transport and Rescue Squadron.*

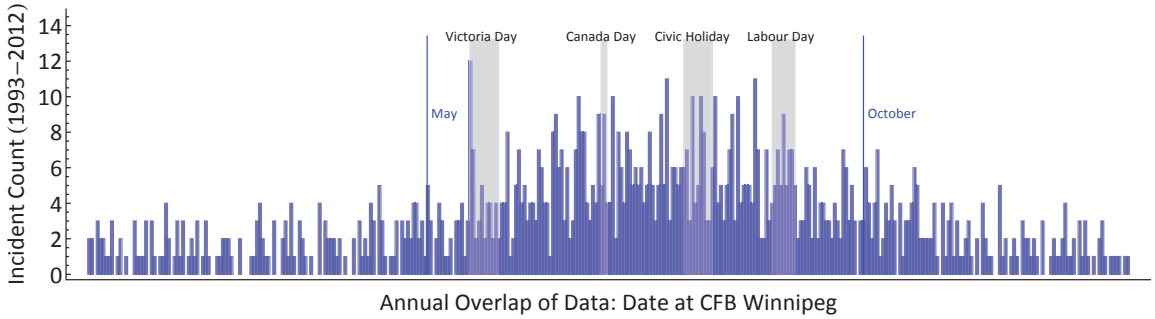


Figure 11: *Cat 1 and 2 incidents occurring between May and September (1993-2012) that could have prompted a response from 435 Transport and Rescue Squadron.*

[10] Only one Cat 1 or 2 incident west of 87.5°W was reported in the 2006 data—presumably an artifical SISAR problem and not reflective of reality.

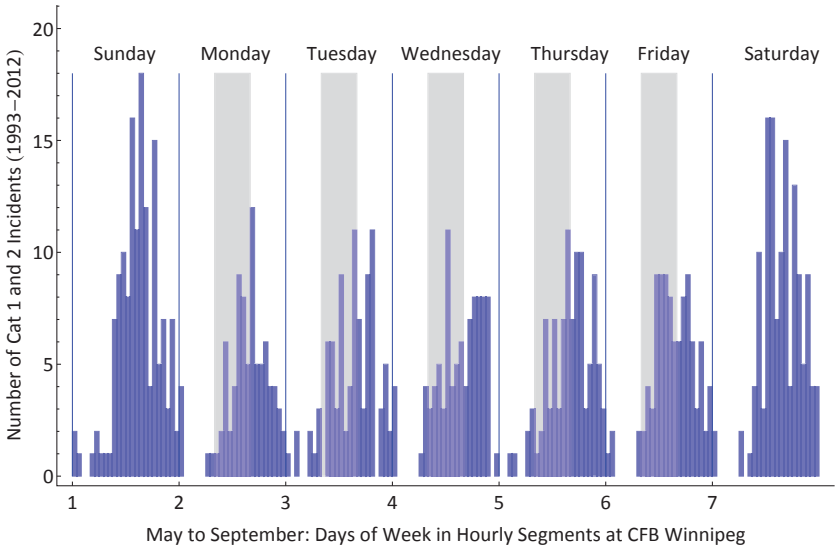


Figure 12: *Weekly pattern by hour at CFB Winnipeg.*

2.4.2 Trenton SRR 424 Squadron area

Figure 13 depicts the annual seasonality of incidents occurring between 1993 and 2012. The figure provides temporal-based evidence that the SISAR database is potentially missing records (e.g., 2006). Combining the years and binning the data into 365 days, Figure 14 depicts the seasonality of incidents occurring in the Trenton SRR 424 Squadron Area between 1993 and 2012 for which 424 Transport and Rescue Squadron (8 Wing CFB Trenton) could have been tasked. 80% of all Cat 1 and 2 incidents occurred between May and September (1993-2012).

Figure 15 depicts the weekly pattern of incident occurrence in the Trenton SRR 424 Squadron Area between 1993 and 2012 (between May and September) for which 424 Transport and Rescue Squadron could have been tasked. Monday to Friday 0800-1600 RP30 schedules aligned with 23% of Cat 1 and 2 incidents. Between 1993 and 2012 the RP30 alignment percentage ranged from 16% to 26% with a mean percentage of 22% and a standard deviation of 2.3%.

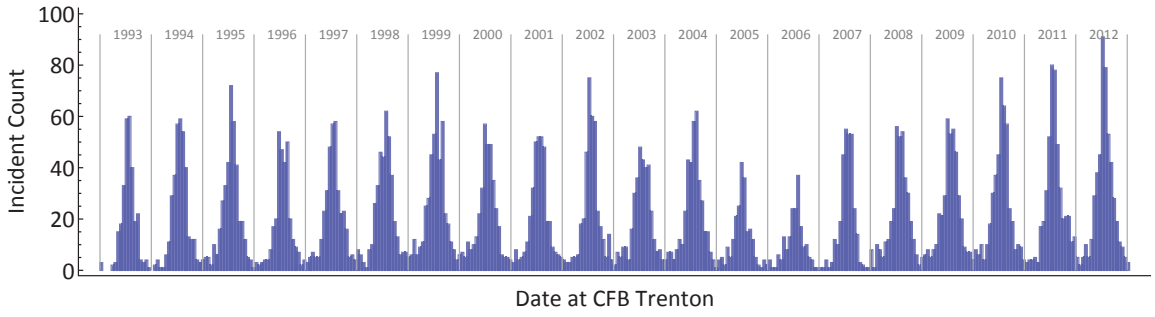


Figure 13: *Seasonality of Cat 1 and 2 incidents between 1993 and 2012 that could have prompted a response from 424 Transport and Rescue Squadron.*

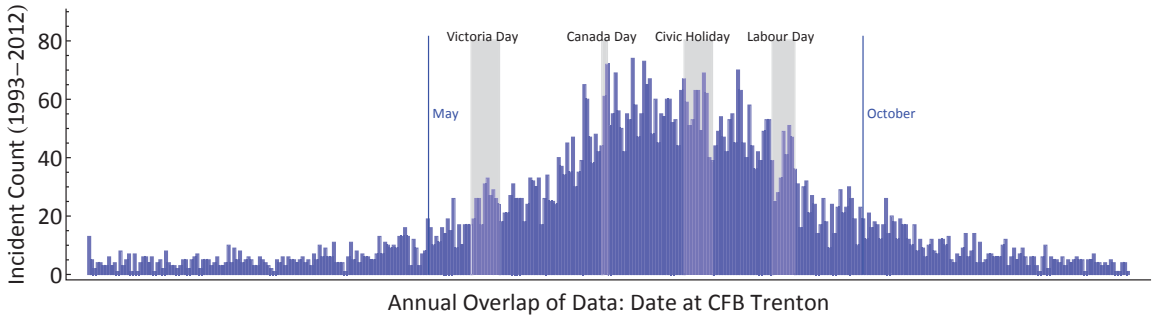


Figure 14: *Cat 1 and 2 incidents occurring between May and September (1993-2012) that could have prompted a response from 424 Transport and Rescue Squadron.*

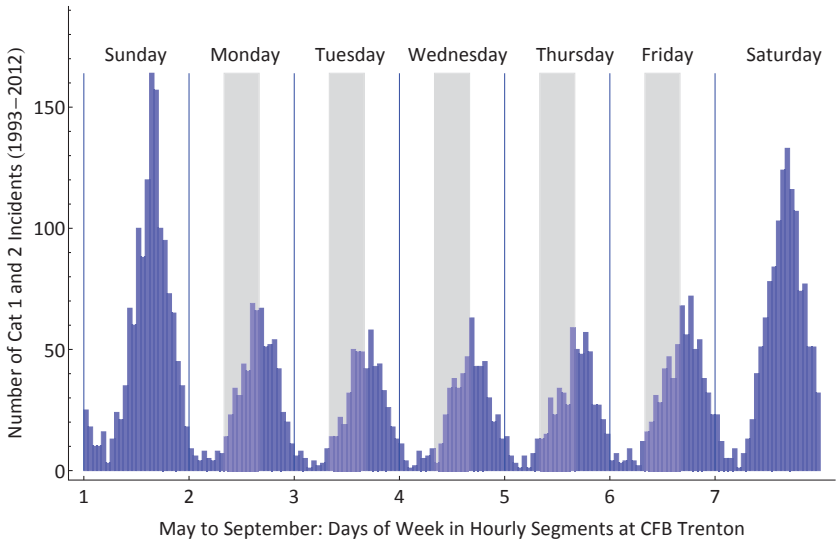


Figure 15: *Weekly pattern by hour at CFB Trenton.*

2.5 1993-2012 Halifax SRR data

Figure 16 depicts the annual seasonality of incidents occurring between 1993 and 2012. The figure provides temporal-based evidence that the SISAR database is potentially missing records (e.g., 2007 and 2009). Combining the years and binning the data into 365 days, Figure 17 depicts the seasonality of incidents occurring in the Halifax SRR between 1993 and 2012 for which 413 Transport and Rescue Squadron (14 Wing CFB Greenwood) or 103 Search and Rescue Squadron (9 Wing CFB Gander) could have been tasked. 61% of all Cat 1 and 2 incidents occurred May-September (1993-2012). The reader should also note a high number of incidents in weeks leading up to the month of May—this is unique to the Halifax SRR.

Binning the incidents that occurred between May and September into the seven days of a week, Figure 18 depicts the weekly pattern of incident occurrence in the Halifax SRR between 1993 and 2012 for which 413 Transport and Rescue Squadron (14 Wing CFB Greenwood) and 103 Search and Rescue Squadron (9 Wing CFB Gander) could have been tasked. Monday to Friday 0800-1600 RP30 schedules (gray bars) aligned with 29% of Cat 1 and 2 incidents. Between 1993 and 2012 the RP30 alignment percentage ranged from 23% to 35% with a mean percentage of 28% and a standard deviation of 3.2%.

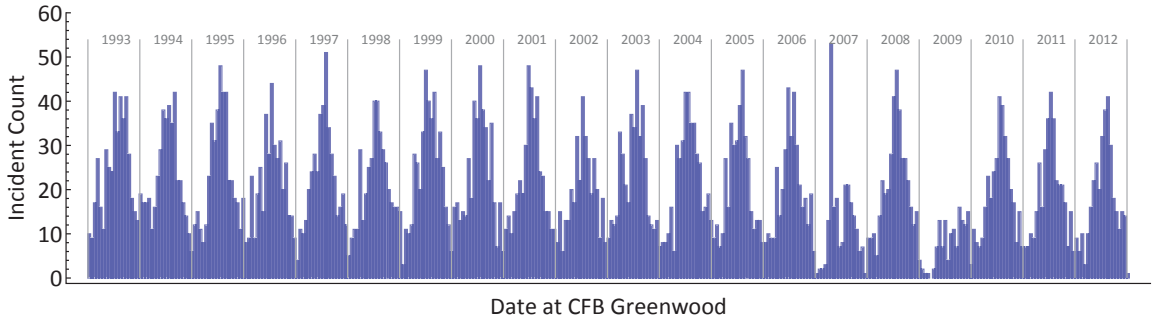


Figure 16: *Seasonality of Cat 1 and 2 incidents between 1993 and 2012 that could have prompted a response from 413 or 103 Squadrons.*

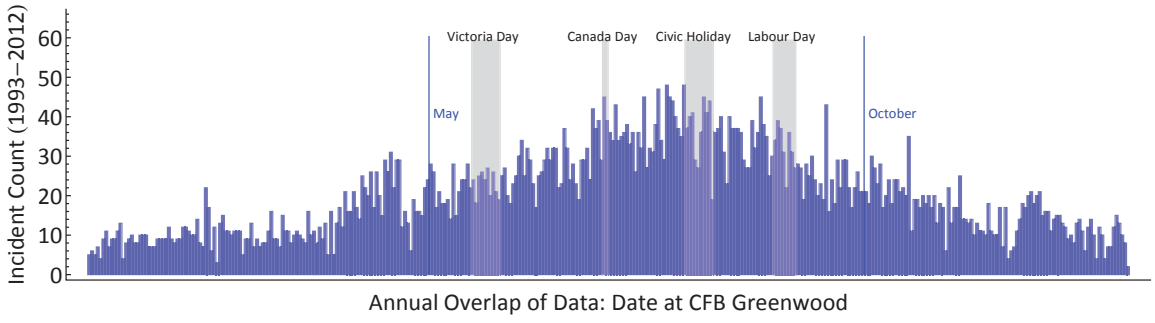


Figure 17: *Cat 1 and 2 incidents occurring between May and September (1993-2012) that could have prompted a response from 413 or 103 Squadrons.*

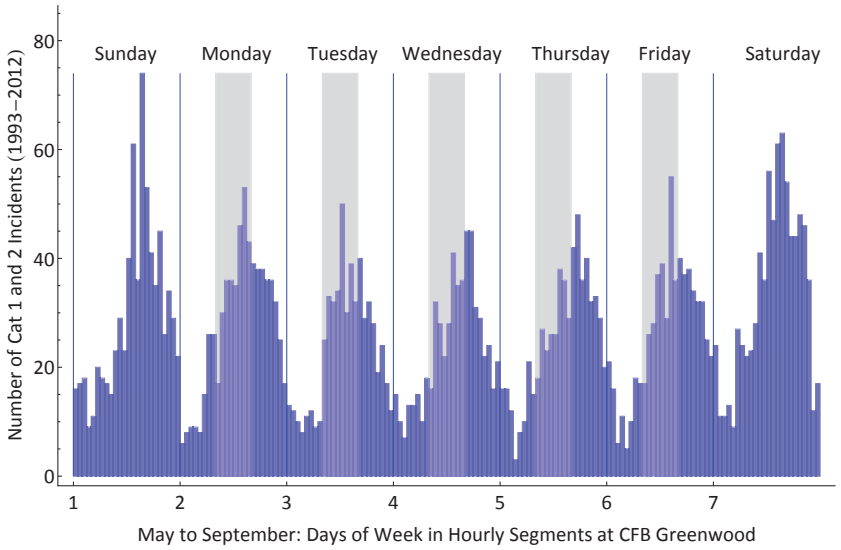


Figure 18: *Weekly pattern by hour at CFB Greenwood (time at CFB Gander offset by half an hour).*

2.6 Key observations

- The analysis confirms and identifies years of potential data inconsistency per SRR;
- Most incidents occur within close proximity to the current SAR bases;
- CAF responds to a significant number of maritime and humanitarian SAR incidents;
- Seasonal, weekly, and hourly patterns are observable in each SRR. There are higher numbers of SAR incidents occurring during summer months, weekends, and evening hours—but to varying degrees per SRR;
- Legacy 0800-1600 hour Monday to Friday CAF RP30 schedules are not aligned with the peaks of observed patterns, missing busy weekend days in particular; and,
- Simple data visualization can facilitate better alignment of RP30 schedules with SAR incidents.

3 Optimization overview

This section presents an overview of the analysis performed adhering to the CJOC J3 SAR request [3] to determine RP30 schedules maximizing the alignment with the occurrence of Cat 1 and 2 incidents based on recent admissible data (2008-2012) and constrained to 40 RP30 hours per week per resource type per squadron. The results presented herein guided CJOC J3 SAR to the selection of RP30 schedule constraints. Subsequent sections (Sections 4, 6, and 7) detail the optimization using the selected constraint set per SRR region that was used to inform CJOC SAR Directives.

