
# ADVANCED DRAFT Whitepaper: Dangerous animal defence

Greenfields Exploration Ltd

January 2020

# EXECUTIVE SUMMARY

This whitepaper sets out the research into the firearm requirements for Greenfields Exploration Ltd's Frontier project in eastern Greenland. It is a Government-imposed condition of entry that people working in the project area carry firearms. This whitepaper presents the findings of research into firearm needs for the Frontier. Greenfields recognises that firearms present risks in addition to those they are intended to counter. The intent of this whitepaper is not to promote or glorify the use of firearms. Instead, the basis of this whitepaper is in safety and is designed to identify what is better than a regulatory minimum and make recommendations accordingly.

The Frontier licences cover a very large area within which there is alpine terrane and an Arctic Desert climate. The licence area falls within polar bear and musk-ox habitat, and the Northeast Greenland National Park. Exploration activity in 2019 is expected to primarily involve foot traverses during the summer months (most likely August), and there is a risk of field personnel having an encounter with polar bears, muskox, and wolves. Furthermore, it is a Government condition of entry to the park that personnel carry firearms chambered for a cartridge of at least a 30-06 Springfield calibre. This whitepaper identifies that the best protection against polar bears in the field is to travel in teams of at least three personnel, as nearly all documented polar bear attacks involve ≤ 2 people. Withstanding this deterrence measure, it is identified that the cartridge chambered by a firearm is more important than the firearm itself as it is the only component that is designed to have direct interaction with the animal from which protection is needed. It is shown that while 30-06 is the regulatory minimum calibre, it is at the low-end of what is generally considered suitable. Furthermore, it is determined that much of the literature concerns hunting, which is an activity that involves significantly different operational requirements to the short-range emergency scenarios that are plausible for the Frontier. It is argued that the emergency use of a firearm is likely to involve human-threatening animals inside of 50m, and less than 6 seconds to prevent a catastrophic interaction. Consequently, the calibre of a firearm and the construction of the bullet must be sufficient enough to work with a single shot. The associated firearm should be fast to deploy and operate at short notice.

While many firearms and cartridges can be reviewed, this whitepaper only considers those that are logistically simple and low risk in context of the Frontier. It is recommended that a firearm be chambered in either a 9.3x62 or 375 H&H cartridge, have stainless-steel components, preferably with an express iron-sight, and have either a synthetic (for 9.3x62) or a wooden laminate stock (for 375 H&H cartridges). The firearm must also be lightweight to minimise the risk promoting a fall risk. Five firearms are identified with no recommended preference among them.

FRONTIER PROJECT

## Commissioning & Reporting Entity

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## Consent & Warranty:

Greenfields prepared this whitepaper and gave its consent to use this document for release into the public domain. Greenfields warrants that it disclosed all relevant material, and to the best of its knowledge the information provided is accurate and true. Greenfields has not provided any information that has is confidential and not to be disclosed. Greenfields made reasonable efforts to verify the accuracy and relevance of the available data within what may be reasonably expected of a whitepaper. Greenfields endeavoured to ensure that opinions provided in this Report have reasonable grounds and to ensure that the Report is not misleading or deceptive.



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[1] http://asic.gov.au/regulatory-resources/find-a-document/regulatory-guides/rg-146-licensing-training-of-financial-product-advisers/
[2] https://www.aig.org.au/
[3] http://aicd.companydirectors.com.au/

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# 1 INTRODUCTION

## 1.1 Purpose

As Greenfield Exploration Limited's ('Greenfields') Frontier project is located in the Northeast Greenland National Park, it is a requirement of the Government of Greenland to carry fire-arms of a minimum calibre of 30-06 Springfield (1; 2; 3) ('30-06') as well as deterrents[4] (4) for protection from polar bear (sp. *Ursus maritimus* (5)) ('bear'). It may also be necessary for personnel to protect themselves from muskox (sp. *Ovibos moschatus* (6)), and plausibly[5] from arctic wolves (ssp. *Canis lupus orion/ Canis lupus arctos* (7; 8)). The purpose of this whitepaper is to examine firearms that may potentially be selected for use in the Frontier, with an emphasis on what is most suitable for the task at hand, rather than meeting the minimum regulatory requirements. This whitepaper represents the first step in managing that risk by providing a reference point for policy and procedure documents for the 2019 exploration program.

## 1.2 Scope

This whitepaper examines the appropriateness potential firearms to be carried by people working in the Frontier project, Greenland. The scope of this whitepaper is restricted to the cartridges and firearms and does not focus on requirements, accessories, maintenance, or training. Due to many potentially suitable cartridges and firearms, the scope is restricted to the cartridges that are readily available in Akureyri, the nearest commercial hub to the Frontier, and firearms that are readily available in Greenland, Iceland and Australia.

## 1.3 Reliance on Other Experts

Greenfields has not relied on third parties in preparing this whitepaper. However, this document draws on interviews, third-party reports, and data, much of which is available in the public domain. Where possible, peer-reviewed documents are the primary sources of information.

## 1.4 Information Sources

In preparing this whitepaper (or 'Report'), Greenfields undertook a review of information available in the public domain, as well as proprietary information. Greenfields confirms that:

- full, accurate, and true disclosure of all material information in its possession has been made available;
- the integrity and accuracy of the conclusion and recommendation is not compromised by the available information or lack thereof; and
- the Report does not contain commercially sensitive or confidential information.

A list of citations is presented at the end of this whitepaper.

[4] Deterrents including the grouping of personnel, shouting or making loud noice, pencil flare launchers or bangers, pistol flare launchers, screamers, sparklers or blanks, bear/pepper spray, and firearms not directed at the mass of the animal (4).
[5] Plausible but improbable as wolves are extremely rare in eastern Greenland



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## 1.5 Site Visit

Greenfields and its joint-venture ('JV') partner carried out an exploration program at the Frontier between 13 and 30 August 2018, and 1 August and 31 August 2019. The year 2018 personnel involved in this site visit involved five JV employees, and in 2019 there were a total of 18 people on a steady-state basis. Dr Jonathan Bell was present for the full duration of both campaigns. Polar Logistics Group AS also had between two and four person's on-site during 2018, and Tangent Expeditions had five personnel on site in 2019. In 2018 BlueWest Helicopters Greenland Aps typically had one pilot on site during the field program, and in 2019 two pilots for the entire duration..

## 1.6 Report costs and Relationships

The cost of this whitepaper is not contingent on its conclusions or success of Frontier as it was internally generated and paid for by Greenfields and was not subject to a third-party commercial contract. The principal author of this Report, Dr Jonathan Bell, is the managing director of Greenfields and at the time of writing, the majority shareholder.

## 1.7 Effective Date

The Effective Date of this whitepaper is 6 January 2019. The outcomes of this whitepaper reflect the prevailing conditions and circumstances that are relevant as at the Effective Date. Greenfields cautions the reader that changes in market conditions and new technical information could result in a rapid change in the merit of the findings and recommendation. Greenfields advises the reader to make an investigation as to whether there are any changes after the Effective Date that may materially affect the risk.

# 2 FRAMING

## 2.1 Activity

Greenfields is an exploration company that holds the licences to, and operates the 'Frontier' project, which located in Northeastern Greenland National Park. The current exploration work involves boots-on ground field work, usually by small teams. The field work typically occurs in July or August and may have a four to six-week duration. Much of the exploration activity typically occurs in the inner-fjord systems however, work on the licences in the (coastal) outer-fjords is also likely. While the Greenland Government strongly recommends carrying firearms in all coastal areas in that country, it is a mandatory requirement in the Northeastern National Park. Most of the proposed fieldwork for 2019 locates within the park (1; 2; 3).

## 2.2 Project

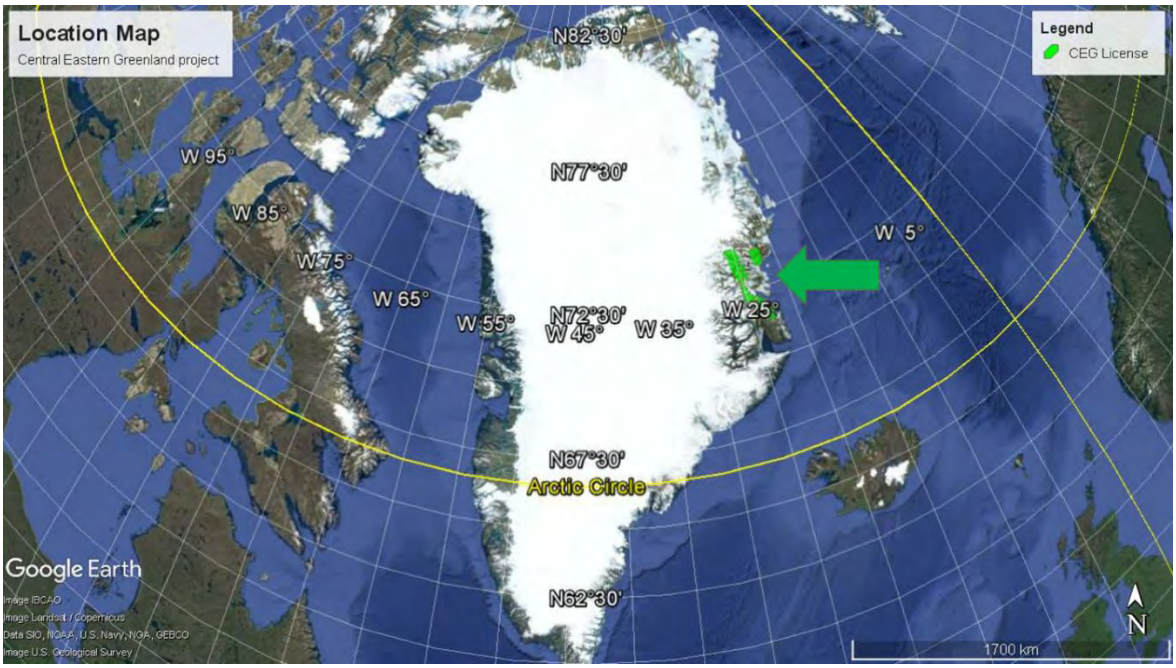
Frontier sits just inside the high-Arctic in the Sermersooq municipality of eastern Greenland and spans approximately 300 km between 71.25°N and 74.25°N, and 130 km between 26°W and 21°W (Figure 1) (9; 10; 11; 12; 13; 14). Frontier covers 14,988km$^2$ but due to the excise of fjords, is officially recorded as 12,975 km$^2$ (Figure 1) (9; 10; 11; 12; 13; 14). Greenfields calculates that this area is approximately equivalent to the size of 5% of Norway or New Zealand, 10% of England, 90% of Northern Ireland; or about five times the size of Hong Kong and eighteen times larger than Singapore. The majority of Frontier is within the boundaries of the North East Greenland National Park, which covers about 972,000 km$^2$ (15) (~45% of Greenland) and has an Arctic Desert climate and ice-cap (15). The physiography of Frontier is dominated by two major northwest-southeast systems, the King Oscar and Kaiser Franz Joseph fjords (16). The coastal areas are of moderate

relief, ranging from sea level to around 500 m above sea level ('ASL'); and the inland area is of high relief (the Stauning Alps), with elevations ranging up to 2,000 m ASL (16). The highest peaks in the Frontier region are Berzelius Bjerg with a topographic prominence of 1,535 m, Svedenborg Bjerg at 1,730 m, and Blaskbjerg at 1,575 m (17).