Based on the data analysis of Section 2, SRR-specific subsets of recent yearly Cat 1 and 2 SAR data were aggregated and used to determine optimal RP30 schedules for respective squadrons serving the SRRs. Table 3 details which data were aggregated per SRR.

Table 3: *Cat 1 and 2 SAR data aggregated per SRR used to determine optimal RP30 schedules.*

SRR	Squadrons	Years
Trenton SRR	435 and 424 Transport and Rescue Squadrons	2008 to 2012
Victoria SRR	442 Transport and Rescue Squadron	2009 to 2012
Halifax SRR	413 Transport and Rescue Squadron and 103 Search and Rescue Squadron	2010 to 2012

For each region, Cat 1 and 2 incident times (time of occurrence) for historical incidents between 1 May and 30 September of the selected aggregate data set were binned to hours of a week (168 bins) and a mixed-integer linear program (MILP) model [35] was developed to generate optimal RP30 schedules for the associated squadrons. The MILP model facilitated a cumulative approach and detailed analysis.[11] The types of schedules generated, each introducing further constraints, as follows:

1. **Unconstrained** RP30 schedules were obtained by simply optimizing the allocation of 40 RP30 hours, potentially yielding multiple RP30 sequences per day or exceedingly long sequences (essentially the 40 bins of the 168 with the most incidents);
2. **Min 5 Max 10** RP30 schedules were obtained by introducing constraints on the minimum (min) and maximum (max) length of an RP30 sequence (five and ten hours respectively) in addition to constraining a maximum of one such sequence per day;
3. **48 hour wknd** RP30 schedules added further constraints to ensure that two consecutive days in the week were only on RP2hrs, hence introducing a "weekend" (wknd);
4. **Best 5×8** RP30 schedules were obtained by adding constraints to ensure shifts were exactly eight hours long and had a consistent start time.

Best 7×8 RP30 schedules were also generated for 424 Transport and Rescue Squadron. These are two staggered Best 5×8 schedules for the CH-146 and CC-130 respectively, with same start times but off-setting 48 hour wknd days to have seven days a week of RP30 (totaling 56 RP30 hours per week).

[11] SARLEP [5] provides a user-friendly interface to determine optimal RP30 schedules with consistent start and end times and equal length RP30 sequences. SARLEP is recommended (for users) when determining schedules constrained as per SARLEP's specifications.

Annex A details the mathematical formulation implementing the above constraints and the solver used to generate solutions. Sample schedules for each of the different types of schedules listed above are also illustrated in the annex.

The RP30 schedules were optimized to align with the maximal percentage of Cat 1 and 2 incidents using the aggregate data set as per Table 3. The schedules were then evaluated retroactively by year for 20 years (1993-2012) of data. Table 4 summarizes the results. As an example of how to read the table, consider the results for Trenton SRR 424 Squadron area: The first row provides the percentage of Cat 1 and 2 incidents (aggregate 2008-2012 data) that the respective RP30 schedules align with—the Best 7×8 RP30 schedule aligns to 65% while a 0800-1600 Mon-Fri schedule aligns with 25%. The subsequent four rows provide statistics on the retroactive yearly alignment of the respective RP30 schedules based on 1993-2012 data—the Best 7×8 RP30 schedule aligns to a mean of 64% and standard deviation of 4.5% points, a minimum of 55% and a maximum of 72%.

Table 4: *Percentage of Cat 1 and 2 incidents aligned with selected RP30 schedules.*

Trenton SRR 424 Squadron Area:		Unconstrained	Min 5 Max 10	48 hour wknd	Best 5×8	8am-4pm Mon-Fri	Best 7×8
2008-2012 Aggregate		55%	54%	54%	52%	25%	65%
1993-2012	Mean	52%	53%	53%	51%	22%	64%
	Stnd dev	3.7%	4.1%	4.2%	5.1%	2.8%	4.5%
	Min	47%	46%	46%	42%	16%	55%
	Max	63%	61%	61%	60%	26%	72%
Trenton SRR 435 Squadron Area:		Unconstrained	Min 5 Max 10	48 hour wknd	Best 5×8	8am-4pm Mon-Fri	
2008-2012 Aggregate		68%	59%	57%	52%	30%	
1993-2005, 2007-2012	Mean	47%	47%	48%	46%	28%	
	Stnd dev	13%	11%	8.7%	7.2%	7.3%	
	Min	26%	29%	35%	36%	15%	
	Max	69%	69%	67%	61%	40%	
Victoria SRR:		Unconstrained	Min 5 Max 10	48 hour wknd	Best 5×8	8am-4pm Mon-Fri	
2009-2012 Aggregate		46%	43%	43%	40%	26%	
1993-2012	Mean	39%	39%	39%	38%	27%	
	Stnd dev	5.2%	4.4%	3.1%	2.9%	2.4%	
	Min	32%	34%	35%	33%	21%	
	Max	52%	52%	44%	46%	30%	
Halifax SRR:		Unconstrained	Min 5 Max 10	48 hour wknd	Best 5×8	8am-4pm Mon-Fri	
2010-2012 Aggregate		50%	47%	46%	43%	25%	
1993-2012	Mean	37%	38%	37%	37%	28%	
	Stnd dev	6.9%	5.6%	5.6%	5.1%	3.2%	
	Min	28%	33%	29%	30%	23%	
	Max	56%	53%	50%	48%	35%	

Figures 19-22 provide a visualization of the Table 4's entries, with the following legend:

- Percentage of Cat 1 and 2 incidents aligned with RP30 schedule (aggregate data used for optimization),
- Mean percentage of Cat 1 and 2 incidents aligned with RP30 schedule (1993-2012 data),
- Range (min to max percentage) of Cat 1 and 2 incidents aligned with RP30 schedule (1993-2012 data).

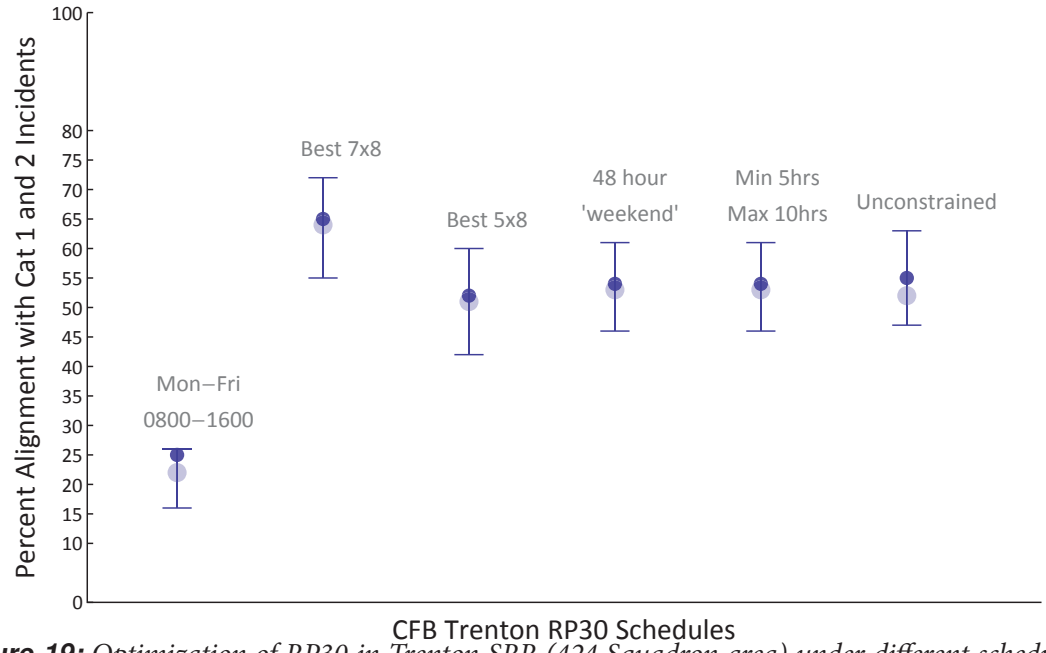


Figure 19: *Optimization of RP30 in Trenton SRR (424 Squadron area) under different scheduling constraints.*

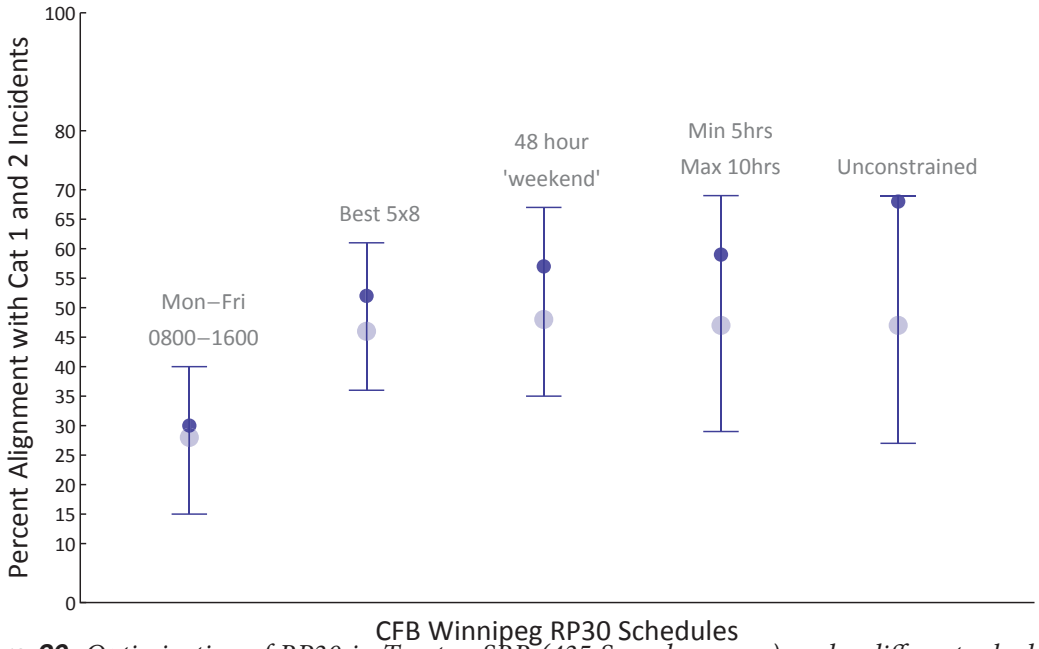


Figure 20: *Optimization of RP30 in Trenton SRR (435 Squadron area) under different scheduling constraints.*

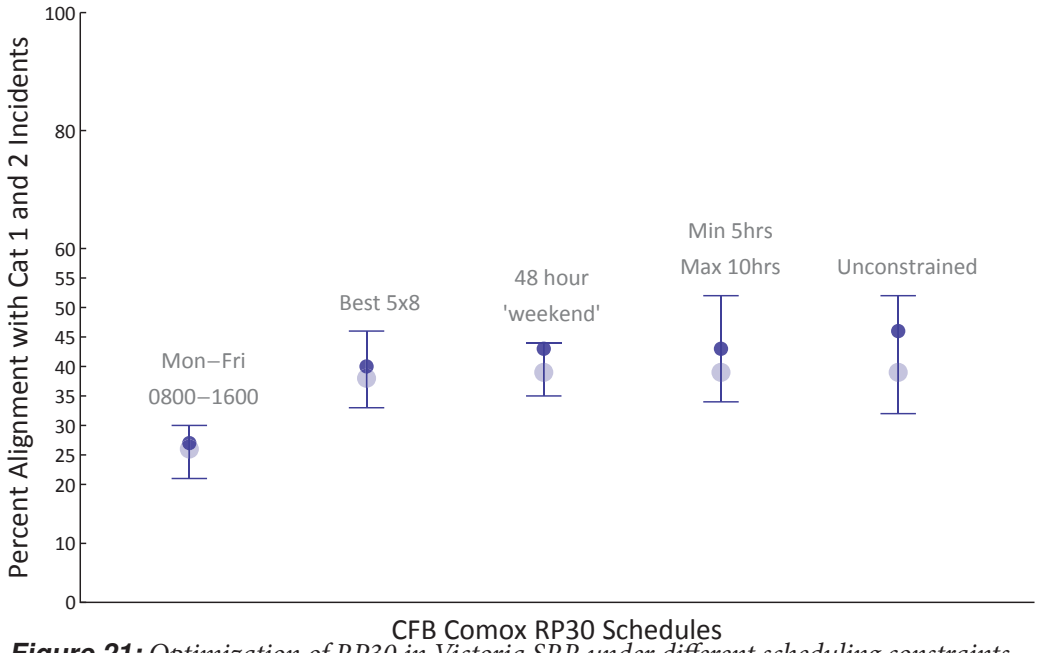


Figure 21: *Optimization of RP30 in Victoria SRR under different scheduling constraints.*

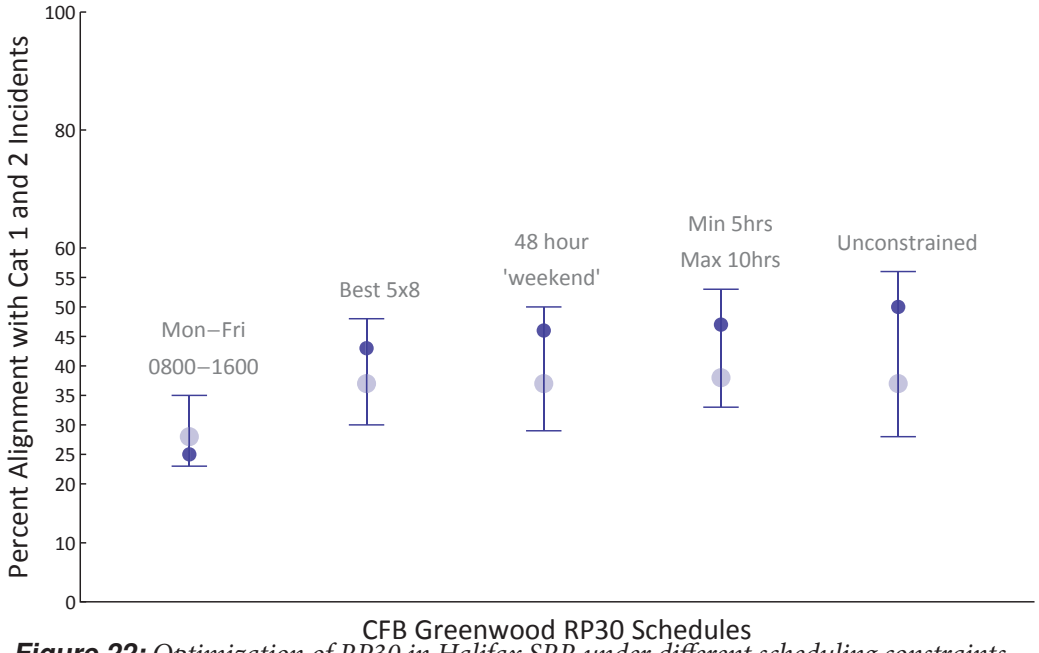


Figure 22: *Optimization of RP30 in Halifax SRR under different scheduling constraints.*

The percentages determined from optimization on the aggregate data sets (darker blue dots) differ less and less from the mean percentage (lighter blue dots) over the retroactive yearly data set as constraints are introduced. This is an indication that less-constrained RP30 schedules may be over-optimized over the selected time frame of the aggregate data. To elaborate by example, one might expect that the

optimal *unconstrained* RP30 schedule (selection of the 40 hours with the most incidents) for 2012 may not correspond to the optimal *unconstrained* RP30 schedule for 2011.