The nearest township to Frontier is Ittoqqortoormiit[6] which is about 100 km south-southeast of the project's boundary. Ittoqqortoormiit has a population of approximately 450 (18) but no significant infrastructure or services. There are no civilian settlements to the north of Ittoqqortoormiit, and the next nearest township in Greenland is Tasiilaq some 850 km to the south. Iceland's capital city, Reykjavik, at 710 km is closer to Ittoqqortoomiit than Tasiilaq (19). The local township is commonly described as one of the most isolated settlements on Earth (20), and has an economy dominated by subsistence hunting (15). Military dogs-sled ('Sirius') patrol (21; 22), research stations (23), and weather stations (24) (~20 to 30 people) (15) exist to the north of Frontier.

Public air access to Frontier is possible via Nerlerit Inaat Airport (25) which was previously known as Constable Point. With permission from the Danish authorities, it is possible to fly to the Mestersvig airstrip[7] (26) located with the southern portion of the licence area. The 1.8 km long Mestersvig runway (27) can accommodate heavy lift aeroplanes like the Lockheed C-130 Hercules (16), which require a length of at least 1.5 km (28). Several airstrips in the Frontier region can support the nimble and common de Havilland Canada DHC-6 Twin Otter aeroplanes (29).

**Figure 1: Frontier's location**



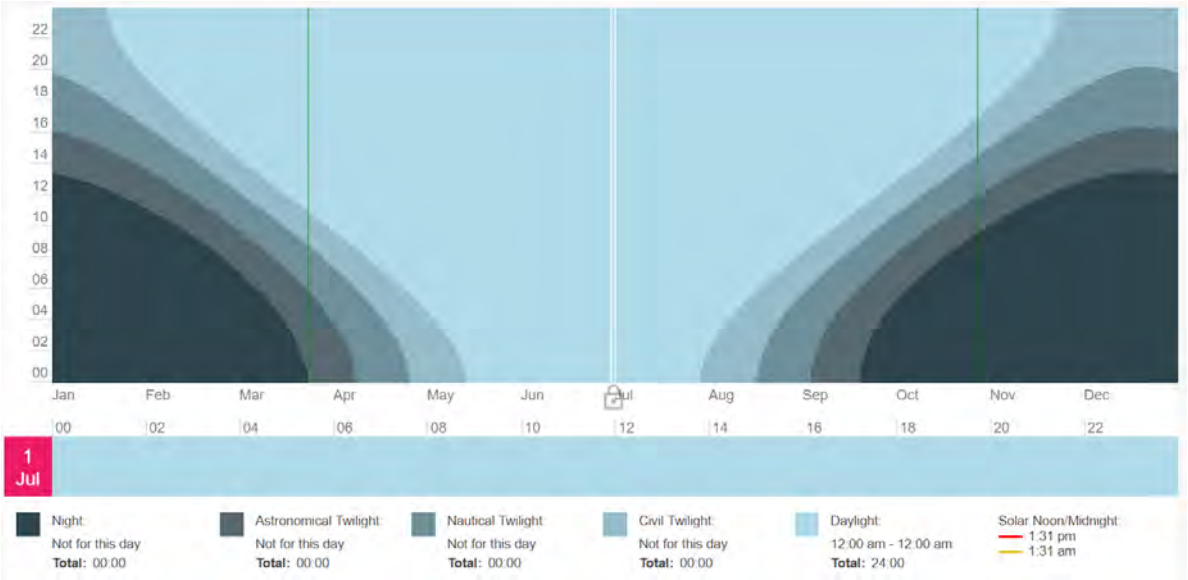

*Source: Generated by GREENFIELDS in Google Earth using shapefiles supplied by the Government of Greenland*

Frontier lies just inside the demarcation of the high-arctic (30), and the Atlantic Ocean moderates its climate (31). At such latitudes, daylight is a significant environmental factor. At Ittoqqortoormiit, there is 24-hour light from around mid-May through to the end of July (32)(Figure 2). The driest month is June, with about an average of 12.4 mm of precipitation (33), July is the warmest with

[6] Located at 70°31 N, 22°00' W
[7] Located at 2°14'7.78"N and 23°55'6.95"W

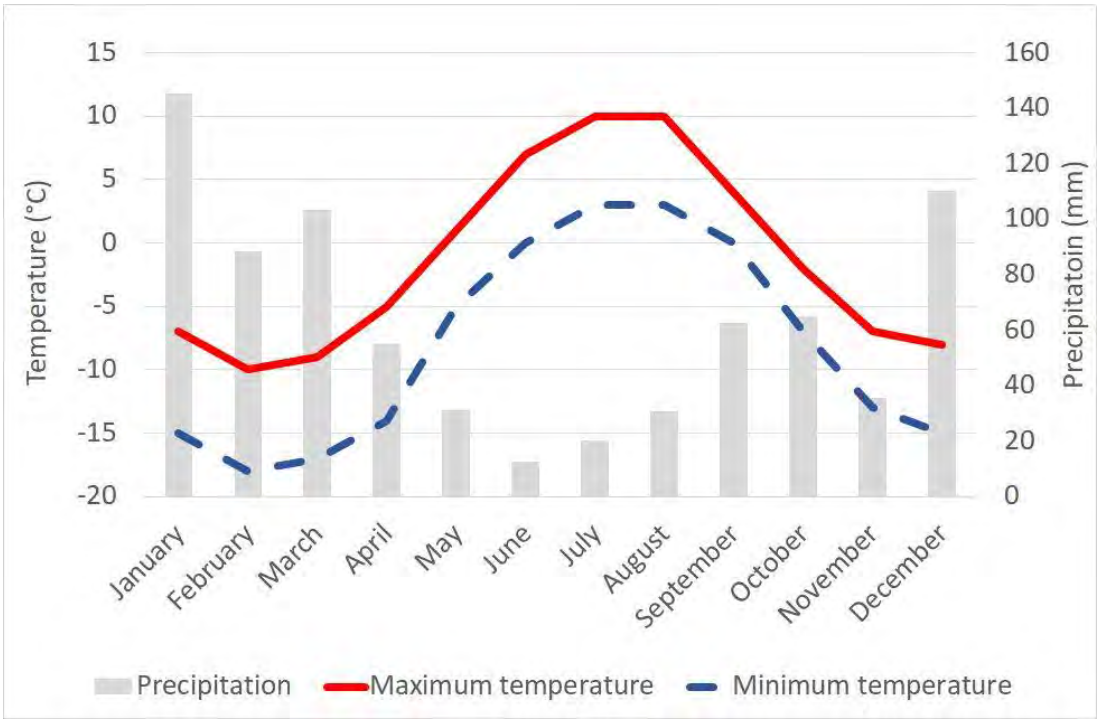
average temperatures ranging from 3° to 7°C (33)(Figure 3). For context, the July average for Perth Australia is 93.1 mm of rain and a temperature range of 8 to 18°C.

**Figure 2: Annual daylight at Ittoqqortoormiit**




*Source: Timeanddate.com* (32)

**Figure 3: Annual temperatures and precipitation at Ittoqqortoormiit**




*Source: Timeanddate.com* (33)

For a more thorough overview of Frontier and its technical qualities, refer to the Technical Assessment Report dated 29 April 2018.

# 3 RISK

## 3.1 Sources

This whitepaper concerns the risk posed by potentially dangerous animals within the Frontier project. Polar bears, muskox and potentially arctic wolves[8] are found throughout the Frontier licence area (34; 35; 36; 37; 6), and Greenfields considers them to be the main sources of animal encounter risk. Some of the salient facts on these 'dangerous animals' are presented below:

- Polar bears are hypercarnivores[9], with the males ('boars') weighing up to 700kg, and females ('sows') may weigh half as much (38). For comparison, an African male lion (sp. *Panthera leo*) weights up to 250kg (39), or a little over a third of the weight of an equivalent bear. Polar bears may view humans as prey (40), and both muskox (41) and bear may act aggressively for other reasons which may harm humans. Bears can run over short distances at speeds of 29 km (42), and they can swim at 10 km/h (43). Polar bears are typically solitary animals (38), and the population in East Greenland is unknown, although the residents of Ittoqqortoormiit believe they are increasing (44). Over the last few decades, the bear-human conflicts in the Ittoqqortoormiit have been rising (44).

- Muskox are herbivores belonging to the same family as sheep and goats (45). Male muskox ('bulls') may weigh up to 360 kg, and females ('cows') up to 230 kg (46). During summer, muskox typically occur in hers of 8 to 20 animals (45). In 1977 it was estimated that in the Frontier region there were ~400 muskox below the 200-m ASL[10] elevation contour, or about 0.6 animals per square kilometre (47).

- Arctic wolves are hypercarnivores (7; 8) that are about 1.5 m in length and weigh 25-30kg[11] (8). The arctic wolf has a running speed of 50 to 60 km/h. Up until 1939, Arctic wolves are recorded to have a mean pack size of mean 3.3 animals (48), although it was estimated that in 2011 there were 23 East Greenlandic wolves contained within three packs (7).

During the proposed 2019 field program and based on their usual seasonal ranges (49; 35), bears are more likely to be encountered in the eastern portions of the Frontier. However, bears are curious and may investigate strange objects, noise or smell[12] (50). Consequently, bears may also be attracted to the camps. During the August 2018 field program, a bear was sighted by the Danish military within a couple of kilometres of the basecamp at Nyhavn, which is further inland than the seasonal distribution shown in Figure 4. All the Frontier project falls within the known muskox habitat defined by Aastrup (2003) and Andersen-Ranberg et al. (2018) (51; 52), which matches Greenfields' observations during the 2018 field program. The most likely place for an encounter with a wolf is in the Gauss Halvø licence (37), however this has a low probability given the rarity of the animal.

[8] Wolves in eastern Greenland are very rare and while an encounter is plausible, Greenfields considers that there is a low probability of a dangerous interaction between human and wolf(ves)
[9] Hypercarnivores have a diet that is more than 70% meat, with the balance consisting of non-animal foods such as fungi, fruits or other plant material (150)
[10] Above Sea Level
[11] Weight is recorded as 26 kg, but these may have been undernourished due to being examined in mid-winter. Consequently, Greenfields has assigned a weight range to reflect the uncertainty
[12] Bears have an acute sense of smell and can detect seal breathing holes in ice up to 3km away (9)



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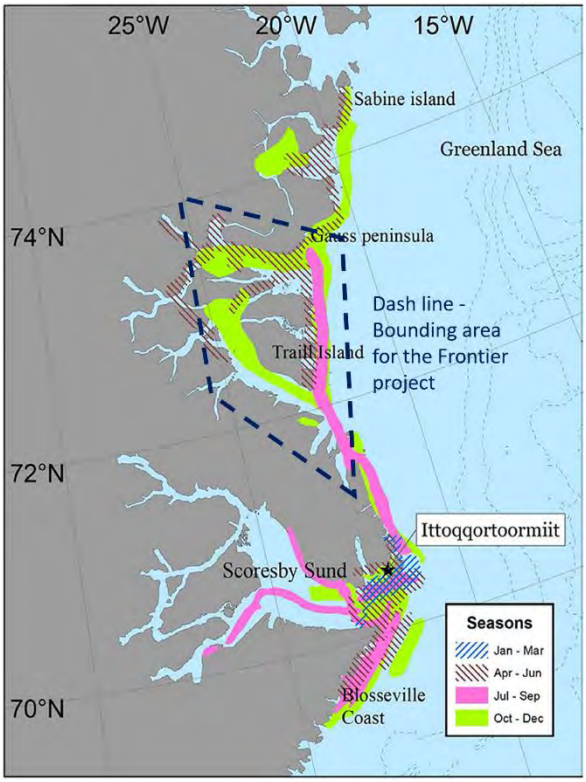
**Figure 4: Typical polar bear distribution during each of the seasons**




*Modified by Greenfields, after Laidre eta al. (2018)* (49)

Human interactions with polar bears are common in Greenland, however, very rarely do they result in human injury or death (1). "*Bears are not creatures to be feared but rather respected and understood*" (53). Wilder et al. (2017) (54) show that between the years 1870 to 2014, there were only 73 documented attacks by wild bears in all of Greenland, Canada, Norway, Russia and Alaska. Of the 73 bear attacks documented by Wilder et al. (2017), only 20 resulted in human fatalities, while another 63 humans were injured[13]. In almost all the recorded attacks there were only one or two humans involved (54), which strongly implies that **field teams should comprise at least three personnel**. However, the past is not necessarily a good predictor of the future. Wilder et al. (2017) also state that many attacks involved nutritionally stressed male bears. As bear hunting grounds are under stress from global warming[14], bears are increasingly found far from their usual habitats (55; 56), and as such may be increasingly found inland to what is shown in Figure 4. Wilder et al. (2017) caution that there is an increased risk of catastrophic outcomes from future human-bear interactions. For such reasons, Greenfields considers it prudent to establish operating guidelines that exceed the regulated minimum standards.

Greenfields did not identify statistics on the threat presented by muskox but given there are over 20,000 muskox in the Northeastern Greenland National Park (6), and Greenfields' experience in 2018, encounters with muskox are probable, but most often not dangerous. Sirius have encountered wolves (37), but Greenfields has not identified any modern records of dangerous encounters.

[13] Discrepancies are due to interactions with more than one human during some of the documented attacks
[14] Polar bears have become the emblem of the negative impacts associated with global warming (103)

## 3.2 Scenarios

The field program for 2019 is proposed to primarily involve extensive walking in the field, based out a camp located on Ymer Ø[15]. Due to the number of personnel in the field, the type of work performed and location, it is plausible that personnel may find themselves in dangerous animal situations both in the field and in camp. To determine the risk scenarios, Greenfields reviewed the literature on dangerous encounters with bears (brown and black bear species) as well as what is identified on polar bears. Greenfields considers polar bears to represent the largest and most probable dangerous animal risk in the Frontier, and as such bear encounter scenarios are used to establish the minimum firearm requirements.

Potential scenarios that may necessitate the use of a firearm include[16]:

- A group of Frontier personnel encounter dangerous animals[17] during fieldwork. The animal(s) act aggressively and there is no place to retreat to safely.
- An individual is isolated from the rest of a group of Frontier personnel in the field, and they encounter a dangerous animal acting aggressively – with no place to retreat.
- Personnel encounter bears within the camp, with detection at distances substantially less than 50 m and they are unable to retreat to a safe building/structure.
- Personnel encounter bears within the camp but can retreat to the safety of a building. However, the bear continues to act aggressive and attempt entry into buildings containing personnel.

In each of the scenarios above, it is possible that there is a need for personal protection ('self-defence') from a dangerous animal encounter, or to protect another person from danger ('group-defence'). The discharge of a firearm may be used to scare away (57), or dissuade an animal acting aggressively (57). To prevent a potentially catastrophic encounter, it may be necessary to cull an animal. Based on the experience of ex-Sirius, there are five levels of bear encounter[18] (58):

- **Danger Level 1 -** Bears observing from a distance without humans being aware of its presence. In these situations, the polar bears will most likely avoid contact and move on.
- **Danger Level 2 -** A curious bear may come within 200 to 500m, from which it observes the humans until its curiosity is satisfied. Through the uses of deterrent measures (e.g. of 'scare devices'), the bear will run away and most likely not return.
- **Danger Level 3 -** A bear ventures within 200 m but is motivated by curiosity. Scare devices are usually effective. However, at this level, it is not safe to assume that the bear will stay away. It is important to emphasise that ongoing curiosity does not constitute a direct threat to humans.
- **Danger Level 4 -** A bear is within 25 to 50m of a human and may displaying very different body language. At this level, it is uncertain whether scare devices have any effect. Personnel should be prepared to engage the bear.

[15] The basecamp location on Ymer Ø is approximately 73° 4' 33"N, 24°35' 42"W
[16] The bulleted scenarios are examples only and must not be interpreted to be exhaustive.
[17] Although typically solitary in habit, more than more bear may be encountered, such as when a sow has cubs
[18] While the levels above are intended for bears, the overall principles are applicable to other potentially dangerous animals in the Frontier.



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- **Danger Level 5 -** A bear is directly threatening personnel. The bear may be fast walking (looks determined) or running directly at people with the head down - a typical attack posture.

Wilder et al. (2017) (54) present the first and only empirical research into polar bear attacks on humans. The Wilder et al. (2017) paper draws on all the confirmed polar bear attacks between 1870 and 2014, in Greenland, Canada, Norway, Russia, and the United States. The total number of confirmed polar bear attacks across these 'range states' for the 144-year period is 73. The Wilder et al. (2017) work is important at identifies and corrects misconceptions and provides guidance on the type of bear encounters, and how to consider risk management. Some of the pertinent facts presented in Wilder et al. (2017) are:

- **88% of all attacks were on one[19] or two people, seldom more[20];**
- **84% of non-fatal attacks involved either the victim or bystander having a firearm in their possession;**
- **56% of all attacks involved a surprise where the victim had no time to respond with a deterrent;**
- **25% of all attacks where a firearm was present, inexperience or stress led to a mishandling of the firearm;**
- **59% of all attacks were partly due to the person's behaviour;**
- 88% of all attacks occurred between July and December;
- 53% of all attacks involved field camps or people travelling across the landscape;
- 27% of all attacks resulted in a human fatality;
- 57% of fatal attacks involved people with no firearms in their possession;
- 93% of fatal encounters involved adult male bears;
- 72% of bears displaying predatory behaviour during an attack were male;
- 61% of bears attacking humans had below-average body condition;
- 74% of human fatalities involved bears with below-average body condition (54).

The statistics above help inform and validate the types of encounter with a bear, and importantly, are useful in formulating means of addressing the dangerous animal risk. Aside from the dangerous animal, it is important to recognise that the mental alertness of the person is a significant variable in potential encounters. Proper mental preparedness is the best defence against violent attack (59). To this end, the United States Geological Survey ('USGS') (59) describes four levels of mental alertness in dangerous animal encounters:

1. **Condition White** – The person is unaware of danger and is mentally and tactically unprepared for self-defence. This may involve a scenario where there is no firearm or plan for passive defence, and personal injury or death is probable. In a Condition White

[19] 61% of attacks were on a solitary/isolated person
[20] Empirical research by Smith & Herrero (2018) (134), whose Alaskan research includes brown and black bear attacks, also show that group size is a major predictor of a bear attack. Smith & Herrero (2018) postulates that larger groups are less likely to surprise bears, and that they represent a greater counter-threat to a bear. Smith & Herrero (2018) state: "*Importantly, we have no records of ≥2persons grouping together and standing their ground when faced with an aggressive bear and being injured*".

scenario, it may take a person **4 seconds to recognise that a problem exists** (59). Greenfields notes that a charging bear may cover 50m (Danger Level 5) in six seconds.

2. **Condition Yellow** – The person is in a relaxed mental state and alert to the potential for danger. A firearm is accessible to either the person or another person in the immediate vicinity/group. Mentally the person has determined a course of action should a dangerous animal appear. By maintaining a Condition Yellow level of alertness, response times can be almost instantaneous (59).

3. **Condition Orange** – A person is alert to a specific threat posed by a dangerous animal. In this level of alertness, the person is actively considering the problem and safety of colleagues. For example, a bear appears within 100m of a person and the person is prepared to shoot if the situation escalates to a Danger Level 5 (directly aggressive). However, no decision to shoot has yet been made. The person bearing a firearm should be conducting a situational awareness scan by accounting for all people in the vicinity, and whether they are in the line of (potential) fire. A firearm is accessible, possibly slung on a shoulder, and ready for use within three seconds (59).

4. **Condition Red** – A dangerous animal is exhibiting hostile behaviour towards a person (e.g. Danger Level 5). In this alertness level, a decision has been made to shoot if necessary. A cartridge has been chambered into the firearm, the safety is in the 'off position' and the firearm is carried in a ready to fire position (e.g. shouldered). A person with Condition Red level of alertness is prepared to shoot a firearm within 1.5 seconds (59).

Understanding the colour code of alertness helps to promote rational thinking and effective reaction (as opposed to a panicked, hysterical reaction) (59).

## 3.3 Management

Firearms a compulsory aspect of dangerous animal risk management in the Frontier. However, the best way to manage risk is to reduce risk exposure wherever possible. Clarkson & Stirling (1994) (60) list methods for managing polar bear risk before the necessity for last-resort lethal measures (Table 1, modified by Greenfields). Furthermore, empirical research by Smith et al. (2008) shows that bear-spray is an effective non-lethal deterrent that stops undesirable bear behaviour in the order of 90% of the time (61). Unfortunately bear-spray is not legal in Greenland (54), and Smith et al. (2008) point out that firearms are a necessary presence[21] in all bear-human interactions.

**Table 1: Polar bear preventative risk measures**

| Category | Measure |
|---|---|
| **Exclusion** | Heavy woven-wire fences at least 2m high. |
| | Purpose designed electric fences. |
| | High metal walls. |
| | Sturdy buildings and iron cages. |
| **Cultural** | Remove snow around buildings and work areas to increase visibility. |
| | Install good lighting in areas where it is essential to detect bears that may be in the vicinity. |
| | Store garbage, human waste, food, and other products in areas not accessible to bears and away from places of inhabitation. |
| | Loud noises, vehicle engines, cracker shells, rifle shots, barking dogs, and air horns. |
| | Trained bear dogs. |

[21] Presence does not signify use of lethal force.