For a particular schedule, notable differences between the optimization results (darker blue dots) and mean percentage when applied to the yearly data (lighter blue dots) may indicate a lack of representativity of the aggregate data set to the full set of yearly data, 1993-2012. The reason for a potential lack of representativity could be inconsistent data, a small data set, or perhaps an actual change in SAR incident occurrence in recent years.

The optimization results indicate that optimizing RP30 schedules in the Trenton SRR 424 Squadron region would achieve the largest percentage point gain, doubling the percentage (to 50%) of aligned Cat 1 and 2 incidents using Best 5×8 schedules and achieving 65% alignment using Best 7×8 schedules. In the Trenton SRR 435 Squadron region, while potentially achieving similar gains with Best 5×8 schedules, the lower number of incidents occuring leads to more variation in the retroactive percentage of incidents aligned with on RP30. The opposite is observed for the Victoria SRR. The large number of incidents occuring per year leads to less variation in the retroactive percentage of incidents aligned with on RP30, likely achieving 40% alignment (approximately a 14% point improvement over the legacy RP30 schedule). Results on aggregate data (2010-2012) for the Halifax SRR show potential for an 18% point gain (25% to 43%) in the alignment of Cat 1 and 2 incidents by adopting a Best 5×8 RP30 schedule. Applying the schedule retroactively shows a 9% point gain (28% to 37%). Sections 4, 6, and 7 detail these RP30 schedules.

Visually, the range (min-max) of possible values of the yearly data (1993-2012) vary slightly between the various optimized RP30 schedules per SRR region. A statistical test was performed to determine if their differences are statistically significant. The Wilcoxon-Mann-Whitney test [36] is a non-parametric test of the null hypothesis that two populations are the same against an alternative hypothesis. It is an appropriate method for testing whether samples (that are independent, or not related) originate from the same distribution. When a test leads to significant results, then at least one of the samples is different from the other samples.[12] Table 5 provides the p-values obtained per SRR regions when comparing the RP30 percent alignment of the Best 5×8 schedules to the Unconstrained schedules between 1993 and 2012. The p-values indicate that there is no statistical evidence that the samples are different (assuming the standard significance threshold of $p \leq 0.05$). In other words, there is no evidence that introducing the additional constraints (to ensure eight hours per day RP30 schedules with consistent start times and two consecutive days on RP2hrs) reduces potential optimization gains compared to the unconstrained allocation of 40 hours (obtained on the aggregate data set).

As evidence that legacy 0800-1600 Monday to Friday RP30 schedules were likely not selected to maximize alignment with Cat 1 and 2 SAR incidents, random 5×8 RP30 schedules were generated per SRR. For each iteration, a random start day for the five consecutive days with RP30 and a random start time for the eight hour sequence were selected. Based on five thousand iterations, Table 6 presents the results when the schedules were applied to the aggregate data set as per Table 3.The results show that legacy RP30 schedules are hardly better than random 5×8 schedules: except for the Trenton SRR 435 Squadron Area, randomly selected 5×8 schedules would have nearly a 50% chance of aligning to

[12]Since it is a non-parametric method, the Wilcoxon-Mann-Whitney test does not assume a normal distribution of the residuals, unlike the analogous one-way analysis of variance. However, the test does assume an identically shaped and scaled distribution for each group, except for any difference in medians.

more Cat 1 and 2 SAR incidents than the legacy RP30 schedules. In other words, 0800-1600 Monday to Friday RP30 schedules are as good as random 5×8 RP30 schedules.

Table 5: *Wilcoxon-Mann-Whitney analysis results comparing the Best* 5×8 *schedules to Unconstrained schedules per SRR.*

	p-value
Trenton SRR 424 Squadron Area	0.73
Trenton SRR 435 Squadron Area	0.99
Victoria SRR	0.52
Halifax SRR	0.43

Table 6: *Alignment of random 5×8 RP30 schedules compared to legacy RP30 schedules.*

SRR	0800-1600 Mon-Fri RP30 Alignment %	Random 5×8 RP30 Alignment	
		Mean %	Stnd Dev
Trenton SRR 424 Squadron Area	25%	24%	16% points
Trenton SRR 435 Squadron Area	30%	24%	15% points
Victoria SRR	26%	24%	10% points
Halifax SRR	25%	24%	11% points

The mean percentage for random 5×8 RP30 schedules is the same for each SRR since

$$\frac{40 \cdot \mathbb{E}(b_1, \ldots, b_{168})}{\sum_{1}^{168} b_i} = \frac{40 \cdot \frac{\sum_{1}^{168} b_i}{168}}{\sum_{1}^{168} b_i} = \frac{40}{168} \approx 24\%, \tag{1}$$

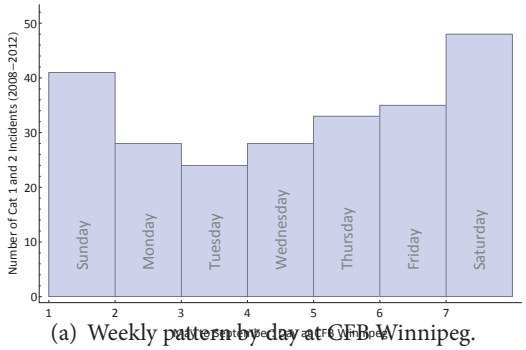
where b_i is the number of Cat 1 and 2 incidents binned to hour i of the week.

4 Trenton SRR response posture optimization

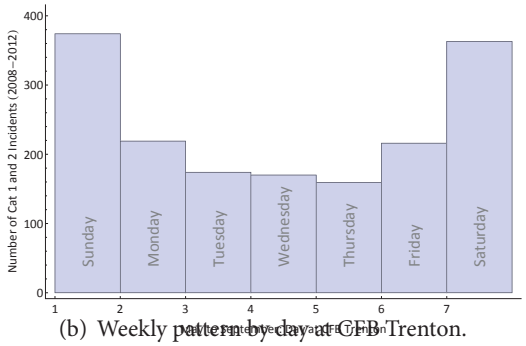
Cat 1 and 2 SAR incident data between 2008 and 2012 in the Trenton SRR were used to determine optimal RP30 schedules for 435 and 424 Transport and Rescue Squadrons (CFBs Winnipeg and Trenton respectively). Between 2008 and 2012 there were 340 Cat 1 and 2 incidents that could have prompted a tasking of resource(s) from CFB Winnipeg. 237 (70%) of these occurred between 1 May and 30 September (approximately 50 per summer). Between 2008 and 2012 there were 2159 Cat 1 and 2 incidents that could have prompted a tasking of resource(s) from CFB Trenton. 1675 (78%) of these occurred between 1 May and 30 September (approximately 375 per summer).

4.1 Data visualization

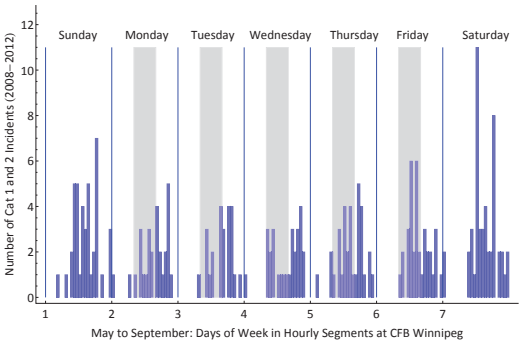
Visualizing the data confirms clear weekly and hourly patterns for SAR incidents occurring between 1 May and 30 September. Figure 23 shows that Cat 1 and 2 incidents have a higher likelihood of occurrence on weekends (in Subfigures 23(a) and 23(b) Cat 1 and 2 incidents are binned by day of week). The occurrence of incidents for which CFB Winnipeg may be tasked to respond to is typically lower on Mondays to Wednesdays; the occurrence of incidents for which CFB Trenton may be tasked to respond to is typically lower on Tuesdays to Thursdays. In Subfigures 23(c)and 23(d) Cat 1 and 2 incidents are binned by hour of week (168 hours). The gray bars highlight the 40 hours of an RP30 schedule of 0800 to 1600 hours Monday-Friday. 0800 to 1600 RP30 schedules for 435 Transport and



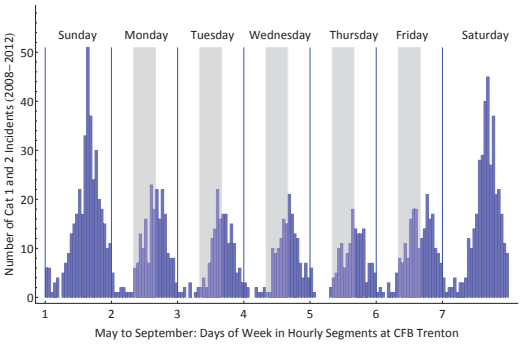
(a) Weekly pattern by day at CFB Winnipeg.



(b) Weekly pattern by day at CFB Trenton.



(c) Weekly pattern by hour at CFB Winnipeg.



(d) Weekly pattern by hour at CFB Trenton.

Figure 23: *Weekly pattern of Cat 1 and 2 incidents in Trenton SRR that may prompt tasking of resource(s) from CFB Winnipeg (Subfigures 23(a) and 23(c)) and CFB Trenton (Subfigures 23(b)and 23(d)).*

Rescue Squadron aligned with 30% of the Cat 1 and 2 incidents that occurred in the summer months of 2008-2012 for which 435 Squadron could have been tasked. 0800 to 1600 RP30 schedules for 424 Transport and Rescue Squadron aligned with 25% of the Cat 1 and 2 incidents that occurred in the summer months of 2008-2012 for which 424 Squadron could have been tasked.

4.2 Optimal schedules

Based on the analysis presented in Section 3, CJOC J3 SAR prepared a decision brief for Comd CJOC resulting in the 2013 CJOC SAR Directive directing the implementation of Best 5×8 and Best 7×8 RP30 schedules for the Trenton SRR.

Figure 24 presents a sample Best 7×8 optimal RP30 schedule for CH-146 and CC-130 crews at CFB Trenton. The 7×8 schedule is composed of two staggered Best 5×8 schedules for the CH-146 and CC-130 respectively, with same start times but off-setting 48 hour wknd days to have seven days a week of RP30 (totaling 56 RP30 hours per week). The hours where a CC-130 and a CH-146 crew are on RP30 are highlighted in orange. When only one type of aircraft is on RP30, hours are highlighted in yellow and green in the figure. The CH-146 and CC-130 5×8 hour days schedules overlap Fridays to Sundays, 1200-2000 hours (highlighted in orange in the figure). Additionally, CH-146 crews would work RP30 shifts Monday and Tuesday and CC-130 crews would work RP30 shifts Wednesday and Thursdays (or vice versa), offsetting days where the respective crews are not on RP30.

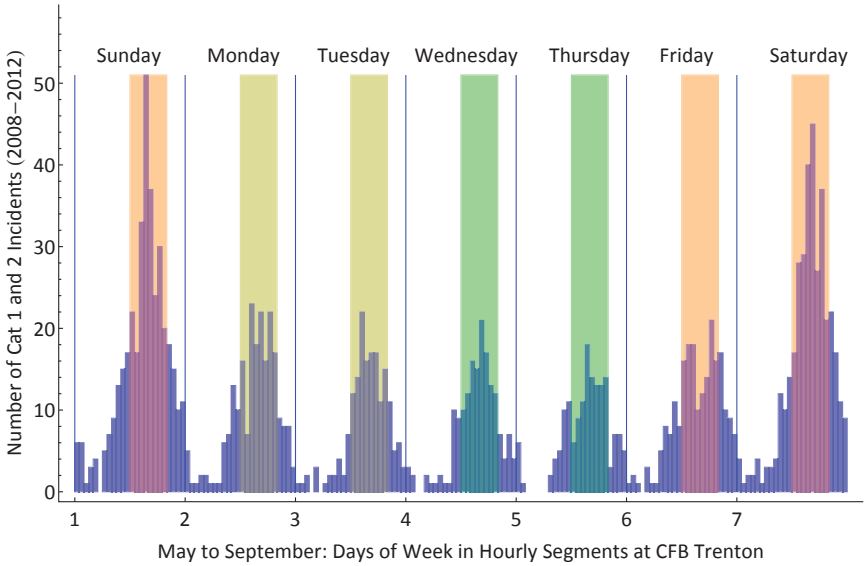


Figure 24: *Sample optimal RP30 schedule for CH-146 and CC-130 crews at CFB Trenton (orange when both aircraft types on RP30, yellow or green when only one on RP30).*

Historically, this schedule aligns with 65% of Cat 1 and 2 incidents that crews at CFB Trenton may be tasked to respond to (percentage of aggregate 2008-2012 data). Implementing this schedule would improve response posture alignment by a median of 112.5 (net) incidents per summer (median of difference each summer, 2003-2012). Table 7 provides a selection of potential shift start times and

their respective RP30 alignment percentage and the median number of incidents for which response posture alignment could be improved on. Results for 0900 and 1400 hour start times are suboptimal, but are included to show the drop-off in alignment. Highlighted in bold are the results corresponding to the schedule depicted in Figure 24.

Table 7: *Selection of 7×8 hour day schedules for crews at CFB Trenton.*

Start Time	Cat 1 and 2 Alignment %	Median # of Incidents Improved On
0900	53%	81.5
1000	58%	101.5
1100	62%	113
1200	**65%**	**112.5**
1300	64%	108
1400	62%	101.5

Figure 25 presents a sample optimal Best 5 × 8 RP30 schedule for CC-130 crews at CFB Winnipeg (local time). The 5×8 hour days schedule runs Friday to Tuesday, 1100-1900 hours (highlighted in orange in the figure). Wednesdays and Thursdays are at RP2hrs. Historically, this schedule aligns with 49% of Cat 1 and 2 incidents that crews at CFB Winnipeg may be tasked to respond to. Implementing this schedule would improve response posture alignment by a median of nine incidents per summer (net). Table 8 provides a selection of potential shift start times and their respective RP30 alignment percentage and the median number of incidents per summer for which response posture alignment could be improved on (net). Results for 0900 and 1300 hours start times are suboptimal, but are included to show the drop-off in alignment. Highlighted in bold are the results corresponding to the schedule depicted in Figure 25.