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| | |
|---|---|
| **Deterrents & frightening devices** | Employ trained bear monitors with firearms and deterrents to protect communities, industry camps, and workplaces. |
| | Non-lethal firearm deterrents such as 12-gauge plastic slugs and 1 1/2- inch (38-mm) rubber bullets. |
| | Vehicles, heavy construction equipment, snowmobiles, and helicopters can be used to chase polar bears away from work and living areas. |
| **Detection Systems** | Dogs, bear monitors, trip-wire fences, and electronic (infra-red, microwave, modulated light beam) alarm systems. |
| | Constant vigilance of personnel working at the site. |
| | Dedicated guards, particularly at night in soft-shell camps. |
| **Repellents** | Capsaicin spray. |
| **Trapping** | Live traps (culvert and barrel traps) and snares (Aldrich foot snares). |
| **Other** | Drugging and immobilization with Telazol (safest and most reliable drug) administered by a dart gun or jab stick. Other drugs can be used with suitable care. |

*Source: Clarkson & Stirling (1994) (60), modified by Greenfields.*

Based on the statistics presented Wilder et al. (2017) (54), Greenfields considers that additional preventative steps include **field teams of more than three people**, and education on bear behaviour. These additional steps may help constrain some of the encounters to Danger Levels 1-3. In the 44% (54) of instances where a human had time to respond to a bear, scare devices may be used. However, in the remaining 56% (54) of bear encounters where there is not time to use a deterrent, it may be necessary to use a firearm or and bear/pepper spray[22]. In 25% (54) of attacks, the user mishandled the firearm because of inexperience or stress (54). In all those instances the mishandling contributed to further human injury or death (54). **Consequently, fire-arm training and familiarisation are important to a dangerous animal risk management plan** for the Frontier. It is also important to ensure that the firearms and cartridges used in the Frontier are appropriate, as Wilder et al. (2017) (54) identify that inadequate firearms were used in some bear attacks.

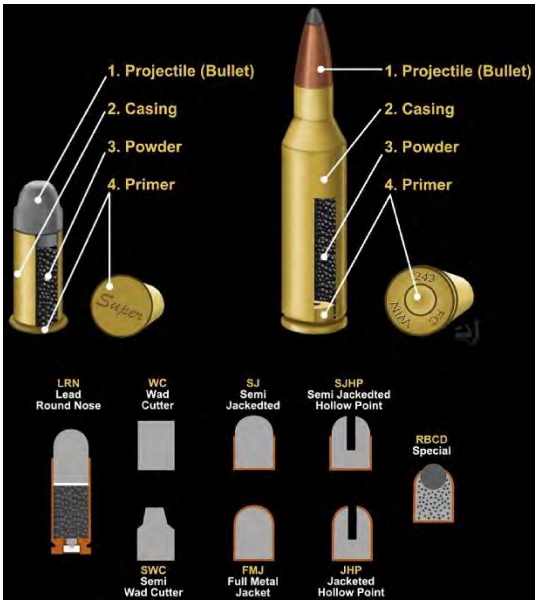
# 4 FIREARMS OVERVIEW

## 4.1 Cartridges and bullets

The purpose of a firearm such as a rifle is to fire a projectile ('bullet', (62)). A bullet is contained within a cartridge that comprises a case containing a propellant powder, and a primer (62)(Figure 5). Cartridges are classified according to the location of the primer (63). For this whitepaper, only centrefire cartridges are considered as rimfire cartridges can only accommodate comparatively low explosive pressure (63), and less suited to dangerous animal defence. The nominal diameter of the bullet is called its calibre (63; 64; 62). Bullet calibres are often grouped into small (<0.33inch/8.38mm), medium (0.33-0.39inch/8.38-9.9m (65)), and large bore (>0.39inch/9.9mm) brackets. Cartridges may also be referred to as 'magnum', which indicates that the case is larger than normal relative to the bullet, thereby giving a higher proportion of propellant to the same size bullet (66; 67).

[22] There are few statistics on the effectiveness of bear-spray, but of 16 known cases, thirteen were successful in deterring a polar bear attack (about 80% effective, (58)).

**Figure 5: Components of a firearm cartridge**




*Source: Hanna et al. 2015* (68)

A bullet is intended to do damage to a target via a permanent cavity/wound channel (69). The permanent cavity is the hole that that is created as the bullet passes through the tissue and is the same diameter as the bullet, or bullet fragments (69). A temporary cavity is also created when a bullet passes through soft tissue and creates a bow-wave-like effect, where the cavity is wider than the bullet's diameter (69; 68). However, the temporary-cavity is a somewhat intellectual point (70) as the primary purpose of a bullet is to kill via the permanent cavity causing blood loss, damage to the nervous system, destruction of vital organs[23] and tissue, septicaemia, asphyxiation[24] (70). The type of wounds inflicted are grouped into penetrative – where the bullet strikes soft tissue and remains in the body; perforating where the bullet enters and exits the body without causing substantial tissue damage; and avulsive injuries – where the bullet passes through the body but inflicting substantial tissue damage (68). While the primary consideration of this whitepaper is for the preservation of human life, Greenfields stresses that any defensive action must be as humane as possible.

The velocity of a bullet affects how much energy imparts on the target, and the potential for the bullet to penetrate deeply and the temporary cavity that it may create. However, it is not a linear relationship where higher velocity equates to better penetration (69). As bullet velocity increases, the drag increases and the tissue being encounter becomes 'harder', which can lead to premature bullet destruction (69).

The design and construction of a bullet have a significant impact on tissue destruction (68). Spitzer (pointy) bullets are better at retaining velocity over long distances, but inside of 200m, round or flat-nosed bullets are not at a significant speed disadvantage (71). However, round and flat-nosed bullets[25] may be preferable at close range due to the way they impart energy and their

[23] The actual cause of death from the destruction of vital organs may be from blood loss (68).
[24] Septicaemia and asphyxiation are highly undesirable, which adds to the importance of bullet placement and appropriate cartridge selection. Lead-poisoning, known as plumbism, is also a potential cause of death of an animal that has been shot but not killed (67). Plumbism is inhumane and all reasonable efforts should be made to avoid this outcome in the event defensive action is necessary.
[25] Flat-nosed bullets full 'wad-cutter'(square shape), are prone to inducing jams in magazine fed rifles (53) as they bounce off the feed ramp at different angles, a characteristic that is more pronounced the larger the calibre (53).



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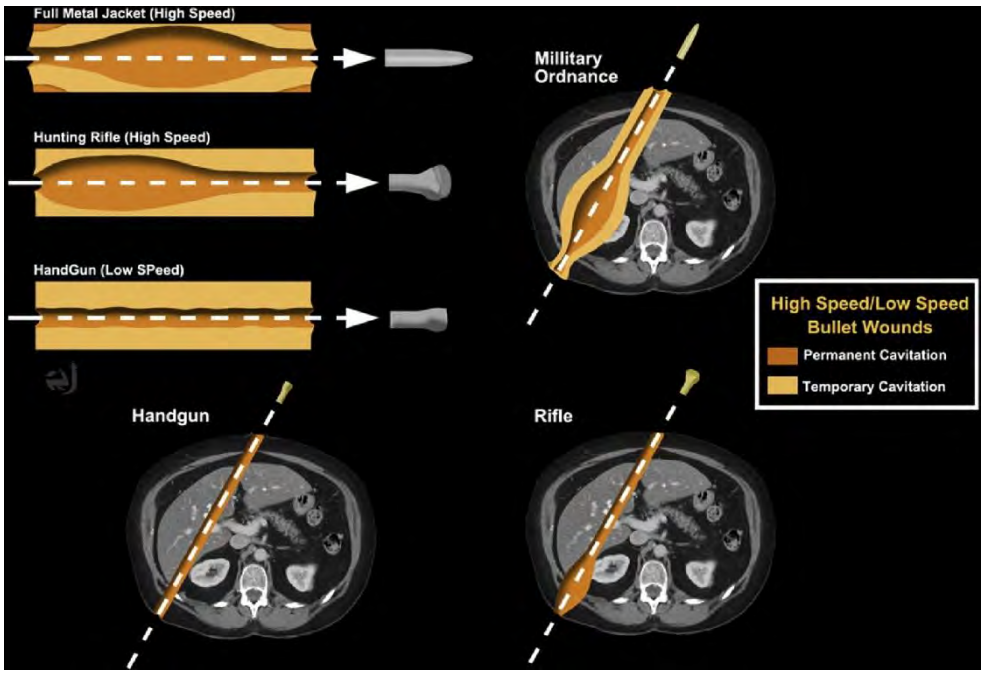
ability to penetrate well (71). The design of a bullet also affects how the bullet deforms and passes through the body, with some designs being more likely to rotate around their centre of mass ('precession') and may tumble allowing a greater surface area to act as a cutting edge, there by enlarging the permanent cavity (68).

There are three bullet types, frangible, expanding, and non-expanding bullets (72). Frangible bullets rapidly break up into small pieces, expanding bullets deform in a controlled manner, whereas non-expanding bullets are intended to retain their general shape (72). For dangerous animals, the most common bullets constructions are full metal jackets ('FMJ') – generally a non-expanding bullet type, hollow-points (controlled expansion), and ballistic-tips (controlled expansion). An FMJ consists of a soft core (typically lead (73)) that is fully encapsulated by a harder metal such as copper (74). FMJ bullets have relatively little deformation when they hit an obstacle/target. A hollow-point has the tip of the bullet removed and may be concave in shape (74). A hollow-point is intended to expand and deform when they hit an object (74), with the intent that it creates a greater wound channel and imparts energy more quickly than an FMJ. A hollow-point has more 'stopping power' than an FMJ bullet. However, the rapid expansion of the bullet means it has more drag and requires more energy to achieve a similar penetration depth as an FJM (69). A ballistic tip bullet is effectively a hollow-point with a plastic tip on the end to enhance its aerodynamic performance (74).

**Figure 6: Wound channels of different bullet types**




*Source: Hanna et al. 2015 (68).* *Note: 'Hunting'rifle refers to controlled expansion bullets.*

Sirius often use a combination of two armour-piercing FMJ with the third being civilian hollow-point (75). The combination of bullet types is in recognition that hollow-points are more suited to stopping a muskox charge, and the magazine is arranged so that every third round is a hollow-

point[26] (75). Greenfields notes that while undoubtedly effective in penetrating, armour-piercing bullets are not likely to be necessary or practical.

The weight of a bullet affects how much mass is behind the front-profile of a bullet, known as its 'sectional-density' ('SD'). A bullet with a higher SD[27] has more momentum and keeping other variable constant, leads to higher rates of target penetration (69). For larger or tougher animals (76), higher SD's are desirable whereas for smaller animals they may result in the bullet passing through the animal without imparting all or much of its energy. Table 2 provides indicative guidance[28] on SDs for a given animal weight (76).

**Table 2: Sectional density and game weight**

| Animal weight (kg) | Sectional Density | Animal weight (kg) | Sectional Density | Animal weight (kg) | Sectional Density |
|---|---|---|---|---|---|
| 2 | 0.11 | 50 | 0.19 | 113 | 0.22 |
| 5 | 0.11 | 54 | 0.19 | 125 | 0.23 |
| 9 | 0.12 | 59 | 0.19 | 136 | 0.23 |
| 14 | 0.13 | 64 | 0.19 | 181 | 0.24 |
| 18 | 0.14 | 68 | 0.20 | 227 | 0.25 |
| 23 | 0.15 | 73 | 0.20 | 272 | 0.26 |
| 27 | 0.16 | 77 | 0.20 | **318** | **0.27** |
| 32 | 0.16 | 82 | 0.21 | **363** | **0.28** |
| 36 | 0.17 | 86 | 0.21 | **408** | **0.28** |
| 41 | 0.18 | 91 | 0.21 | **454** | **0.29** |
| 45 | 0.18 | 102 | 0.22 | **567** | **0.29** |

*Source: Chuckhaws.com (76) Note: Greenfields has used bold font to denote the weight range of a boar and sow.*

## 4.2 Rifle action

A firearm is a device designed to be carried by hand and to fire shot, bullets or other projectiles using a burning propellant (62). Long-firearms, such are rifles, comprise three main components (62):

- Action/lock – the mechanism which fires a cartridge
- Stock – the part by which the firearm is held, the butt and the fore-end; and
- Barrel – a metal tube through which the bullets are fired (62).

There are seven basic functions of a firearm (62), although the action of these vary depending on the action (Table 3). The firearm actions in Table 3 indicate that the manual movement of a bolt-action rifle is more involved than either a lever-, or pump-action rifle. This translates into bolt-action rifles being the slowest of the rifle action types (77), yet the mechanical simplicity tends to make it the most reliable action. The strength of the simple bolt-action means that it can handle powerful cartridges that are not possible in other action types (78). A variation on the bolt-action is the straight-pull, which is a more complicated design that removes the rotation movement from a bolt-action and allows for a slightly faster cycling speed than a rotating bold (78). Lever-action rifles are faster than bolt-action rifles, however they are comparatively weak and cannot handle

[26] Greenfields did not identify in the literature whether the FMJ or hollow-points bullets are at the top of the magazine.
[27] SD is calculated by dividing a bullet's weight in imperial pounds, buy the square of the bullet's diameter in inches (149)
[28] Many factors effect suitability, and a lower SD cartridge may be suitable depending on the bullet construction. However, it is difficult to adequately and objectively account for all the variables and as such, SD is a relatively fast and easy measure to implement.



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high-pressure cartridges. Lever-action rifles may also have exposed hammers which can be hazardous to decock with wet hands, or when the shooter is under stress (59). Pump-action rifles offer the benefit of being simple, fast, reliable and able to handle high-pressure cartridges (77). However, Greenfields did not identify pump-action rifles with a calibre greater than 30-06 (79) (80), and by contrast, bolt-action rifles are widely available with a great diversity cartridge chambers.

**Table 3: Rifle function and action**

<table>
<tr><th colspan="2" rowspan="2">FUNCTION</th><th colspan="4">ACTION</th></tr>
<tr><th>Bolt-action</th><th>Lever-action</th><th>Pump-action</th><th>Straight-pull</th></tr>
<tr><td>Feed</td><td>Insert a live cartridge into the chamber.</td><td>Bolt handle forward</td><td rowspan="2">Lever moved upward</td><td rowspan="2">Slide action bar forward</td><td rowspan="2">Slide bolt forward</td></tr>
<tr><td>Lock</td><td>Secure the bolt to the rear end of the chamber (‘breech’ (62)) face in readiness for the trigger being pulled</td><td>Bolt handle lowered</td></tr>
<tr><td>Fire</td><td>Discharge/fire the cartridge which propels the bullet</td><td colspan="4">Pull trigger</td></tr>
<tr><td>Unlock</td><td>Release the bolt from the breech face.</td><td>Bolt handle lifted</td><td rowspan="4">Lever moved downward</td><td rowspan="4">Slide action bar rearward</td><td rowspan="4">Slide bolt rearward</td></tr>
<tr><td>Extract</td><td>Remove the spent cartridge.</td><td rowspan="3">Bolt handle moved rearward</td></tr>
<tr><td>Eject</td><td>Throw the spent cartridge from the firearm.</td></tr>
<tr><td>Cocks</td><td>Compress the firing pin spring and engaging it to the trigger mechanism</td></tr>
</table>

*Source: Attorney General's Department (2002) (62), modified by Greenfields.*

The different cartridges also affect the speed at which a bolt-action rifle can be cycled (81). The 30-06[29] marks the lower end of what is known as the ‘standard action’ bolt throw and the 375 H&H cartridge marks the start of the magnum-length bolt throw (81). The longer the length of these bolts, the slower they are to cycle. The smoothness of a bolt’s operation also affects speed (81). Finally, there are bolt-cycling speed differences between brands (81).

In terms of the bolt rotation component of the rifle action, there is variability in the how far the bolt is rotated (e.g. 57° (82) compared to the 90° (82; 83)). Manufacturing marketing suggests that the difference in bolt rotation affects speed, however in practice there is little difference (84 p. 51).

## 4.3 Cartridge feed

Within bolt-action rifles, there are two main mechanisms for chambering a cartridge:

1. Push-feed (‘PF’) – the bolt pushes the cartridge from a chamber, up a ramp and into the chamber (85). An extractor mechanism clamps onto the rim of the cartridge at the end of the ramp, and as such, the bolt is not physically holding onto the cartridge until it is chambered. When the bolt is moved rearward, the cartridge is (typically) removed from the extractor using a spring-loaded ejector (86); and

2. Controlled-round-feed (‘CRF’) – the extractor grabs hold of the cartridge rim immediately as it is released from the magazine and guides it into the chamber. The cartridge is controlled as the extractor physically holds the cartridge through the entire motion.

[29] The common 308 cartridge (165), which uses the same bullet as the 30-06, marks the top of the short-action bolt throw (164).

There is significant debate about the strengths and weaknesses of both cartridge feed types (86). The discussion points include:

- Hesitation- feeding[30] a PF bolt may result in a second round being forced into an occupied chamber, leading to a jam (82). Hesitation-feeding a CRF has no jamming implication.

- Short-stroking[31] a PF will result in an empty chamber, resulting in lost time in rechambering a cartridge. Short-stroking a CRF bolt may result in the cartridge case not being ejected, resulting in a jam when it is pushed forward (82). Short-stroking a PF will result in an empty chamber, resulting in lost time in rechambering a cartridge.

There are a number of other points of difference between a PF and CRF, however for dangerous animals they appear to be less relevant (or over claimed (87)) than hesitation- and short-stroke feeding. Furthermore, while CRF is often cited as the most suitable for dangerous animals, the cartridges suited for such animals may extenuate the risk of a double feed in a CRF (88). However, it appears that much of the actual difference in reliability is much more theoretical than practical (88).

## 4.4 Rifle materials

Rifles come in combinations of different barrel, and stock materials. The most common barrel materials are made of carbon-steel with a blued finish, and stainless-steel (89) (90), although variations include use of aluminium, titanium and carbon-fibre and even fibre-glass (90). Table 4 presents the different types of metal alloys used in a firearm, and where they are often used. Blued-steel refers to metal that has externally been oxidised to give it a partial-rust proofing (91). The process involves electrochemically converting the surface so that it forms magnetite ($Fe_3O_4$) (91), which reduces the ease at which red-oxide/haematite ($Fe_2O_3$) can form. A blued-steel surface typically requires a water dispersant, such as an oil coating, to further inhibit red-rust from developing (91). Even with this treatment, non-stainless steel may start to rust within a space of hours[32] in in high-moisture situations (84 p. 62). Consequently, stainless steel offers superior all-weather rust resistance (90). The downside of stain-less steel is that it doesn't dissipate heat as well as blued-steel, however in the context of this whitepaper, heat build-up from high-frequency firing is an unlikely issue.

**Table 4: Metal alloys commonly used in firearms**

| Metals used in firearms | Description |
|---|---|
| Carbon-steel 1020 and 1520 | Common, 'plain' or cold-rolled steel. Typically, this steel is used in trigger guards, floorplates, sights, sling swivels and other peripheral hardware. |
| Carbon-steel 4140 | Known as ordnance steel or chrome-moly steel, it contains 0.4% carbon and is strong while still being cost-effective to machine. This steel is often found in barrels, bolts receivers and high-stress items like muzzle brakes. |
| Carbon-steel 4150 | The same as ordnance steel but with a 0.5% carbon content. This steel holds up better to serious abuse, and it's found primarily in military specification barrels. |
| Carbon-steel 41V45 | A chrome-moly variant that includes vanadium. This steel is often used to produce hammer-forged barrels. |

[30] Hesitation feed is where the bolt is pushed forward, backward and forward without rotating the bolt.
[31] Short-stroking is where the bolt is not pulled back to its entire extent of travel.
[32] In locations in New Zealand, corrosion may set in within 12 hours even when treated with a water dispersant (81 p. 63).



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| | |
|---|---|
| Carbon-steel 8620 | This is a full-up allow that contains 0.2% carbon, as well as nickel, chromium, and molybdenum. Cast receivers are made of this alloy because it fills the mould well, machines cleanly and ends up very tough and strong. |
| Stainless-steel 316 | This stainless steel is commonly referred to as 'marine' grade as it resists corrosion due to its o molybdenum content but is difficult to harden. This stainless steel is often used in trigger guards and floorplates. |
| Stainless-steel 17.4 | This is an alloy with 17% chromium and 4% nickel. 17-4 is readily hardened and is used in barrels, bolts and receivers. |
| Aluminium alloy 6061 | Known as aircraft aluminium, this material is useful because of its light weight and ease of fabrication which allows it to be formed in into complex parts. Floorplates on hunting rifles, scope rings and some handguards and buffer tubes are made of 6061. |
| Aluminium alloy 7075 | Much stronger than 6061, 7075 alloy is used in upper and lower receivers, some military-specification buffer tubes and railed handguards. In military specification circles, this alloy is known as 7057-T6; the last part designating the heat treatment it receives. |

*Source: RifleShooter (2011) (92), modified by Greenfields.*

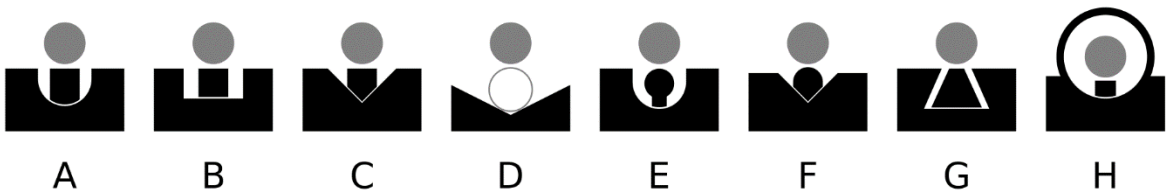
Stocks may be constructed of wood, wood-laminate, or synthetic materials (93). Prior to 1987, rifles were mostly made with wood (often walnut) stocks (94) however wood-laminate is now the predominant natural material. Wood-laminate is generally regarded as being superior to wood stocks as they can be lighter, stronger, stiffer and are stable at a wider range of temperature, and less prone to moisture absorption (94; 95; 84 p. 7). A downside to wood-laminate is that it can be slightly heavier than wood (84 p. 10). Synthetic stocks may be made from a range of materials including polymers (96), and carbon-fibre (97). Synthetic stocks are light and impervious to moisture and may be inexpensive, however there is significant variability in how strong and durable they are. Synthetic stocks may be used to keep production costs low on entry-level firearms or may be used to keep weight down for high-performance firearms (98).