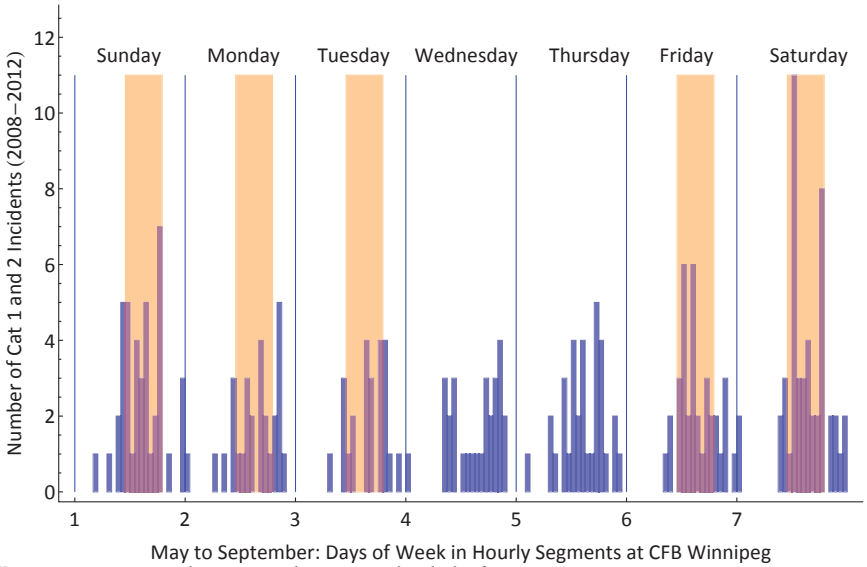


Figure 25: *Sample optimal RP30 schedule for CC-130 crews at CFB Winnipeg.*

Table 8: *Selection of 5×8 hour day schedules for CC-130 crews at CFB Winnipeg.*

Start Time	Cat 1 and 2 Alignment %		Median # of Incidents Improved On	
	RP2hrs on Mon-Tues	RP2hrs on Wed-Thurs	RP2hrs on Mon-Tues	RP2hrs on Wed-Thurs
0900	43%	44%	5	6
1000	46%	45%	8	8
1100	50%	**49%**	10	**9**
1200	49%	47%	9	9
1300	42%	43%	5	6

Staggered RP30 schedules of CC-130 crews at CFB Winnipeg and CFB Trenton would provide seven days a week of CC-130 RP30 reaction time to the Canadian North.

CFB Trenton or CFB Winnipeg SAR resources were tasked to respond to a mean of 22% of Cat 1 and 2 incidents between 2008 and 2012 (standard deviation of four percentage points). With the caveat that it is unclear whether RP30 schedules impact the number of Cat 1 and 2 incidents for which CAF is tasked,[13] combining the response rate with the median number of incidents showing net improved alignment, one could expect that implementing the 424 and 435 squadron RP30 schedules highlighted above may have net positive impact (in terms of reduced response time) to between 14 and 41 Cat 1 or 2 incidents per summer. These bounds are obtained by using the 95% confidence range centred around a distribution obtained by a Monte Carlo simulation combining the CAF response rate (normal distribution with mean 22% and standard deviation of 4%) and expected number of Cat 1 and 2 incidents to which CAF RP30 is better aligned with (uniform distribution based on 2003-2012 data).[14]

[13] It is re-iterated that retroactively determining the number of SAR incidents that may have benefited from revised RP30 schedules is problematic since it is unclear if the number of CAF taskings would change (e.g., increase) when squadrons are on RP30 during times of higher incident occurence.

[14] Kaluzny [26] predicted an improvement to 17 cases based on a national CAF response rate of 15% observed in 2011.

5 Analysis of Trenton SRR 2013 trial

Based on the 2013 Comd CJOC SAR Directive [28, 29], between 18 May and 30 September 2013, 435 Transport and Rescue Squadron implemented a Friday to Tuesday 1000-1800 hours (local time at CFB Winnipeg) RP30 schedule. 424 Transport and Rescue Squadron implemented a seven days a week 1200-2000 hours (local time at CFB Trenton) RP30 schedule, off-setting CH-146 (Wednesday and Thursday) and CC-130 (Monday and Tuesday) RP2hrs days. As a result, seven days a week of CC-130 RP30 hours, either eight or nine hours per day, was achieved.

In this section the alignment of RP30 schedules to the occurrence of Cat 1 or 2 SAR incidents is examined (Section 5.1) as well as to the SAR incidents (all categories) responded to by the CAF (Section 5.2.1), and the subset of Cat 1 or 2 incidents which were responded to by the CAF (Section 5.2.2).

5.1 Alignment with Cat 1 and 2 incidents

Data records indicate that 230 Cat 1 or 2 incidents occurred between 18 May and 30 September 2013 in the Trenton SRR: 23 occurred west of 87.4°W and 207 occurred east of 87.4°W (mid-point longitude between CFB Winnipeg and CFB Trenton facilitating the approximation of the number of incidents that 435 and 424 squadrons could have been tasked to respond to respectively). Data records indicate that 435 Transport and Rescue Squadron responded to 15 Cat 1 or 2 incidents and that 424 Transport and Rescue Squadron responded to 48 Cat 1 or 2 incidents. The response rate of CAF to Cat 1 and 2 incidents in the Trenton SRR in 2013 was 27% (5% points higher than the observed mean of 22% between 1993 and 2012).

The hourly pattern for 2013 Cat 1 and 2 incidents is consistent with the analysis of previous years. In Figures 26 and 27 Cat 1 and 2 incidents are binned by hour of week (168 hours).[15] In Figure 26 the light orange bars highlight the 40 hours of the 2013 RP30 schedules (1000 to 1800 hours, Friday to Tuesday) for CC-130 crews at CFB Winnipeg. In Figure 27 the coloured bars highlight the RP30 schedule for CH-146 and CC-130 crews at CFB Trenton: hours where both CC-130 and a CH-146 crews were on RP30 are highlighted in orange; when only the CC-130 crews were on RP30 the hours are highlighted in yellow and when only the CH-146 crews were on RP30 the hours are highlighted in green in the figure. The schedule provided 56 hours of RP30, 1200-2000 every day of the week. Overlapping CFB Winnipeg and CFB Trenton CC-130 crew RP30 schedules achieved at least eight hours of CC-130 RP30 every day of the week in the SRR.

Of the 23 Cat 1 or 2 incidents that 435 squadron could have been tasked to respond to, the 2013 RP30 schedule aligned with 10 (44%). A legacy RP30 schedule of 0800-1600 Monday to Friday would have aligned with five incidents (22%).

Of the 207 Cat 1 or 2 incidents that 424 squadron could have been tasked to respond to, the 2013 RP30 schedule aligned with 140 (68%). A legacy RP30 schedule of 0800-1600 Monday to Friday would have aligned with 48 incidents (23%).

[15] Data for 18 May to 27 September was used to have an integer number of weeks.

Combined, a net improvement (in terms of RP30 alignment) to 97 Cat 1 or 2 incidents was achieved between 18 May and 30 September in the Trenton SRR. The findings are comparable to the predicted values, as per Tables 7 and 8.

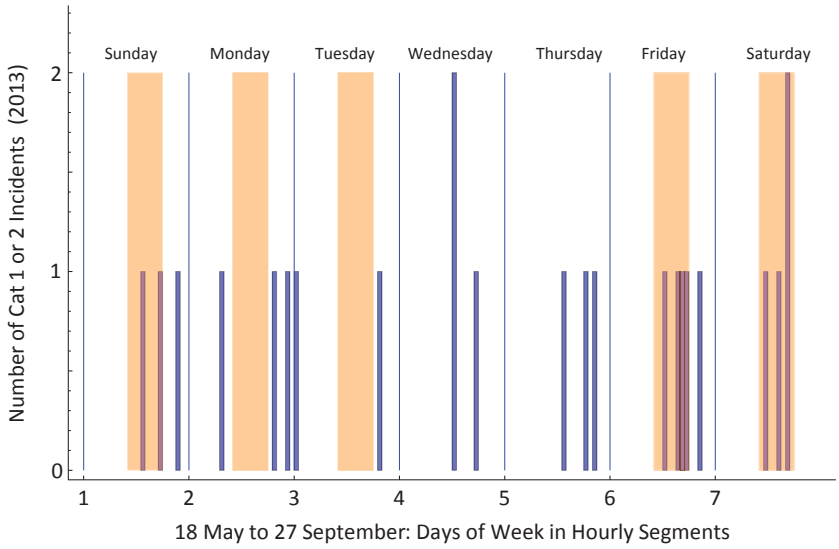


Figure 26: *Cat 1 and 2 incidents that could have prompted a response from 435 squadron binned by hour of week.*

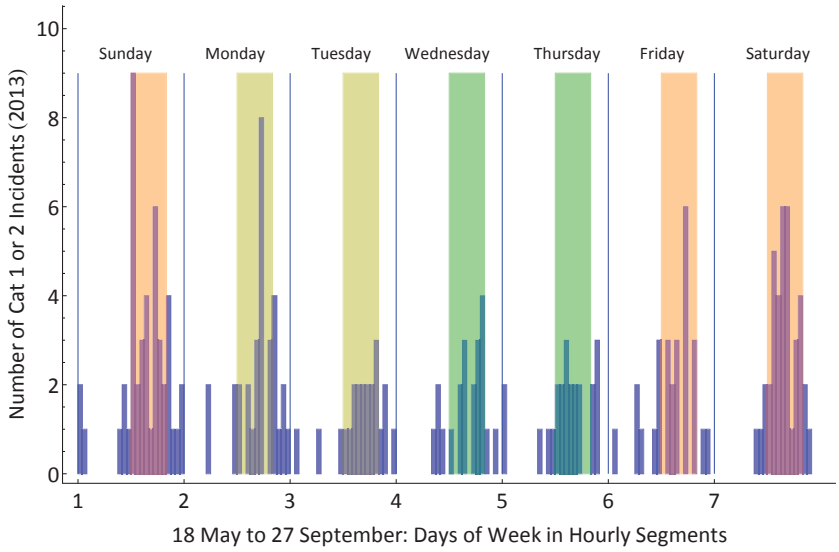


Figure 27: *Cat 1 and 2 incidents that could have prompted a response from 424 squadron binned by hour of week.*

5.2 CAF responses

5.2.1 CAF responses to all incidents

Data records indicate that 435 Transport and Rescue Squadron responded to 35 SAR incidents (all categories) between 18 May and 30 September 2013. For 15 of these incidents (41%), Trenton SRR JRCC tasked the squadron during RP30 hours. In comparison, on a Monday to Friday 0800-1600 hours RP30 schedule, the squadron would have aligned with 13 of the 35 incidents (37%) during RP30 hours. A net improvement to the RP30 alignment with two SAR incidents (all categories) responded to by the CAF was achieved.

Data records indicate that 424 Transport and Rescue Squadron responded to 138 SAR incidents (all categories) between 18 May and 30 September 2013. For 73 of these incidents (53%), Trenton SRR JRCC tasked the squadron during RP30 hours. In comparison, on a Monday to Friday 0800-1600 hours RP30 schedule, the squadron would have aligned with 33 of the 73 incidents (24%) during RP30 hours. A net improvement of RP30 alignment with 40 SAR incidents (all categories) responded to by the CAF was achieved.

5.2.2 CAF responses to Cat 1 and 2 incidents

Data records indicate that 435 Transport and Rescue Squadron responded to 15 Cat 1 and 2 incidents between 18 May and 30 September 2013. For four of these incidents (27%), Trenton SRR JRCC tasked the squadron during RP30 hours. In comparison, on a Monday to Friday 0800-1600 hours RP30 schedule, the squadron would have also aligned with three incidents (20%) during RP30 hours. Table 9 details the distribution of the incidents per days and times of the week. Three incidents were responded to during 2013 RP30 hours which would have been RP2hrs hours in previous years, and two incidents were responded to during 2013 RP2hrs hours which would have been RP30 hours in previous years. This results in a net improvement to the RP30 alignment of one incident responded to by the CAF was achieved. However, a closer examination of the incidents reveals that both 435 squadron and 424 squadrons were tasked to incident T2013–01942 occurring on a Wednesday afternoon: CC-130 crews in Winnipeg were on RP2hrs and CC-130 crews in Trenton where on RP30 (hence, it could be argued that the net improvement of the 435 squadron RP30 alignment is two).

Table 9: *Time of Cat 1 and 2 incidents (18 May - 30 September 2013) responded to by 435 Transport and Rescue Squadron.*

Time Period	Saturday/Sunday	Monday/Tuesday/Friday	Wednesday-Thursday	Total
0000-0759	1	3	0	4
0800-0959	0	0	0	0
1000-1559	2	1	2	5
1600-1759	1	0	0	1
1800-2359	1	2	2	5
Totals:	**5**	**6**	**4**	**15**

Data records indicate that 424 Transport and Rescue Squadron responded to 48 Cat 1 and 2 incidents between 18 May and 30 September 2013. For 27 of these incidents (56%), Trenton SRR JRCC tasked the squadron during RP30 hours. In comparison, on a Monday to Friday 0800-1600 hours RP30 schedule, the squadron would have aligned with 12 incidents (25%) during RP30 hours. Table 10 details the distribution of the incidents per days and times of the week. 17 incidents were responded to during 2013 RP30 hours which would have been RP2hrs hours in previous years, and two incidents were responded to during 2013 RP2hrs hours which would have been RP30 hours in previous years. A net improvement to the RP30 alignment with 15 incidents responded to by the CAF was achieved.

Table 10: *Time of Cat 1 and 2 incidents (18 May - 30 September 2013) responded to by 424 Transport and Rescue Squadron.*

Time Period	Saturday/Sunday	Monday-Friday	Total
0000-0759	1	5	6
0800-1159	0	2	2
1200-1559	7	10	17
1600-1959	6	4	10
2000-2359	3	10	13
Totals:	**17**	**31**	**48**

Combined, a net improvement (in terms of RP30 alignment) to 17 Cat 1 or 2 incidents responded to by the CAF was achieved between 18 May and 30 September in the Trenton SRR. [16] The observed improvement lies within the range predicted in Section 4. Table B.1 of Annex B details the 22 Cat 1 and 2 SAR cases, prompting a tasking of the CAF SAR resources, which were affected by revised RP30 schedules 18 May to 30 September 2013.

5.3 1 CAD after action reports and recommendations

1 CAD A3 SAR Fleet Readiness reconciled 8 and 17 Wing After Action Reports and presented them to the CJOC Commander [37] in order to depict a comprehensive evaluation of the trial considering force generation and SAR crew quality of life issues. Based on the 2013 trial, a subset of 1 CAD's recommendations included:

- RP30 schedules be tailored per squadron as, permitted by existing in-service support contracts, to maximize alignment with Cat 1 and 2 incidents;
- Revert to Monday to Friday schedules for 435 Squadron due to low number of incidents within the Trenton SRR 435 Squadron area; and,
- Squadron resources (fixed- and rotary-wing) should share the same RP30 schedule.

[16] According a net improvement of two to 435 squadron's RP30 alignment accounting for the dual 435 and 424 response to incident T2013–01942 for which 424 squadron was on RP30 and 435 squadron was on RP2hrs.

For 2014, an 1100-1900 Thursday to Monday RP30 schedule for 424 Squadron and a 1000-1800 Monday to Friday RP30 schedule for 435 Squadron was proposed. Table 11 provides a selection of RP30 schedules for 424 Squadron for Thursday to Monday RP30 schedules.

Table 11: *Selection of 5×8 hour day schedules for 424 Squadron for summer 2014 based on 1 CAD recommendations.*

Start Time	Cat 1 and 2 Alignment %	Median # of Incidents Improved On (Net)
900	42%	50.5
1000	45%	61
1100	**49%**	**72.5**
1200	50%	78
1300	50%	75

Given that CAF resources were tasked to respond to a mean of 22% of Cat 1 and 2 incidents between 2008 and 2012 in the Trenton SRR (standard deviation of four percentage points), one could expect that implementing an 1100-1900 Thursday to Monday RP30 schedule for 424 squadron may have net positive impact (in terms of reduced response time) to approximately 10 to 27 Cat 1 or 2 incidents per summer over the legacy 0800-1600 Monday to Friday schedule.[17]

1 CAD's recommended schedule for 435 Squadron is not analyzed in detail herein, however the results from Table 9 provide evidence that implementing a 1000-1800 Monday-Friday RP30 schedule is expected to impact the response time to just a few cases per summer.

For 2014, an 1100-1900 Monday to Friday RP30 schedule for 442 Squadron (CFB Comox) and an 0800-1600 Monday-Friday RP30 schedule for 413 and 103 squadrons in the Halifax SRR was proposed constrained by existing CH-149 in-service support contracts. The following sections detail the optimal alignment of RP30 schedules in the Victoria and Halifax SRRs, potentially applicable once new CH-149 in-service support contracts are in place in 2015.

5.4 Comparison to previous studies

The results presented in Table 11 show a higher percentage of incident alignment (50%) in comparison to Steele's [2] findings (43%), but similar optimal schedules. Based on 1983-1986 data, Shurson and Fitch [1] identified Thursday as the best start of a five day shift, and 1300hrs as the best start of the eight hour shift.

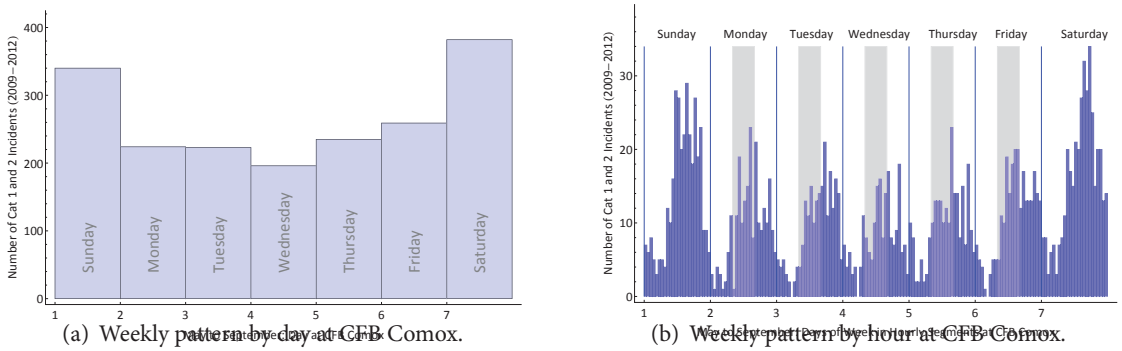
[17] These bounds are obtained by using the 95% confidence range centred around a distribution obtained by a Monte Carlo simulation combining the CAF response rate (normal distribution with mean 22% and standard deviation of 4%) and expected number of Cat 1 and 2 incidents to which CAF RP30 is better aligned with (uniform distribution based on 2003-2012 data).

6 Victoria SRR response posture optimization

Cat 1 and 2 SAR incident data between 2009 and 2012 in the Victoria SRR were used to determine optimal RP30 schedules for 442 Transport and Rescue Squadron (CFB Comox). Between 2009 and 2012 there were 2913 Cat 1 and 2 incidents that could have prompted a tasking of resource(s) from CFB Comox. 1859 (64%) of these occurred between 1 May and 30 September (approximately 372 per summer).

6.1 Data visualization

Visualizing the data confirms clear weekly and hourly patterns for SAR incidents occurring between 1 May and 30 September. Figure 28 shows that Cat 1 and 2 incidents have a higher likelihood of occurrence on weekends (in Subfigures 28(a) Cat 1 and 2 incidents are binned by day of week). The occurrence of incidents for which CFB Comox may be tasked to respond to is typically lower on weekdays. In Subfigure 28(b) Cat 1 and 2 incidents are binned by hour of week (168 hours). The gray bars highlight the 40 hours of an RP30 schedule of 0800 to 1600 hours Monday-Friday. 0800 to 1600 RP30 schedules for 442 Transport and Rescue Squadron aligned with 26% of the Cat 1 and 2 incidents that occurred in the summer months of 2009-2012 within the Victoria SRR.



(a) Weekly pattern by day at CFB Comox.

(b) Weekly pattern by hour at CFB Comox.

Figure 28: *Weekly pattern of Cat 1 and 2 incidents in Victoria SRR that may prompt tasking of resource(s) from CFB Comox (Subfigures 28(a) and 28(b)).*

6.2 Optimal schedules

Figure 29 presents a sample optimal RP30 schedule for 442 Transport and Rescue Squadron. The 5×8 hour days schedule runs Friday to Tuesday, 1000-1800 hours (highlighted in orange in the figure). Wednesdays and Thursdays are at RP2hrs. Historically, this schedule aligns with 40% of Cat 1 and 2 incidents that crews at CFB Comox may be tasked to respond to (percentage of aggregate 2009-2012 data). Table 12 provides a selection of potential shift start times and their respective RP30 alignment percentage (based on aggregate 2009-2012 data). Table 13 provides the corresponding median number of incidents per summer (2003-2005, 2009-2012) for which response posture alignment would have been improved on (net). A Friday to Tuesday 1000-1800 schedule would have improved (net) response posture to a median of 53 incidents per year. Results for 0800 and 0900 hour start times are suboptimal, but are included to show the drop-off in alignment. Similarly, RP2hrs schedules on Saturday and Sundays are suboptimal. Highlighted in bold are the results corresponding to the schedule depicted in Figure 29.

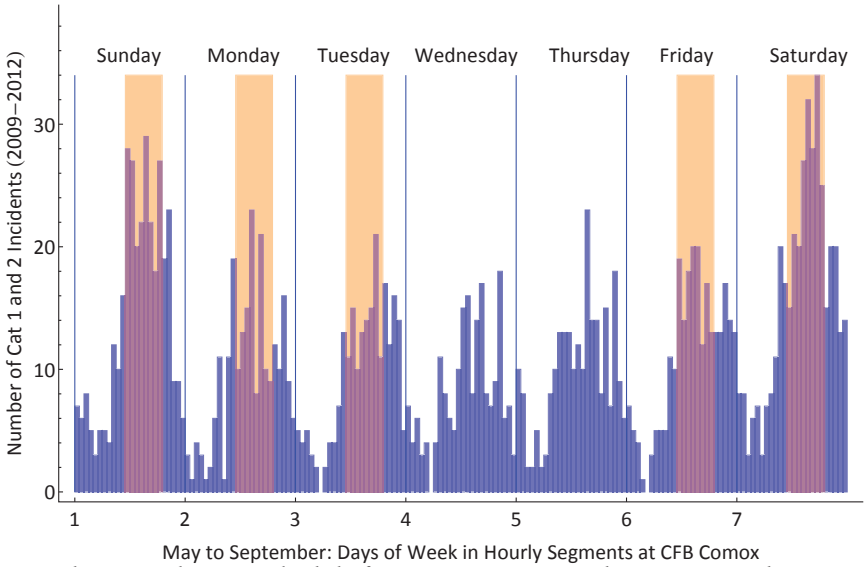


Figure 29: *Sample optimal RP30 schedule for 442 Transport and Rescue Squadron at CFB Comox.*

Table 12: *Selection of 5×8 hour day schedules for 442 Transport and Rescue Squadron at CFB Comox.*

Start Time	Cat 1 and 2 Alignment %		
	RP2hrs on Mon-Tues	RP2hrs on Wed-Thurs	RP2hrs on Sat-Sun
0800	34%	34%	26%
0900	36%	37%	29%
1000	38%	**40%**	30%
1100	39%	40%	30%
1200	38%	40%	30%
1300	38%	40%	29%

Table 13: *Selection of 5×8 hour day schedules for 442 Transport and Rescue Squadron at CFB Comox.*

Start Time	Median # of Incidents Improved on per Year (2003-2005, 2009-2012) RP2hrs on Mon-Tues	RP2hrs on Wed-Thurs	RP2hrs on Sat-Sun
800	26	30	0
900	38	44	9
1000	36	**53**	16
1100	52	62	19
1200	46	57	19
1300	47	53	25

CFB Comox SAR resources were tasked to respond to a mean of 12% of Cat 1 and 2 incidents between 2008 and 2012 (standard deviation of two percentage points).[18] Combining the response rate with the median number of incidents showing net improved alignment, one might expect that implementing the optimal 442 Squadron RP30 schedules highlighted above may have net positive impact (in terms of reduced response time) by between four and nine Cat 1 or 2 incidents per summer.[19]

6.3 Comparison to previous studies

In 2006 Grenkow and Julien [7] studied the occurrence of SAR incidents in the Victoria SRR between 1994 and 2005. They considered the subset of incidents responded to by the CAF (regardless of category/classification). Summer months were determined to be twice as busy as winter months, but found no evidence that the CAF responds to more incidents on any particular day of the week in the summer. Grenkow and Julien also found that when standby posture is relaxed (to RP2hrs), the number of CAF taskings decreased.

The findings in Section 6.2 are inconsistent with the Grenkov and Julien finding that *no evidence that the CAF responds to more incidents on any particular day of the week in the summer*. This discrepancy is due to Grenkow and Julien considering only SAR incidents responded to by the CAF, as opposed to optimizing RP30 schedules to align with all Cat 1 and 2 incidents. Their finding that *when standby posture is relaxed (to RP2hrs), the number of CAF taskings decrease* highlights the fact that several other non-CAF SAR resources are available on the west coast for JRCC dispatchers to task, and not that the number of SAR incidents is lower when the CAF is on RP2hrs (weekends and between 1600 and 0800 hours during weekdays).

The results in Section 6.2 show the same percentage (40%) of incident alignment as per Steele's findings [2], but also shows that an earlier start time (e.g., 1100hrs) is expected to have equivalent

[18] It is re-iterated that retroactively determining the number of SAR incidents that may have benefited from revised RP30 schedules is problematic since it is unclear if the number of CAF taskings would change (e.g., increase) when squadrons are on RP30 during times of higher incident occurence.

[19] These bounds are obtained by using the 95% confidence range centred around a distribution obtained by a Monte Carlo simulation combining the CAF response rate (normal distribution with mean 12% and standard deviation of 2%) and expected number of Cat 1 and 2 incidents to which CAF RP30 is better aligned with (uniform distribution based on on 2003-2005, 2009-2012 data).

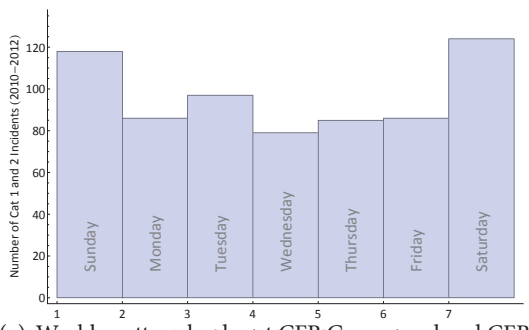
impact as the schedule with the start time proposed by Steele (1300hrs). Based on 1983-1986 data, Shurson and Fitch [1] identified Wednesday or Thursday as the best start of a five day shift, with a best start of the eight hour shift between 1000-1300hrs.

7 Halifax SRR response posture optimization

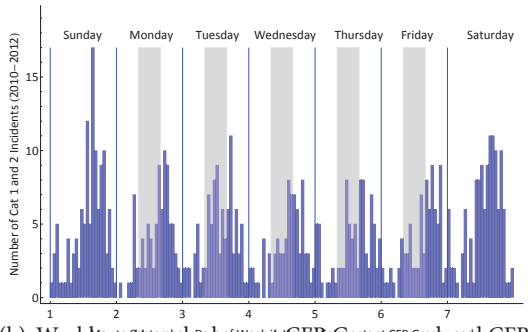
Cat 1 and 2 SAR incident data between 2010 and 2012 in the Halifax SRR were used to determine optimal RP30 schedules for 413 Transport and Rescue Squadron (CFB Greenwood) and 103 Search and Rescue Squadron (CFB Gander). Between 2010 and 2012 there were 1029 Cat 1 and 2 incidents that could have prompted a tasking of resource(s) from CFB Greenwood or CFB Gander. 675 (66%) of these occurred between 1 May and 30 September (approximately 225 per summer).

7.1 Data visualization

Visualizing the data confirms clear weekly and hourly patterns for SAR incidents occurring between 1 May and 30 September. Figure 30 shows that Cat 1 and 2 incidents have a higher likelihood of occurrence on weekends (in Subfigures 30(a) Cat 1 and 2 incidents are binned by day of week), albeit to a lesser extent than that observed for Victoria and Trenton SRRs. In Subfigure 30(b) Cat 1 and 2 incidents are binned by hour of week (168 hours). The gray bars highlight the 40 hours of an RP30 schedule of 0800 to 1600 hours Monday-Friday (local time in Greenwood[20]). 0800 to 1600 RP30 schedules for 413 Transport and Rescue Squadron and 103 Search and Rescue Squadron aligned with 25% of the Cat 1 and 2 incidents that occurred in the summer months of 2010-2012 within the Halifax SRR.



(a) Weekly pattern by day at CFB Greenwood and CFB Gander.



(b) Weekly pattern by hour at CFB Greenwood and CFB Gander.

Figure 30: *Weekly pattern of Cat 1 and 2 incidents in Halifax SRR that may prompt tasking of resource(s) from CFB Greenwood and CFB Gander (Subfigures 30(a) and 30(b)).*

[20] Time in Gander is offset by half an hour.

7.2 Optimal schedules

Figure 31 presents a sample optimal RP30 schedule for 413 Transport and Rescue Squadron. The 5×8 hour days schedule runs Friday to Tuesday, 1000-1800 hours (highlighted in orange in the figure). Wednesdays and Thursdays are at RP2hrs. Historically, this schedule aligns to 43% of Cat 1 and 2 incidents that crews at CFB Greenwood or CFB Gander may be tasked to respond to (percentage of aggregate 2010-2012 data). Table 14 provides a selection of potential shift start times and their respective RP30 alignment percentage (based on aggregate 2009-2012 data) and the corresponding median number of incidents per summer (2003-2006, 2008, 2010-2012) for which response posture alignment would have been improved on. A Friday to Tuesday 1200-2000 schedule would have improved response posture by a median of 24.5 incidents per year. Results for 0800 hour start times are suboptimal, but are included to show the drop-off in alignment. Highlighted in bold are the results corresponding to the schedule depicted in Figure 31.