## 4.5 Rifle sights

Firearms are aimed using a sight, the purpose of which is to aid in the placement of a bullet on its intended target (99). Most modern rifles rely on a separate, externally mounted device, such as a telescope or red-dot sight. However, traditionally rifles relied on integrated 'iron-sights' that are integrated into the construction of the barrel. There are advantages to both externally mounted, and integrated sights.

Iron sights are simple, two-piece devices that rely on the alignment of a rear sight device, and a front marker (99). Rear sights are mounted close to the bolt and the user's eye. Iron-sights are typically classed into open (relying on a notch), and aperture (relying on a circular hole) (100). There are many variations on the open and aperture sights, some of which are shown in Figure 7. The 'express sight is considered the fastest iron-sight (100), and at close quarters the circular front sight allows the firearm to be used like a shotgun bead (100). The advantage of iron-sights is that they are robust and reliable, uncomplicated, do not require batteries, inexpensive, lightweight and resistant to severe environmental condition (100). However, iron-sights are imprecise for long-range shooting, require correct alignment of the eye(s) with the front and rear sights and target, and consequently, require a higher degree of skill than some sight alternatives (99).

**Figure 7: Common iron-sight configurations**




*Note: A) U-notch and post, B) Patridge, C) V-notch and post, **D) Express**, E) U-notch and bead, F) V-notch and bead, G) trapezoid, H) ghost ring. The grey dot represents the target (100), however depending on how the rifle is sighted the*

*impact point may overlap with the front-sight as opposed to lolly-popping. Source: Fluzwup at the English language Wikipedia [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0/)]*

Telescopic sights ('scopes') are usually mounted on top of the barrel, such that the eyepiece is close to the end of the action of the bolt (101; 102). A scope is an optical device within which there is some sort of graphic pattern used to inform where the bullet is likely to be placed (101) if it is correctly mounted and aligned. A scope may attach to a firearm using a variety of mounts (102). Scopes are usually used to increase precision in long-range shooting, be it for hunting or competitive shooting purposes. Low-magnification scopes may be used for short range, rapid reaction situations, such as shooting within densely vegetated areas. Scopes provide the most precise means of placing a bullet on a target and are easier to learn to use than iron-sights (103; 104). However, scopes are large relative to the firearm itself, angular, are vulnerable to being misaligned or crucially damaged when knocked.

Laser-dots are largely a military device that project a laser beam onto the target (105) and should not be confused with red-dot sights. These devices require a power source to operate, and as such as unsuited to the Frontier where there needs to be instant availability reliability in sub-zero temperatures.

Relative to iron-sights, red-dot sights new technology (106). To the user of a red-dot, the target looks like it is being illuminated like a laser-dot. However, red-dot sights do not project a laser and instead projects a point of light only within the device itself. This light projection is achieved using lower power light emitters, and prisms. Use of prisms in this manner is advantageous as the 'red-dot' is always on the target, no matter from what angle the device is being used (107), which is shown to improve the precision of shot placement in rapid reaction scenarios (106). Removing the need to align the user's eyes with the sighting device, and the ability to keep both eyes open, means that the user has **better situational awareness** compared to one using iron-sights (106). Overall, red-dot sights are better than iron-sights as they:

- don't require alignment of a front and back sight (108);
- are substantially faster (109) irrespective of the user's experience (108);
- have better accuracy (106);
- improve situation awareness (110); and
- are easier to use by people with less than perfect vision (107).

However, the drawbacks of red-dot sights are that they require initial training (110) due to the counterintuitive need to keep both eyes open; are less suited to situations where there are strong lighting contrasts between the viewpoint and the target; lower accuracy over long range (108); and require more maintenance/servicing than iron-sights (even those that do not require batteries[33]). If the sight is knocked out alignment, it may not be apparent that there is an issue, necessitating more stringent inspection and maintenance.

[33] [33] The Trijicon dual-illuminated sights (220) use fibre optics paired with tritium to illuminate the reticle. The fibre-optics inherently self-adjust for the prevailing light conditions, while the tritium provides additional light in poorly lit/night time conditions. These non-battery dependent sights require the tritium to be replaced



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**Figure 8: Eye focus of iron-sights and red-dots**


*Source: Cowan 2017* (106)

Red-dot sights can be combined with an iron-sight rifle to create a 'co-sight' so that both systems can be used (111; 112; 113). The dot of a co-sighted rifle should sit on the tip of the front post of an iron-sight (114). This is possible as most red-dot sights are not magnified (115). By co-witnessing, the speed and accuracy advantages can be retained, as well as the outright reliability of an iron-sight (116).

## 4.6 Other

There are many additional aspects of a firearm that can be considered. To keep this document concise, the peripheral elements are briefly discussed below:

- **Recoil** – Recoil is the effect of a firearm being pushed back into the user in response to the firing of a cartridge (117). Recoil can be an unpleasant experience that with larger calibre cartridges, may result in soft-tissue damage (118). The felt recoil is a function of the muzzle energy[34], the weight of the firearm, and any anti-recoil devices (119). Heavier rifles dampen the rate of acceleration compared to lighter rifles, which improves the felt recoil (119). Anti-recoil devices such as soft pads on the stock of a rifle, also serve to decelerate a firearms backwards motion. From a safety-equipment perspective, the amount of felt-recoil is of lower importance than a cartridge+rifle combination's ability to protect human life (120).

- **Muzzle brake** – These factory fitted or after-market[35] devices serve to reduce the amount of felt recoil, which may be in the order of a 40-50% reduction (121; 122). Muzzle brakes work by dispersing the propellant gasses orthogonally to the direction of the bullet's trajectory (122). Without a muzzle brake, the equal and opposite reaction of the propellant gasses is to push the rifle back into the user (117). The use of a muzzle brake makes for a more manageable and pleasant shooting experience. However, muzzle brakes are

[34] Muzzle energy is, in turn, a function of the mass of the bullet being fired and its acceleration and terminal speed at the muzzle.
[35] After-market installation is only possible if the muzzle is thick enough, and it may also require the front-sight of an iron-sight to be removed.

controversial devices as they can significantly increase the noise exposure to the user and bystanders. The increase in sound can result in temporary hearing loss after one shot[36], and long-term hearing damage even after a few shots (123). Furthermore, a muzzle brake may cause debris that can be hazardous to individuals not wearing eye-protection (124; 84 p. 107). Due to the risk posed to bystanders, some African jurisdictions have banned muzzle brakes on hunting rifles (123). As a firearm in Frontier is to be used exclusively for self- and group-defence in field conditions, temporary hearing loss can be a major safety factor if electronic communications are needed to evacuate personnel from the field back to camp.

- **Slings and carry-straps** – These devices both serve to carry a firearm (125). A sling has an added benefit in that it can be used to stabilise the shooter's arm (126), thereby increasing accuracy (125). For the potentially rapid reaction, short to medium range scenarios expected in the Frontier, the precision benefits of a sling are not a significant factor particularly as they are most relevant at distances greater than 50m (59). However, carry-straps in some instances may be overly oriented towards comfort by extensive use of high-grip materials like soft rubber (127). Consequently, some carry-straps may be slower to de-shoulder and affect the reaction time.

- **Rifle cases** – Firearm cases are required to keep a firearm adequately protected and in serviceable condition while being stored or transported. Due to restricted space in a helicopter, soft-cases may be more practical than bulky hard-cases that are a legal requirement of commercial air travel. However, a case should not be excessively thin (like a sock). Ideally for field work, the case is water-resistant or waterproof to reduce the amount of maintenance for the firearm[37], and improve its serviceability and service life

# 5 REQUIREMENTS

## 5.1 Regulatory

The police regulate and manage firearms in Greenland. The law in Greenland prohibits the possession and use of handguns, semi-automatic, and fully automatic firearms (128), unless permission has been granted by the police. Hunting is not allowed within the Northeast Greenland National Park, with the exception for traditional hunters in Ittoqqortoormiit (129). However, it is a condition of entry to the park that personnel carry firearms of a minimum 30-06 calibre[38] (3). The Greenland police also allow, but do not recommend the use of shot-guns irrespective of the cartridge type (130), and the Governor of Svalbard specifically highlights that magazine fed shot-guns are prone to icing and condensation problems (131). As such, the regulatory requirements constrain the Frontier firearms to long-guns (i.e. non-repeating rifles).

[36] Temporary being measured by days! This assumes that the user not wearing hearing protection, as is the likely case in a dangerous animal scenario (81 p. 107). It is also important to emphasise that most ear-plugs are insufficient for noise protection, and muffs may also need to be worn (81 p. 107).
[37] Rifles should not be stored in soft-cases for long periods of time as it may induce corrosion if there is trapped moisture (81).
[38] 7.62 mm diameter bullet, 63 mm long cartridge length (151; 167).



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## 5.2 Logistical

### "*The best firearm solution is the one that is locally available*"

The Frontier has a simple logistical supply line that centres on the township of Akureyri in Iceland. All essential items must, wherever possible, be available close in the supply line. The local availability of firearms and ammunition is also recommended by the USGS (59). Logistical simplicity means that superior firearms may not be practicable or logistically safe for a self-sufficient, remote exploration program. While it is possible to transport ammunition from Australia, it would require trans-shipping through at least three jurisdictions[39] (and temporary importation to Greenland) which increases the risk of supply line disruption. As firearms are a mandatory condition of entering the Frontier, non-supply of firearm or ammunition could stop a multi-million-dollar exploration program from starting.