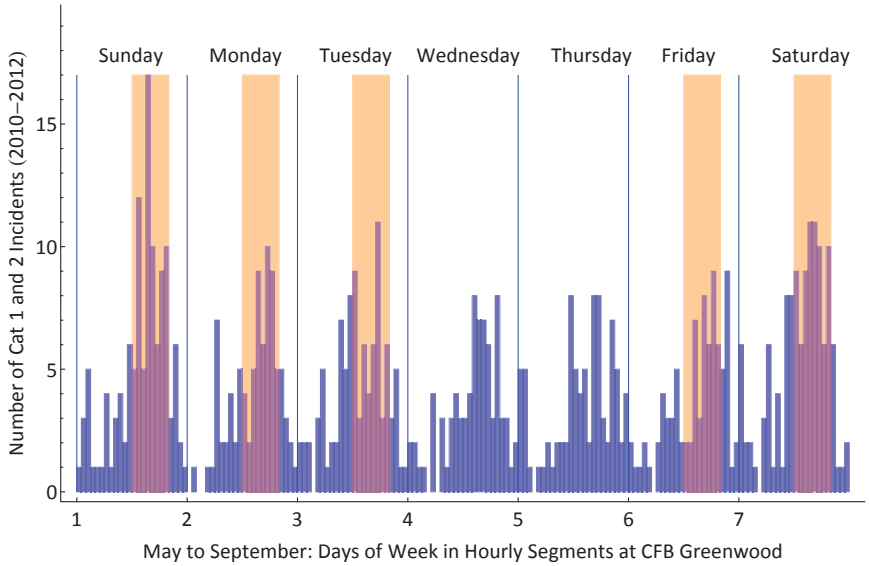


Figure 31: *Sample optimal RP30 schedule for crews at CFB Greenwood and CFB Gander.*

Table 14: *Selection of optimal RP30 schedules for crews at CFB Greenwood and CFB Gander.*

Start Time	Cat 1 and 2 Alignment %		Median # of Incidents Improved on per Year (2003-2012)	
	RP2hrs on Wed-Thurs	RP2hrs on Sat-Sun	RP2hrs on Wed-Thurs	RP2hrs on Sat-Sun
800	32%	25%	14.5	0
900	36%	28%	20	7
1000	39%	32%	25	12.5
1100	41%	33%	25	10.5
1200	**43%**	33%	**24.5**	10.5
1300	41%	33%	20.5	10.5

CFB Greenwood or CFB Gander SAR resources were tasked to respond to a mean of 36% of Cat 1 and 2 incidents between 2008 and 2012 (standard deviation of 11 percentage points).[21] Combining the response rate with the median number of incidents showing net improved alignment, one could expect that implementing the optimal RP30 schedules for 413 and 103 Squadrons highlighted above may have net positive impact (in terms of reduced response time) by between 2 and 20 Cat 1 or 2 incidents per summer.[22]

7.3 Comparison to previous studies

The results in Section 7.2 show a higher percentage (43%) of incident alignment than Steele's findings [2] (35%) and similar weekend coverage, but also find that a later start time provides better alignment (the optimal RP30 schedule found in Steele was Saturday to Wednesday 0900-1700hrs). Based on 1983-1986 data, Shurson and Fitch [1] identified Wednesday or Thursday as the best start of a five day shift, and 1200hrs as the best start of the eight hour shift.

[21] It is re-iterated that retroactively determining the number of SAR incidents that may have benefited from revised RP30 schedules is problematic since it is unclear if the number of CAF taskings would change (e.g., increase) when squadrons are on RP30 during times of higher incident occurence.

[22] These bounds are obtained by using the 95% confidence range centred around a distribution obtained by a Monte Carlo simulation combining the CAF response rate (normal distribution with mean 36% and standard deviation of 11%) and expected number of Cat 1 and 2 incidents to which CAF RP30 is better aligned to (uniform distribution based on 2003-2012 data).

8 Conclusion

The CAF maintain a response posture to Search and Rescue (SAR) operations 24 hours per day, seven days per week. Recently, SAR squadrons maintained RP30 for 40 hours a week per resource (aircraft type): eight hours a day, Monday to Friday (five days/week, excluding holidays), 0800-1600hrs local time and RP2hrs for remaining hours.

In response to a CJOC J3 SAR request, a study was undertaken to determine optimal RP30 schedules maximizing the alignment with the occurrence of distress or potential distress incidents based on recent data (last five years), focusing in the busy summer SAR season. This report details the data, modelling and analysis for optimizing RP30 hours for the summer SAR season. The results provided Commander (Comd) CJOC with quantitative evidence to base response posture direction in the 2013 and 2014 CJOC SAR Directives [28, 29, 30]. The recommended optimal RP30 schedules were trialled in the Trenton SRR between May and September 2013. A post-analysis of the trial informed CJOC and 1 CAD decision makers and were used to guide the 2014 CJOC SAR Directive. Supporting the latter, the report also documents the optimization of RP30 schedules in the Victoria and Halifax SRRs as reference for future CJOC SAR Directives.

Confirmed facts include:

- Confirmation that summer months represents the period with most SAR activity;
- The occurrence of distress or potential distress incidents are most prevalent on weekends and afternoons/evenings, but to different degrees per SAR region.

A summary of study findings include:

- Realistic scheduling constraints do not diminish potential optimization gains;
- In the Trenton SRR, implementing Best 5×8 RP30 schedules (eight hours a day for five consecutive days a week, with consistent start times) is anticipated to increase the percentage of Cat 1 and 2 incidents aligned with from 25% to 52% in the CFB Trenton region and from 30% to 52% in the CFB Winnipeg region;
- In the Victoria SRR, implementing Best 5×8 RP30 schedules is anticipated to increase the percentage of Cat 1 and 2 incidents aligned with from 26% to 40%;
- In the Halifax SRR, implementing Best 5×8 RP30 schedules is anticipated to increase the percentage of Cat 1 and 2 incidents aligned with from 25% to 43%;
- The 2013 trial in the Trenton SRR validated anticipated gains in the number of Cat 1 and 2 incidents aligned with on CAF RP30;
- The variation in effectiveness between good (optimal) schedules is small—other criteria other than number of incidents can be used to select the preferred schedule (from the menu of choices provided).

The above findings are consistent with the 1987 results of Shurson and Fitch [1] (based on 1983-1986 data). The optimal schedules determined herein align with schedules determined therein. This is a strong indication that the occurrence and pattern of SAR incidents has not changed much in the last 25+ years.

CJOC OR&A continues to support CJOC J3 SAR in the yearly evaluation and update of CAF response posture optimization efforts. Recommendations for further analysis include:

- Optimization of non-summer schedules (October to April), including exploring the potential of lowering RP30 hours per week during this time to enable an increase during summer months;
- Force generation study of crewing schedules and impact of increasing RP30 hours seasonally;
- Study the idea of seasonal "SAR squadron deployments" (similar to expeditionary deployments);
- Follow-on to Steele's work [2] to determine the implication of response posture on lives saved between 2005-2013;
- Study of JRCC dispatcher decision flow to better understand the impact of CAF response posture on decision time;
- Qualitative analysis, including surveys, to objectively capture potential quality-of-live issues reported by squadrons due to revised RP30 schedules;
- A comprehensive cost-personnel-benefit analysis of response posture;
- Trend analysis of the occurrence of SAR incidents; and,
- Identification/confirmation of special periods of increased SAR demand or potential (e.g., Halifax SRR lobster fishing season) to inform adjustments/surges. These should include analysis of holidays and holiday long-weekends.

This page intentionally left blank.

References

[1] Shurson, A. and Fitch, F. (1987), An Analysis of the Alert Posture of the Search and Rescue Squadrons, (Research Staff Note 87/17) DASOR.

[2] Steele, J. (2012), The Impact of Primary Air SAR Response Postures on Incident Outcomes, (TR 2012-077) DRDC – Centre for Operational Research and Analysis.

[3] LCol C. Denko, CJOC J3 SAR, SAR Incident Analysis, email to B. Kaluzny on 18 December 2012.

[4] National Search and Rescue Manual (2000), (Report B-GA-209-001/FP-001-DFO 5449) Department of National Defence, Ottawa, Canada.

[5] Innes, S., Corbett, N., and Nguyen, B. (2000), SAR Location Evaluation Program, (RN 2000-003) DRDC – Centre for Operational Research and Analysis.

[6] Bourdon, S. and Rempel, M. (2005), Analysis of Fleet Requirements for Fixed-Wing Search and Rescue Replacement Aircraft, (TR 2005-015) DRDC – Centre for Operational Research and Analysis.

[7] Grenkow, C. and Julien, I. (2006), 442 Squadron Search and Rescue (SAR) Response Posture (MS Powerpoint presentation).

[8] Drover, P. and Reid, S. (2008), Canadian Forces Search and Rescue 30-Minute Continuous Readiness Posture Force Generation Analysis.

[9] Collin, I., McCourt, R., Billyard, A., and Wesolkowski, S. (2010), Multi-Hop Shortest Path Computation for Rotary Wing Search and Rescue, (TM 2010-064) DRDC – Centre for Operational Research and Analysis.

[10] Asiedu, Y. and Rempel, M. (2005), Determining Optimal Locations for CASARA Units using Multi-Objective Genetic Algorithms, (TR 2005-025) DRDC – Centre for Operational Research and Analysis.

[11] Bourdon, S. and Rempel, M. (2005), Analysis of Optimal CASARA Locations, (TR 2005-014) DRDC – Centre for Operational Research and Analysis.

[12] Bourdon, S. (2005), Support to Air Force Transformation (Search and Rescue), (TR 2005-015) DRDC – Centre for Operational Research and Analysis.

[13] Karasakal, O. and Koektener, E. (2003), Locating the Search and Rescue Bases in the Presence of Partial Coverage, (RN 2001/03) DOR(MLA).

[14] Innes, S., Corbett, N., and Nguyen, B. (2000), SAR Location Evaluation Program, (RN 0003) DRDC – Centre for Operational Research and Analysis.

[15] Collin, I., McCourt, R., Billyard, A., and Wesolkowski, S. (2010), Rotary Wing Search and Rescue Demand for Joint Rescue Co-ordination Center Trenton: Historical Trends - Trenton Analysis, (TM 2010-247) DRDC – Centre for Operational Research and Analysis.

[16] Collin, I., Billyard, A., and Wesolkowski, S. (2010), RWSAR Study for Trenton SRR, (TM 2010-181) DRDC – Centre for Operational Research and Analysis.

[17] Pall, R. (2008), On the Availability of the CH149 Cromorant Fleet in an Ideal Sparing Situation, (TM 2008-011) DRDC – Centre for Operational Research and Analysis.

[18] Pall, R. (2007), On Forecasting the Availability of the CH149 Cormorant Fleet, (TM 2007-020) DRDC – Centre for Operational Research and Analysis.

[19] Corbett, N. (2003), The Impact of Offshore Oil Operations on the Delivery of East Coast Search and Rescue Services, (PR 0201) DRDC – Centre for Operational Research and Analysis.

[20] Grant, S. (2011), General Findings from the Rotary Wing Search and Rescue Flight Training Device Experiment, (LR 2011-101) DRDC – Centre for Operational Research and Analysis.

[21] Hrychuk, H. (2009), International Usage of Synthetic Environment in Rotary Wing Search and Rescue Force Generation, (TM 2009-052) DRDC – Centre for Operational Research and Analysis.

[22] Gauthier, S. (2009), Operational Differences Between MEOSAR and GEO/LEOSAR Capabilities, (TM 2009-011) DRDC – Centre for Operational Research and Analysis.

[23] Scales, C. (2007), Spotter Window Field of View Analysis for Fixed-Wing Search and Rescue Aircraft, (TM 2007-015) DRDC – Centre for Operational Research and Analysis.

[24] Chouinard, A. (2000), An Update of the Impact of Emergency Distress Beacons on Canadian Search and Rescue Flying Times, (RN 2000/08) DOR(CAM).

[25] Nguyen, B. and Ng, K. (2000), Intercept Mechanism and Assessment of Simple Search Patterns, (RN 0002) 1 CAD/CANRHQ.

[26] Kaluzny, B. (2013), Search and Rescue Response Posture Optimization, (LR 2013-055) DRDC – Centre for Operational Research and Analysis.

[27] Kaluzny, B. (2013), Search and Rescue Incident Data Analysis: Response Posture of Victoria and Halifax Regions, (LR 2013-109) DRDC – Centre for Operational Research and Analysis.

[28] 1 CAD AR Fleet Readiness (2013), Briefing Note for Comd 1 CAD - SAR Response Posture Trenton SRR.

[29] LGen S. Beare, Comd CJOC (2013), 2013 CJOC Search and Rescue Directive.

[30] LGen S. Beare, Comd CJOC (2014), 2014 CJOC Search and Rescue Directive.

[31] SAR Mission Management System (online), `http://smms.forces.gc.ca` (Access Date: 9 September 2013).

[32] Robert, Capt. M. (8 Wing JRCC Trenton), private communication with S. Bourdon (DASOR), 28 February 2012.

[33] Chief Review Services (2008), Evaluation of the CF/DND Component of the National Search and Rescue Program, (Report 1258-159 (CRS)) Department of National Defence, Ottawa, Canada.

[34] Bourdon, S. and Kaluzny, B. (2012), Preliminary Spatial Analysis of Historical Search and Rescue Incidents, (LR 2012-080) DRDC – Centre for Operational Research and Analysis.

[35] Achterberg, T. (2009), SCIP: Solving constraint integer programs, *Mathematical Programming Computation*, 1(1), 1–41. http://mpc.zib.de/index.php/MPC/article/view/4 (Accessed: 4 April 2014).

[36] Mann, H. and Whitney, D. (1947), On a Test of Whether one of Two Random Variables is Stochastically Larger than the Other, *Annals of Mathematical Statistics*, 18(1), 50–60.

[37] Tromp, K. and Frost, S. (2013), JFACC Recommendations for SAR Posture Summer 2014.

[38] Koch, T. (2004), Rapid Mathematical Programming, Ph.D. thesis, Technische Universität Berlin. ZIB-Report 04-58.

[39] Wunderling, R. (1996), Paralleler und objektorientierter Simplex-Algorithmus, Ph.D. thesis, Technische Universität Berlin. http://www.zib.de/Publications/abstracts/TR-96-09/ (Accessed: 4 April 2014).

This page intentionally left blank.

Annex A: Mathematical formulation

To determine schedules optimally aligning RP30 hours to historical incident occurence, the RP30 optimization problem was formulated as an integer linear program detailed in the following. The occurrence times of Cat 1 and 2 SAR incidents in a given period (e.g., summers of 2008-2012) were aggregated and binned by hour of the week (168 hours). Let $T = \{1, \ldots, 168\}$ be the set of hours in a week and C_t, for $t \in T$, to be the number of Cat 1 and 2 SAR incidents binned to hour t. $S = \{1, 25, 49, 73, 97, 121, 145\}$ is a subset of T denoting the first hour of each of the seven days of a week. Binary variables x_t, for $t \in T$, are defined to represent the decision whether to start a RP30 sequence ($x_t = 1$) or not ($x_t = 0$). Binary variables y_t, for $t \in T$, are defined to represent the decision whether to end a RP30 sequence ($y_t = 1$) or not ($y_t = 0$). Binary variables w_t, for $t \in T$, are defined to represent whether hour t is part of an RP30 sequence ($w_t = 1$) or not ($w_t = 0$). Binary variables r_t, for $t \in S$, are defined to represent whether the day starting at hour t is strictly RP2hrs ($r_t = 1$) or not ($r_t = 0$).

The objective is to maximize the alignment of RP30 hours with historical incident occurrence:

$$\text{maximize} \sum_{t=1}^{168} w_t \times C_t. \tag{A.1}$$

The total number of hours on RP30 is constrained:

$$\sum_{t=1}^{168} w_t = W, \tag{A.2}$$

where W is a fixed integer (e.g., set to 40 when maximizing the alignment of 40 RP30 hours per week).

Unconstrained RP30 schedules were obtained by simply optimizing the allocation of 40 RP30 hours, potentially yielding multiple RP30 sequences per day or exceedingly long sequences (essentially the 40 bins of the 168 with the most incidents). Figure A.1 illustrates such a schedule for 442 Transport and Rescue Squadron at CFB Comox.

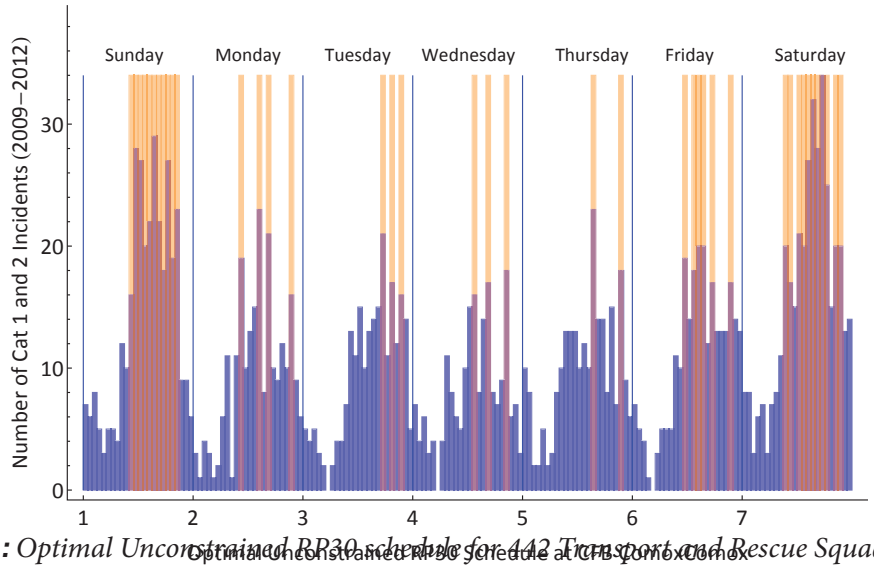


Figure A.1: *Optimal Unconstrained RP30 schedule for 442 Transport and Rescue Squadron at CFB Comox.*

A.1 Min 5 Max 10 RP30 schedules

Min 5 Max 10 RP30 schedules were obtained by introducing constraints on the minimum (min) and maximum (max) length of an RP30 sequence (5 and 10 hours respectively) in addition to constraining a maximum of one such sequence per day.

A maximum of one RP30 sequence can start in a given day:

for all times t in S,

$$\sum_{s=0}^{23} x_{t+s} \leq 1. \tag{A.3}$$

There must be an equal number of RP30 sequence starts and ends:

$$\sum_{t=1}^{168} x_t = \sum_{t=1}^{168} y_t, \tag{A.4}$$

and the decision to start an RP30 sequence must be tied to a decision to end a RP30 sequence (within 10 hours):

for all times t in T,

$$\sum_{s=1}^{9} y_{((t-1+s) \bmod 168)+1} \geq x_t, \tag{A.5}$$

$$\sum_{s=1}^{9} x_{((t-s-2) \bmod 168)+1} \geq y_t. \tag{A.6}$$

Hours on RP30 are linked and constrained to lie in between decisions to start and end RP30 sequences, and RP30 sequences were constrained to be a minimum of 5 hours and a maximum of 10 hours:

for all times t in T,

$$\sum_{s=1}^{4} x_{((t-s-1) \bmod 168)+1} \leq w_t, \tag{A.7}$$

$$\sum_{s=1}^{4} y_{((t-1+s) \bmod 168)+1} \leq w_t, \tag{A.8}$$

$$\sum_{s=1}^{9} x_{((t-s-1) \bmod 168)+1} \geq w_t, \tag{A.9}$$

$$\sum_{s=1}^{9} y_{((t-1+s) \bmod 168)+1} \geq w_t. \tag{A.10}$$

Together, inequalities (A.7)-(A.10) constrain RP30 sequences to be between 5 and 10 hours long. Inequality (A.7) ensures that if an RP30 sequence started in the past 4 hours then variable w_t is set to one, (A.8) ensures that if a RP30 sequence ends in the next 4 hours then variable w_t is set to one, (A.9) ensures that if an hour is designated as RP30 then an RP30 sequence must have started up to 10 hours before, (A.10) ensures that if an hour is designated as RP30 then an RP30 sequence must end in the next 10 hours.

Figure A.2 illustrates a Min 5 Max 10 RP30 schedule for 442 Transport and Rescue Squadron at CFB Comox.

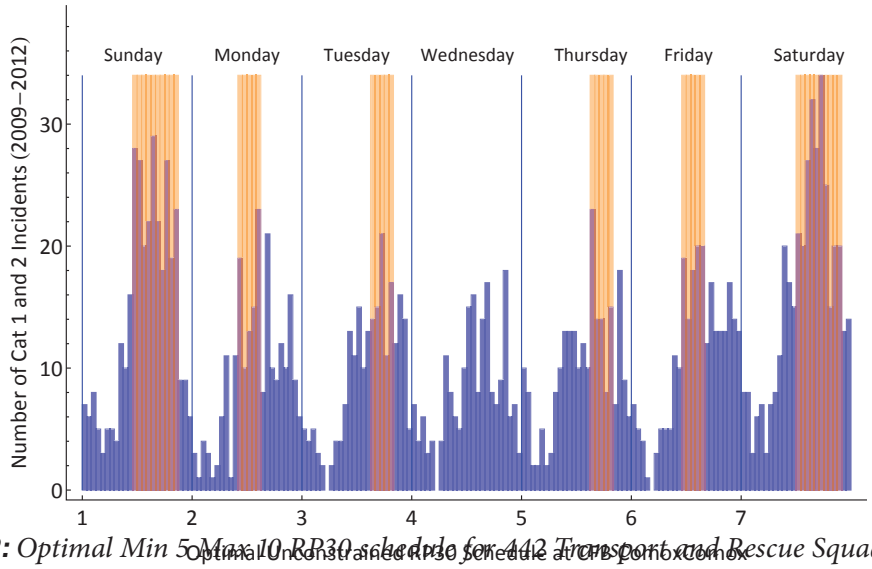


Figure A.2: *Optimal Min 5 Max 10 RP30 schedule for 442 Transport and Rescue Squadron at CFB Comox.*

A.2 48 hour wknd RP30 schedules

48 hour wknd RP30 schedules added further constraints to ensure that two consecutive days in the week were only on RP2hrs, hence introducing a "weekend" (wknd).

To enforce a day to be strictly RP2hrs:

for all times t in S,

$$\sum_{s=0}^{23} w_{((t+s-1) \bmod 168)+1} \leq M - M \times r_t, \tag{A.11}$$

where M is set as a very large number (e.g., 200).

The number days R on RP2hrs (void of RP30 sequences) can be modelled as:

$$\sum_{s \in S} r_s = R. \tag{A.12}$$

To enforce two consecutive days on RP2hrs (void of RP30 sequences) the constraints

for all times t in S,

$$\sum_{s=0}^{47} w_{((t+s-1) \bmod 168)+1} \leq M - M \times r_t, \tag{A.13}$$

setting R in constraint A.12 to one and hence making constraint A.11 redundant.

Figure A.3 illustrates a 48 hour wknd RP30 schedule for 442 Transport and Rescue Squadron at CFB Comox.

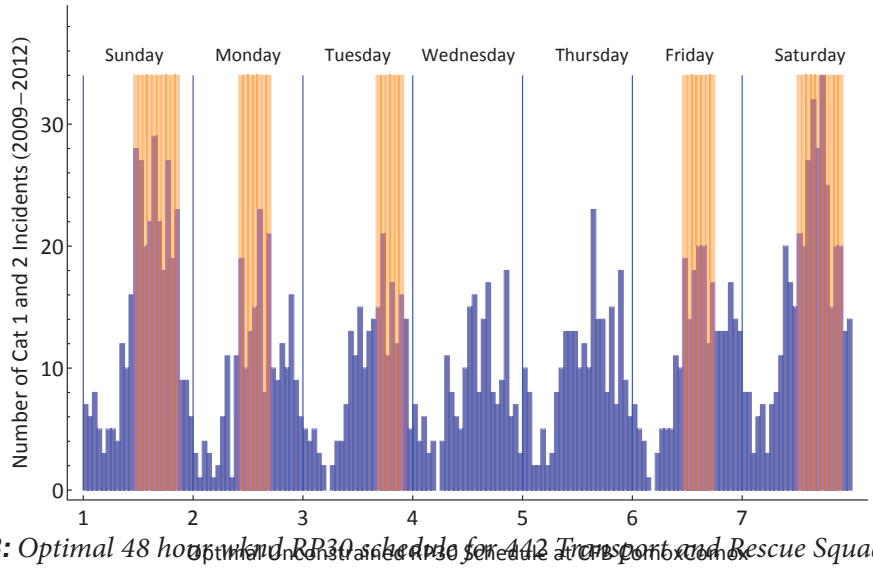


Figure A.3: *Optimal 48 hour-wkend RP30 schedule for 442 Transport and Rescue Squadron at CFB Comox.*

A.3 Best 5×8 RP30 schedules

Best 5×8 RP30 schedules were obtained by adding constraints to ensure shifts were exactly 8 hours long and had a consistent start time.

To enforce RP30 sequences to be exactly 8 hours:

for all times t in T,

$$x_t = y_{((t+6) mod 168)+1}. \tag{A.14}$$

To enforce a consistent start time to RP30 sequences, define $D = \{0, \ldots, 23\}$ to be the set of hours in a day and define binary variables b_s, for $s \in D$, to represent whether hour s of each day is the selected (consistent) start time ($b_s = 1$) or not ($b_s = 0$):

$$\sum_{s \in D} b_s = 1, \tag{A.15}$$

for all times s in D,

$$M \times b_s \geq \sum_{t in S} x_{s+t}, \tag{A.16}$$

where M is set as a very large number.

Best 7×8 RP30 schedules were obtained by setting $W = 56$ and removing constraints A.11-A.13.

A.4 Formulation size and solver

The size of a formulation, measured in the number of variables and constraints, often provides a preliminary indicator as to the whether or not good solutions can be found in a reasonable amount of time. The formulation presented above has up to 535 binary variables and up to 1057 constraints. The formulation was implemented in ZIMPL [38] and solutions were found to problem instances using the open-source SCIP-SoPLEX integer program solver[35, 39], typically within seconds.

Annex B: 2013 SAR cases affected by shift in RP30 schedule

Table B.1: *Cat 1 and 2 SAR Incidents Responded to by the CAF Affected by Revised RP30 Schedules.*

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-00250	45.22	-80.17	A1	Crash	CELLULAR PHONE	25/05/2013 21:12	26/05/2013 14:12	Rescue

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
2	2	0	0	0	GRIF 419 424	30 M	25/05/2013 21:25	25/05/2013 21:25	25/05/2013 22:20

Advised by OPP through local sailboat on Georgian Bay area of a floatplane crash near shore in Parry Sound area. Both occupants exited inverted aircraft and swam to nearest remote island. Reported to be cold, wet and stranded. 424 sqn Griffon R419 tasked as well as CCG zodiac. Party picked up by OPP and brought to medical authorities in Parry Sound. Resources stood down in transit case closed.

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-00471	47.47	-72.08	A1	Crash	CELLULAR PHONE	16/06/2013 16:23	17/06/2013 19:46	Monitoring

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
2	2	0	0	0	HERC 343 424	30 M	16/06/2013 16:24	16/06/2013 16:43	16/06/2013 17:50

SQ HQ reported a plane crash on Lac Des Passes, east of La Tuque, QB. The aircraft flipped and sank. An off-duty SQ officer heard the crash and assisted. Herc and Griffon from 424 Sqn tasked as a precaution until SQ could ascertain the extraction was successful. Griffon RTB when injuries were found to be minor. Ambulance was able to pick up the 2 POBs. C-130 RTB. TSB and CACO notified. Case closed.

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-00557	45.08	-76.83	H1	Missing Person(s)	VISUAL LAND CONTACT	23/06/2013 21:30	24/06/2013 2:07	Investigation

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
1	1	0	0	0	GRIF 493 424	30 M	23/06/2013 21:37	23/06/2013 21:37	23/06/2013 22:00

OPP requested helo assistance to look for 54 YOM in the area of Sharbot Lake. R493, 424 Sqn Griffon was tasked. Griffon returned to base due to poor weather. OPP advised JRCC shortly thereafter that the person had been located. No medical attention required. Case closed.

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-00637	43.71	-81.73	M2	Capsized	VISUAL LAND CONTACT	29/06/2013 17:16	30/06/2013 1:22	Rescue

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
2	2	0	0	0	HERC 344 424	30 M	29/06/2013 17:24	29/06/2013 17:25	29/06/2013 17:43

Capsized sailboat reported of Blue water beach south of Goderich. MAYDAY relay issued, Cape Rescue and Hercules tasked. Rescue on scene and rescue 2 POBs. Herc stood down. S/V and POBS brought back to Goderich. Case Closed

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-00743	45.95	-78.16	H1	Other	OTHER	06/07/2013 19:02	07/07/2013 3:16	Evacuation

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
1	1	0	0	0	GRIF 491 424	30 M	06/07/2013 20:29	06/07/2013 20:39	06/07/2013 21:35

Smith Falls OPP Communications requested helicopter assistance for injured person in Algonquin Park on the Petawawa River. Ornge helo arrived on scene but was unable to reach 15 YOM patient with neck injuries 6 km away from nearest landing site. 424 Sqn Griffon R491 tasked: patient hoisted out and brought to Pembroke hospital. RTB after delivery. case closed.

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-00847	45.81	-77.05	H1	Stranded	VISUAL LAND CONTACT	13/07/2013 17:26	14/07/2013 1:19	Rescue

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
1	1	0	0	0	GRIF 491 424	30 M	13/07/2013 17:31	13/07/2013 18:22	13/07/2013 19:15

Request for assistance from OPP for a person stranded in the Ottawa river rapids, OPP on scene but unable to retrieve person due to fast currents. 424 sqn Griifon R491 tasked. OPP rescuer on a rope became stranded himself after rescuing person. R491 hoisted OPP officer out the water and brought to Pembroke hospital. Griffon RTB case closed.

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-00875	44.62	-77.27	H1	Missing Person(s)	OTHER	14/07/2013 16:57	15/07/2013 12:15	Rescue

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
1	1	0	0	0	GRIF 491 424	30 M	14/07/2013 17:01	14/07/2013 16:30	14/07/2013 17:30

OPP requested Air assistance in locating a missing 72 YOF Alzheimer patient who has wandered off into the woods and swampy area near Tweed, ON. 424 Sqn Griffon R491 tasked while airborne. They located the dehydrated, but otherwise okay, lady and took her to the Belleville hospital as a precaution. Case closed.

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-00880	43.84	-77.15	M1	Missing Person(s)	OTHER	14/07/2013 18:49	17/07/2013 12:56	Search

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
1	0	0	1	0	GRIF 491 424	30 M	14/07/2013 19:41	14/07/2013 23:22	15/07/2013 3:56

Sailboat found on the rocks at Point Petree. Sailboat is registered in NY with personal effects onboard. Mayday relay issued. Tasked R344, R491 and CCGA Wellington. Informed D9 Cleveland and Sector Buffalo, they are searching the owner of the boat in the US. CGS Cape Hearne and USCG MLB Katmai Bay have also been tasked. Case transferred to D9 Cleveland when onboard GPS information was used to determine the LKP to be on the U.S. side. R344 was used overnight but since released. R491 flew all night. R493 launched at noon. Cape Hearne and R319 retasked to assist. R319 RTB Trenton after completing search area and becoming time expired for crew day. USCG D9 reduced search. Case closed.