## 5.3 Operational

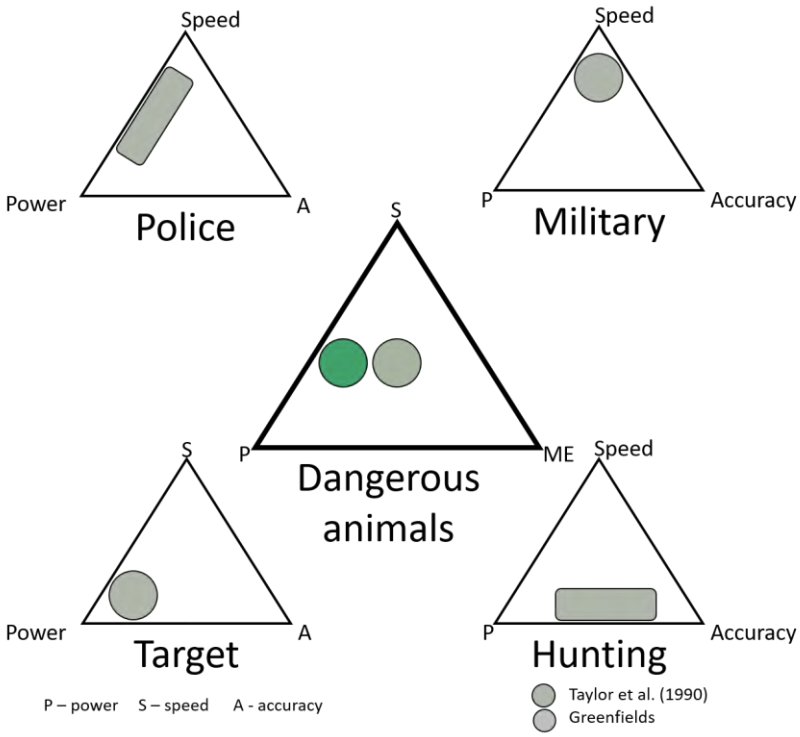
### '*30-06 is what you can get away with, but not what is best*'

Greenfields identifies that a firearm should primarily be considered in terms of its short-range performance for self-defence[40] (~<50 m (60)), and medium-range (up to ~200 m) for group-defence. Wilder et al. (2017) (54) determined that in 44% of attacks, people had time to react with deterrents which implies that bears were detected at distances greater than 50 m/Danger Level 4 as a bear can cover such a distance in ~6 seconds. Such short time frames require self-defence firearms that are fast to deploy and fire. Similarly, the USGS Condition Red implies an engagement distance of around 12m. Similarly, research by Smith et al. (2015) shows that there is no significant difference in the efficacy of rifles versus handguns[41] (132). Group defence may have a similar requirement for speed, but with a greater emphasis on accuracy to help ensure shot placement that does not endanger the person being protected. The short time frames also necessitate that the firearm calibre should be enough to stop an attack with one shot, as there may be insufficient time to fire a second time before a bear is upon a person.

All rifles are inherently accurate, and Greenfields does not consider precision a significant factor in firearms being used exclusively for dangerous animal defence. Consequently, Greenfields determines that a dangerous animal rifle should have an emphasis on being powerful and quick, at the relative expense of speed. This balance of requirements is shown in the ternary diagrams of Figure 9, which is based upon the findings of the USGS (59). Greenfields' ternary diagram differs from that of the USGS as Greenfields does not include shot-guns or hand-guns in its assessment, due to regulatory restrictions and recommendations by Greenlandic authorities (130).

[39] For example, the United Kingdom, Denmark, Iceland, and Greenland
[40] Based on Danger Level 4, where the bear displays a distinctly different body language.
[41] The article is statistical and does not present a reason for no significant difference between long-guns and handguns, despite the latter often having lower muzzle energy. A possible, but untested reason may be the speed at which handguns can be used.

**Figure 9: Accuracy-speed-power trade-off**




*Source: Based on Taylor et al. (1990)* (59)

The purpose of a firearm at the Frontier is to stop an attack as fast as possible (59). The highest probability of stopping a dangerous animal attack is to accurately place a deep penetrating shot into the vital organs (59), such as the:

- Central nervous system – brain or spinal cord, which will result in an immediate halt (59).
- Heart/lung region – this may not result in an immediate stop (59).
- Mobility destruction – crushed hip, shoulder bones etc. This less than ideal bullet placement may buy time for a follow-up shot to the central nervous system (59).

In a high-stress Danger Level 5 encounter with a dangerous animal, the most reliable[42] shot placement is in the centre of mass (59) when faced front-on; and the locomotive and vital-organs near the shoulder from side on (Figure 10). Shot placement should never be in the stomach, as this is likely to lead to an unnecessary painful and slow death. The operation requirement of the cartridge is that it can penetrate deeply enough to reach the vital organs.

[42] Head shots are desirable from an ethical kill perspective, however they represent small, bobbing targets (176) in a high-stress environment, and as such have a lower probability of being successfully placed.



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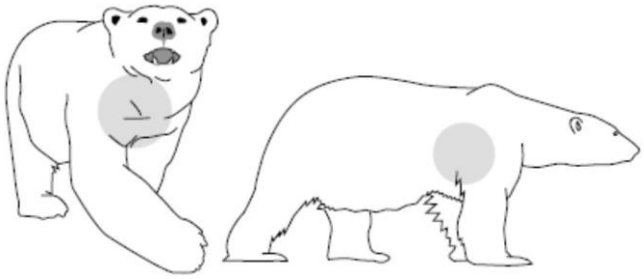
**Figure 10: Shot placement on a polar bear**



*Source: Governor of Svaldbard* (57; 131)

Greenfields emphasises that while the 30-06 is the regulatory minimum, there is a lot of variance in the individual cartridges. For a 30-06, it is generally considered necessary to have bullet weights of more than 180 grains (133). Furthermore, the USGS considers that the 30-06 has marginal muzzle energy[43] for large bear species (59), implying that it is a sub-optimal cartridge. Qualitatively, much of the online literature refers to cartridges that are larger than the 30-06 when being discussed in the context of large bears. At the other end of the spectrum, the 375 Holland & Holland Magnum ('375H&H') is generally considered to be at the upper end of the performance spectrum required for large bears (59).

As the current scope for the Frontier exploration work involves people walking over large distances in remote locations, ergonomics is an important consideration. A large/long rifle may be a trip hazard when working on uneven terrain. Similarly, over a day the weight of a rifle will become increasingly noticeable and may contribute to fatigue and negatively impact a person's reflex speed. To reduce the negative impact of a rifle on a person's mobility, energy, alertness and reflexes, a firearm selection should preferentially be based on being lighter and shorter than otherwise equivalent alternatives. Nationally, the operational ergonomics of a Frontier firearm are similar to the 'scout-rifle' concept (~1 m long, <3kg weight, iron-sights, synthetic stocks, accurate but not precise etc (134)). While the design concept of a scout rifle is appropriate for the Frontier, Greenfields did not identify any that were chambered with enough calibre or where the ammunition is locally available.

The above points indicate that a firearm should be as small and light as possible, not have a fixed muzzle break, be carried using a sling with minimal rubberization, and transported in a soft weather-proof case. Furthermore, the firearm should be ideally chambered in a cartridge starting at the equivalent of a 93x62 and up to 375H&H. Bullets need to be adequately constructed to ensure penetration to the vital organs. Overall, both ammunition and spare parts should be locally available in Greenland or Iceland.

## 5.4 Analogies

Much of the popular literature on firearms concerns hunting or sports shooting. The handling and performance expectations of such firearms are substantially different from that needed for defence against a dangerous animal. Furthermore, there is extensive opinion in popular literature, with many contradicting positions. Consequently, it is necessary to review operational analogues of exploration in the Frontier. However, there are comparatively few analogues to working in at the Frontier where self-sufficiency and polar bears are a key consideration[44]. Greenfields has

[43] Muzzle energy is a function of the weight of the bullet and the speed at which it is propelled
[44] Most bear considerations in North America involve black bears (lower 48 states), inland brown bears which are smaller than coastal brown bears. Only the Kodiak sub-species of brown bear is larger than a polar bear.

identified the Canadian Rangers, USGS, Alaskan gun guides, and Sirius as firearms users from which suitable guidance may be taken.

Having firearms in a geological exploration program is common in North America, as evidenced by the USGS operating procedures (59). The USGS recommends selections based on local availability, and rifles chambered in 338 Winchester Magnum ('338'), 375 Holland & Holland[45] ('375 H&H'), or 458 Winchester Magnum (59).

Alaskan guides to recreational shooters carry back-up firearms in the case of the need for an emergency intervention. From a hunting point of view, the Alaska Department of Fish and Game 30-06 as an adequate cartridge (135), however, the supporting guides preferentially carry rifles chambered in the larger 338 (133). This difference reflects the operational requirements of a recreational firearm and a safety device.

Sirius and Canadian Rangers are non-combat military units that operate small teams, or individual, remote locations where dangerous animals such as bears are a consideration. Both these units favour simplicity and reliability in their firearms. In 2010, Defence Research and Development, Canada conducted an eight-day workshop involving 135 Canadian Rangers, to determine the replacement characteristics for that unit's .303 Lee Enfield No4, Mk1 rifles (136). The primary purpose of this antiquated firearm is to provide self-defence against large predators and to serve as a hunting tool for self-survival (136). Key outcomes from this work are:

- The firearm must have a bolt-action;
- There is indifference whether a firearm is CRF or PF;
- Firearms should have iron-sights with protective hoods;
- Durability is a significant consideration, and the barrel should have a stainless-steel barrel;
- There should be recoil absorbing pads built into the stock
- The calibre should be 308[46] or 30-06[47]; and
- A sling (not carry strap) and lockable water-proof hard-case[48] are necessary peripheral equipment.

Sirius currently retains the M1917 Enfield rifle chambered in 30-06 (137), a rifle of similar vintage and features to the Canadian Rangers' superseded .303 Lee Enfield No4 Mk1 (138).