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-01012	44.21	-76.54	M1	Other	CELLULAR PHONE	20/07/2013 23:11	21/07/2013 1:51	Search

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
2	2	0	0	0	GRIF 491 424	30 M	20/07/2013 23:25	20/07/2013 23:19	20/07/2013 23:23

Report from a concerned citizen about boat debris near the Dupont intake, Kingston ON. Hearne MRKVII and 424 Sqn Griffon tasked to investigate. Kingston PD on the scene talked to the owners and everyone is accounted for. Units stood down, CG FRC cleaning up flaotsam in the area. No medical issues. Case Closed

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-01064	45.42	-80.34	M1	Taking On Water	CELLULAR PHONE	23/07/2013 22:47	25/07/2013 1:41	Rescue

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
8	8	0	0	0	GRIF 492 424	30 M	23/07/2013 23:01	23/07/2013 23:03	23/07/2013 23:30

Report of Sinking vessel with 8 POB near Sunnyside Island BX issued tasked: CG 1007 CG 1000 CCGA Marine 2, CCGS Cove Isle Workboat, OPP vessel tribute, and Griffon Helo R491 tasked to assist. CCGA Marine 2 arrived on scene and recovered the 8 persons from the island. The POB and boat were brought to Dillon dock. All units stood down. Case Closed

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-01176	42.66	-80.32	M2	Other	CELLULAR PHONE	29/07/2013 20:41	30/07/2013 1:18	Search

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
2	2	0	0	0	GRIF 432 424	30 M	29/07/2013 20:42	29/07/2013 20:46	29/07/2013 20:52

Report of a raft blowing off shore from Turkey Point. CG 04, Thundercape and Helo tasked to search. Raft was blown ashore and persons were found safe ashore. All stood down. Case Closed.

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-01353	48.53	-86.27	M1	Capsized	OTHER	10/08/2013 17:24	11/08/2013 3:38	Rescue

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
2	1	1	0	0	HERC 344 424	30 M	10/08/2013 17:45	10/08/2013 17:48	10/08/2013 18:30

SPOT beacon activation on Lake Superior by Pakaskwa Provicial Park. CGA vessel Melissa June tasked and located capsized canoe with one person on shore. 1 PIW found vital signs absent. 424 Sqn Herc R344 tasked; upon arrival onscene SAR techs jumped to assist with CPR and attempt revival. Griffon tasked and cancelled. Park vessel also tasked. PIW recovered from the water by Parks vessel and transported to their dock where they co-ordinated a patient transfer to ambulance. R344 RTB with stop in Marathon to recover ST. Case closed.

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-01608	48.30	-70.60	A1	Crash	VISUAL AIR CONTACT	24/08/2013 19:46	25/08/2013 16:04	Rescue

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
2	2	0	0	0	HERC 343 424	30 M	24/08/2013 20:10	24/08/2013 21:04	24/08/2013 21:05

Report from Bagotville tower of floatplane crash in the woods near Lac Otis, SE of Bagotville. Trenton Hercules and Bagotville Griffon tasked. Police located crash scene. C-FTFD with 2 POB OK. ELT turned off. Hercules stood down. Griffon confirmed no ELT signal heard and stood down. No distress. Case closed.

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-01632	46.25	-79.63	H1	Person In Water	VISUAL MARINE CONTACT	25/08/2013 20:01	26/08/2013 2:27	Assist Another JRCC/MRSC

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
2	1	0	1	0	GRIF 432 424	30 M	25/08/2013 20:11	25/08/2013 20:11	25/08/2013 21:21

Overturned boat with 2 PIWs. 1 PIW a female swam to a nearby island and was recovered by OPP The second PIW 52 YOM was last seen swimming behind the female holding a PFD but did not make it to shore. OPP have 3 police boats on scene conducting search in area. OPP requested Helo assistance, 424 Sqn R432 tasked airborne to assist. Griffon searched area and shoreline of islands without success. OPP helicopter resumed search after Griffon helicopter off scene. OPP released R432. RTB Trenton. Case closed.

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-01811	43.14	-79.04	M1	Person In Water	VISUAL MARINE CONTACT	08/09/2013 18:18	08/09/2013 21:25	Rescue

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
1	1	0	0	0	GRIF 432 424	30 M	08/09/2013 18:29	08/09/2013 18:21	08/09/2013 18:47

Report of a capsized PWC on the lower Niagara River. BX issued. USCG Stn Youngstown Cape Storm tasked. Lewistown FD located the person transported him safely to shore. Case Closed

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-01913	68.90	-94.57	M2	Other	OVERDUE	21/09/2013 21:08	24/09/2013 20:06	Search

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
2	2	0	0	0	HERC 339 435	30 M	21/09/2013 21:50	22/09/2013 0:30	22/09/2013 4:45

EMO Iqaluit called reporting an overdue boat with 2 POB that departed from Talovak (aka Spence Bay) Sept 20 AM and was supposed to arrive in Gjoa Haven same day. 435 Sqn Herc, Winnipeg CASARA spotters and CCGS Sir Wilfrid Laurier tasked. Hunters were found by 435 Herc on ground with disabled boat. People have been evacuated back to Gjoa Haven on Helo from CCGS Sir Wilfrid Laurier. Case closed.

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-00246	53.91	-94.95	A2	Airborne Emergency	VHF/HF/UHF RT AIR	25/05/2013 16:40	25/05/2013 22:45	Search

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
4	4	0	0	0	HERC 333 435	30 M	25/05/2013 16:50	25/05/2013 16:55	25/05/2013 18:10

Call received from an airborne Calm Air flight through Winnipeg FSS. aircraft C-GYLT on floats had called advising of propeller failure near Waasagamach Lake, Manitoba. Winnipeg Hercules tasked airborne to search in the area. Floatplane with 4 POB landed safely on Raven Lake 26 NM West of St Theresa point. They were picked up by company floatplane and Hercules escorted them to their floatbase at St Theresa point. No injuries. Hercules RTB Winnipeg. No further assistance required. Case closed.

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-01604	69.65	-82.34	M2	Other	OVERDUE	24/08/2013 16:54	26/08/2013 4:45	Search

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
4	4	0	0	0	HERC 338 435	30 M	24/08/2013 19:25	24/08/2013 23:11	25/08/2013 1:39

Report from EMO of an overdue green freighter canoe off Igloolik with 4 pobs. Enhanced group call and Mayday relay broadcast issued. CCGS Pierre Radisson and 435 SQN Hercules R338, 424 SQN Hercules R343, 103 SQN Cormorant R915, Transport 922 tasked. 424sqn Herc found the people in good health. Supplies and radio dropped. Party reports motor broken down on an island all safe and sound. Local vessel went out towed the persons back to the community. CASE CLOSED

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-01572	44.91	-80.75	M2	Other	OVERDUE	22/08/2013 12:19	23/08/2013 6:52	Search

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
5	5	0	0	0	HERC 344 424	2 HRS	22/08/2013 14:30	22/08/2013 12:45	22/08/2013 13:41

Report of a 20 foot vessel that had departed a dock NE of Owen ound on a local trip. BX issued search commenced. 424 Hercules R344 R343, 424 Griffon R432, Cape Providence, CCGS Cove Isle, CG 1000 a VOO tasked. Hercules R343 located the vessel Cape Providence towed vessel to port. Case Closed

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-00706	56.36	-95.29	A1	Crash	OVERDUE (AIR)	02/07/2013 3:46	03/07/2013 3:07	Search

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
1	0	0	1	0	HERC 340 435	2 HRS	02/07/2013 4:08	02/07/2013 5:56	02/07/2013 7:30

Overdue helo Bell 206 on company flight note area of Gillam MB 1 POB 70 YOM. Unable to reach helo, was due back 1 Jul 2130Z. Forest fires in area with lots of smoke. 435 sqn Herc R340 tasked to investigate, company dispatched own helos at daybreak. Currently on scene but forest fires and smoke hampering visual search efforts. 424 Sqn Herc R344 tasked to be on scene to relieve R340. Casara C182 also tasked out of The Pas. Company helo discovered debris approximately 0.5NM East of destination. They confirmed colour of debris matched missing aircraft and able to identify personal belongings. R340 also confirmed seeing debris. R340 and R343 advised to RTB and Casara aircraft released prior to take off. TSB and CACO adviised. Case handed over to RCMP as missing persons at 1608Z. Case number 2013-803181. Case closed.

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-00281	57.87	-111.79	A1	Crash	ELT/EPIRB/PLB SARSAT	29/05/2013 17:00	31/05/2013 0:07	Rescue

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
3	1	2	0	0	HERC 341 435	2 HR	29/05/2013 17:13	29/05/2013 20:07	29/05/2013 21:00

Unlocated 406 ELT detection from CMCC. Company contacted and confirmed helo with 3 POB was flying north of Fort McMurray AB, unable to reach pilot or any occupants. Winnipeg Herc R341 and Cold Lake Griffon R417 tasked, Company also tasked their own helos to search the area. Company aircraft located crash site, one survived with injuries and two deceased. Survivor evacuated by company helo to Fort Mac, bodies evacuated by R417. Coroner, TSB and CACO advised. Herc RTB during transit. No further assistance required case closed.

Incident Number	Latitude	Longitude	Cat	Situation	Type	Time	Closed Time	Action Taken
T2013-01942	58.30	-88.75	A1	Airborne Emergency	ELT/EPIRB/PLB SARSAT	25/09/2013 17:56	27/09/2013 23:59	Search

Persons					CAF Response				
Affected	Saved	Lost	Missing	Assisted	Resource	RP	Tasked	Departed	On Scene
1	0	0	1	0	HERC 341 435	2 HR	25/09/2013 19:03	25/09/2013 18:21	25/09/2013 20:57
					HERC 307 424	30 M	25/09/2013 18:19	25/09/2013 18:21	25/09/2013 20:57

SARSAT detected 406 ELT registered to aircraft CFEXV. Aircraft had departed out of Sault Ste Marie and was flying north. 435 and 424 Herc tasked. Three transiting vessels and a Transport Canada pollution plane were also tasked. Floating debris and a small oil slick were located. Debris identified as part of the airframe of the missing aircraft. Investigation subsequently revealed pilot had sent suicidal messages to family while airborne and activated his 406. Company confirmed there were no life rafts onboard. Survival model showed the survival time to be long expired. NOK briefed. Case officially reduced by SRR Commander as of 1800(Z). R307 located a larger debris field. R307 recovered at home base in Trenton. TC Transport 950 and tug Nelson River resumed normal operations. RCMP Arviat has taken over the case as a Missing Person. Case closed.

This page intentionally left blank.

List of symbols/abbreviations/acronyms/initialisms

1 CAD	1 Canadian Air Division
A	Aeronautical
AOR	Area of Responsibility
CAF	Canadian Armed Forces
Cat	Category
CCG	Canadian Coast Guard
CFB	Canadian Forces Base
CJOC	Canadian Joint Operations Command
COIC	Commandement des opérations interarmées du Canada
Comd	Commander
CORA	Centre for Operational Research & Analysis
1 DAC	1re Division aérienne du Canada
DND	Department of National Defence
DRDC	Defence Research and Development Canada
FAC	Forces armées canadiennes
Fri	Friday
GSAR	Ground Search and Rescue
H	Humanitarian
hrs	hours
JRCC	Joint Rescue Coordination Centre
M	Maritime
Max	Maximum
MILP	Mixed Integer Linear Program
Mon	Monday
Min	Minimum
NSP	National Search and Rescue Program
RP	Response Posture
RRS	Région de recherche et sauvetage
SAR	Search and Rescue
SARLEP	SAR Location Evaluation Program
Sat	Saturday
SISAR	System of Information for Search and Rescue
SMMS	SAR Mission Management System
SRR	Search and Rescue Region
Sun	Sunday
Thurs	Thursday
Tues	Tuesday
Wed	Wednesday
wknd	Weekend

This page intentionally left blank.

DOCUMENT CONTROL DATA

(Security markings for the title, abstract and indexing annotation must be entered when the document is Classified or Designated.)

1. ORIGINATOR (The name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's report, or tasking agency, are entered in section 8.)

DRDC – Centre for Operational Research and Analysis
Dept. of National Defence, MGen G. R. Pearkes Bldg., 101 Colonel By Drive, 6CBS, Ottawa ON K1A 0K2, Canada

2a. SECURITY MARKING (Overall security marking of the document, including supplemental markings if applicable.)

UNCLASSIFIED

2b. CONTROLLED GOODS

(NON-CONTROLLED GOODS)
DMC A
REVIEW: GCEC APRIL 2011

3. TITLE (The complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title.)

Optimal alignment of search and rescue response posture with historical incident occurrence

4. AUTHORS (Last name, followed by initials – ranks, titles, etc. not to be used.)

Kaluzny, B. L.

5. DATE OF PUBLICATION (Month and year of publication of document.)	6a. NO. OF PAGES (Total containing information. Include Annexes, Appendices, etc.)	6b. NO. OF REFS (Total cited in document.)
April 2014	74	39

7. DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Scientific Report

8. SPONSORING ACTIVITY (The name of the department project office or laboratory sponsoring the research and development – include address.)

DRDC – Centre for Operational Research and Analysis
Dept. of National Defence, MGen G. R. Pearkes Bldg., 101 Colonel By Drive, 6CBS, Ottawa ON K1A 0K2, Canada

9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.)	9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.)
FE1-06ac	

10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document.)	10b. OTHER DOCUMENT NO(s). (Any other numbers which may be assigned this document either by the originator or by the sponsor.)
DRDC-RDDC-2014-R12	

11. DOCUMENT AVAILABILITY (Any limitations on further dissemination of the document, other than those imposed by security classification.)

(X) Unlimited distribution
( ) Defence departments and defence contractors; further distribution only as approved
( ) Defence departments and Canadian defence contractors; further distribution only as approved
( ) Government departments and agencies; further distribution only as approved
( ) Defence departments; further distribution only as approved
( ) Other (please specify):

12. DOCUMENT ANNOUNCEMENT (Any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11). However, where further distribution (beyond the audience specified in (11)) is possible, a wider announcement audience may be selected.)

Unlimited

13. ABSTRACT (A brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual.)

The Canadian Armed Forces (CAF) maintain a response posture to Search and Rescue (SAR) operations 24 hours per day, seven days per week. Recently, SAR squadrons maintained a 30-minute response posture (RP30) for 40 hours (hrs) a week per resource (aircraft type): 0800-1600hrs, Monday to Friday, and a 2-hour response posture (RP2hrs) for remaining hours.

This report details the data, modelling and analysis for optimizing CAF SAR RP30 hours. Based on recent data, the report presents optimal RP30 schedules that maximize the alignment of CAF SAR response posture with the occurrence of distress or potential distress incidents.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Search and Rescue; Optimization; Response Posture; Integer Linear Program

DRDC | RDDC

SCIENCE, TECHNOLOGY AND KNOWLEDGE FOR CANADA'S DEFENCE AND SECURITY | SCIENCE, TECHNOLOGIE ET SAVOIR POUR LA DÉFENSE ET LA SÉCURITÉ DU CANADA

www.drdc-rddc.gc.ca