# 6 REVIEW

## 6.1 Ammunition

***"local, heavy and strong."***

Bullet hits to the central nervous system are the most effective in stopping a violent attack and heavy calibres with strongly constructed bullets give the best results (59; 139). Examples include

[45] There are similar sounding cartridges, like the 375 Ruger, however these are incompatible with 375 H&H chambered rifles and are less widely available.
[46] 308 has the same bullet diameter as a 30-06; however, it has a shorter case which means that it does not meet the regulatory requirement of the Frontier.
[47] The identified cartridges are based on a balance of ammunition availability, and the firearm's use for survival hunting and self-defence from dangerous animals. This operational requirement is different to that of the Frontier where hunting is not a consideration.
[48] Greenfields notes that Canadian Rangers are more likely to transport firearms loosely in a vehicle and may be more prone to damage compared to regular transport in a helicopter.

the 338, 375 H&H and 458 Winchester Magnum cartridges (59). High velocity-low mass bullets may break upon hitting an animal, especially at short ranges, which may result in minimal or insufficient penetration (59). Examples of such unsuitable cartridges are those that use .223, 6mm and .270 bullets (59). Bullet construction advice is variable, with some advocating that only FMJ are suitable (e.g. Taylor et al., 1990) while others advise that strongly constructed controlled-expansion hollow-point bullets are the most suitable (131; 140). Minimum bullet weights are typically recommended to be around 180 grains[49] (133; 131), and recommended weights are up to 220 grains[50] (133; 59). However, bullet weight must be considered with sectional density, as large calibres may easily surpass 220 grains while not providing certainty on their ability to penetrate deeply enough. Empirical research[51] by Stokke, Arnemo & Brainerd (2019) shows that bullets made entirely of copper, compared to traditional copper-jacketed lead-cored bullets have similar effectiveness (141). "C*opper ammunition exhibited a larger, more reliable and stable expansion compared to lead-based ammunition. This characteristic seems to offset the advantage lead-based ammunition has in terms of killing efficiency due to fragmentation effects*" (141). As lead-core bullets are considered to have negative impacts on the environment and human health (142), that research recommends that homogenous copper bullets be used where possible.

There is a wide variety of ammunition that meets the regulatory requirement to meet or exceed the 30-06. However, the local availability is a significant consideration (59) in ensuring logistical certainty, and only those cartridges available in Akureyri in Iceland, and Greenland are considered in this document. Furthermore, only commercially loaded ammunition is recommended for use at the Frontier (59). Greenfields identified that there are sixteen cartridge types available in Akureyri that meet the regulatory requirements[52]. Within these cartridge types are 36 different offerings, with varying performance characteristics. To help evaluate the merits of the cartridges available in Akureyri, Greenfields compared the muzzle energy[53] and sectional density[54] of each option.

- **Sectional density** – This is a proxy for the potential of a bullet to penetrate deeply. A high-powered cartridge firing a bullet with a low sectional density may hit hard but may not penetrate deeply enough to ensure a quick kill. Greenfields identified that an approximate appropriate sectional density for dangerous animals such as bear, is ~0.30 (143). Such sectional densities are typically found in bullets that are heavy for the calibre (139).

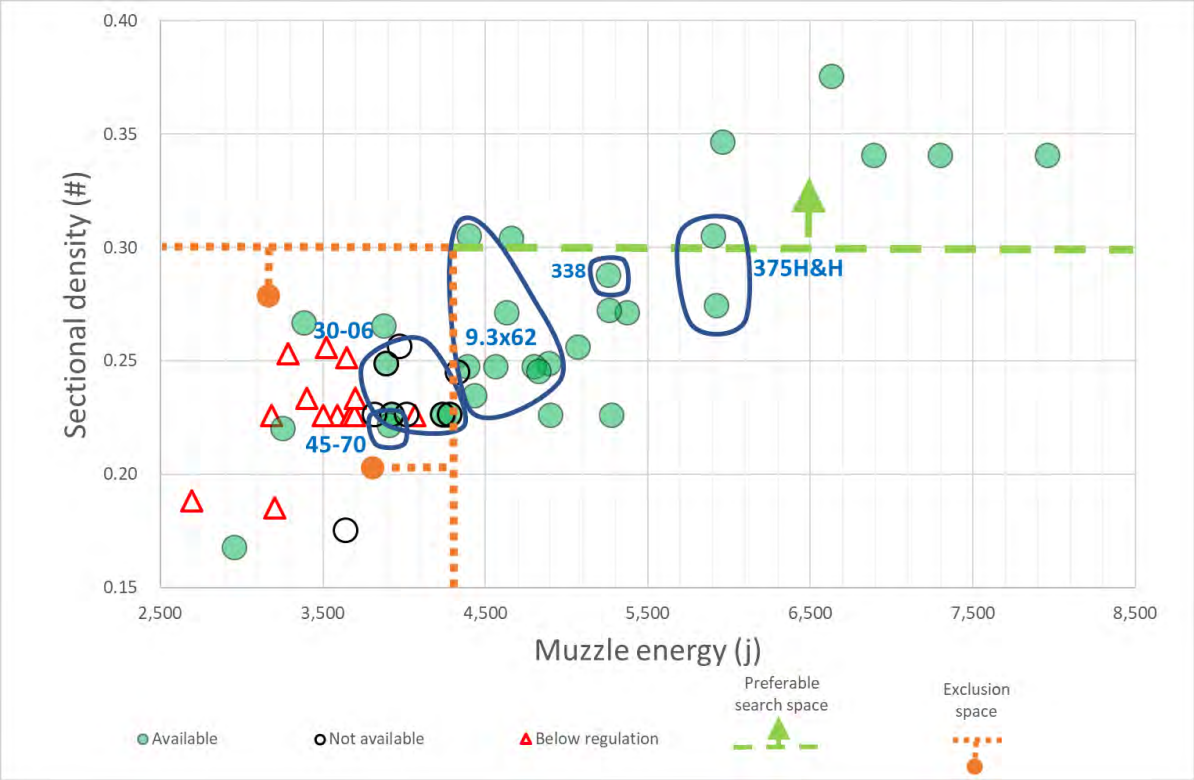
- **Muzzle energy** – This is a proxy for the momentum of a bullet needed to push a bullet deeply enough to reach critical areas within a target. Greenfields did not identify a satisfactory source for guidance on minimum muzzle energy so it reviewed the requirements for the African 'Big Five' game, which includes lions (up to 250kg (144), compared to 700 kg for a polar bear boar). In Zimbabwe, the minimum muzzle energy regulation is for more than 4,300 joules[55] (145), while in Namibia it is more than 5,400 joules (146).

The muzzle energy and sectional density of the cartridges available in Akureyri are shown in Figure 11. What is significant is that by applying an approximate muzzle energy threshold of 4,300 joules on the Akureyri cartridges in all 30-06 bar one being too low powered, with one being marginal. This 'marginal' position of the 30-06 is consistent with the view of the USGS. Figure 11

[49] 180 grains equate to 11.66 grams.
[50] 14.26 grams
[51] Statistics based on Fennoscandian hunts involving 5,245 moose, 637 brown bear, 38 roe deer, and 1 red deer.
[52] 30-06, 300 Winchester Magnum, 300 Weatherby Magnum, 300 Norma Magnum, 3030 British, 8.57JS, 8x68S, 8x57JRS, 338 Winchester Magnum, 338 Lapua Magnum, 9.3x62, 9.3x74R, 375 H&H, 458 Win, 458 Lott, 45/70 Government.
[53] Muzzle energy is calculated by $\frac{1}{2}mv^2$, where $m$ is the mass of a bullet and $v$ is the velocity of that bullet (167)
[54] Sectional density represents the mass behind the cross-sectional area of a bullet. The sectional density is calculated using Imperial measurement units such that the $\frac{m}{d^2}$, where $m$ is the mass of a bullet in pounds, and $d$ is the diameter of that bullet in inches
[55] Using a bullet with a diameter greater than 7mm

also shows that none of the available 30-06 cartridges have enough sectional density, and as such would require non-expanding bullets (FMJ) to help achieve adequate penetration in an emergency. This observation is consistent with the practice of Sirius, which use 30-06 FMJ for a polar bear, and civilian-controlled expansion bullets for muskox (137).

**Figure 11: Momentum and penetration potential of Akureyri cartridges**




*Source: Researched and collated by Greenfields. Note: The 'unavailable' cartridges are 450 Bushmaster; and most of the 'below regulation' cartridges are 308.*

Of the cartridge options identified in Akureyri shown in Figure 11, the 9.3x62 is the most plentiful, followed by the .375 H&H and lastly the 338. There are also other cartridges, however these are less universally common. Greenfields makes the following observations:

- **375 H&H** – This cartridge has a governmental recommendation for use for protection against coastal brown bears (59), of which some sub-species are larger than polar bears. Furthermore, the 375 H&H is offered by virtually all major manufacturers (147) the advantage of which is that offerings it can be obtained from both European and North American manufacturers. This cartridge has global logistical certainty, local logistical flexibility at Akureyri, and has ample performance for the purpose.

- **338** - This cartridge is recommended for use for protection against coastal brown bears (56). The 338 'has a North American origin and is less common in Europe. The solitary offering in Akureyri is a testament to this. It is also important to emphasise that while Iceland has significant tourists visiting from North America, it is still economically and

[56] A large species that may be used as an analogue for polar bear



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culturally within the European sphere of influence. Consequently, while the 338 is an appropriate cartridge for safety at the Frontier, the local logistics may be frail.

- **9.3x62** – The USGS does not mention this cartridge. Presumably, this is because the 9.3x62 is widely available in Iceland in Europe, available in Africa, and rare in North America (148). Greenfields assumes that the USGS is silent on 9.3x62 due to its lack of availability United States, rather than inadequate performance.

- **45-70 Government** ('45-70') – This offering while being physically large as a bullet, the solitary option available at Akureyri has neither the momentum nor sectional density needed to give certainty in an emergency at the Frontier. Greenfields is aware that this cartridge is used for bear defence (140), however the commercially available options tend to have weak powder charge, designed for smaller game than bear (59), are slow to kill (149) and compared to the cartridges above, is overly reliant on precision shooting.

## 6.2 Rifles

In assessing the suitability of rifles, Greenfields reviewed the firearm adopted by the Canadian Rangers to replace the 303 Lee Enfield. This firearm, which is effectively the Tikka Arctic (150), uses a 308 cartridge that does not meet the minimum regulatory requirements. However, the design of this rifle provides useful insights into the requirements of a rifle to be used for reliable[57] defence against dangerous animals in remote and uncontrolled situations. These qualities include stainless steel barrel and components, whether it has a muzzle brake[58]; stocks construction[59]; iron-sights[60], accessory mounts[61]. In addition, Greenfields considered calibre[62], weight[63], length[64], magazine design[65], feed-type (CRF vs PF)[66]. Greenfields then considered whether the rifle availability, in terms of Greenland, Iceland and globally. Appendix 1 contains a short list of the firearms that Greenfields reviewed. Many rifles were identified in addition to those in Appendix 1, however they are omitted as they do not meet Greenfields' minimum criteria.

# 7 FINDINGS

The probability of a dangerous animal encounter in the Frontier is low, however interactions are potentially catastrophic. While muskox and wolves are dangerous, polar bears pose a higher risk as they may actively predate humans. A significant finding is that maintaining group sizes of at least three people may have a significant bear deterrent effect, however the statistics for polar bears are less strong than those for brown or black bears. While deterrence should always be maximised, it is necessary to maintain dangerous animal defence in the form of firearms. The defence requirements are for self/group-defence at ranges less than 50 m, which in a charging bear situation gives less than 6 seconds to diffuse. Consequently, the operational requirement of

[57] The Canadian army fired the Tikka Arctic 8,000 times without significant failure (217).
[58] If the rifle includes a muzzle break, and whether it can be removed
[59] Whether stocks are synthetic, wood-laminate, or wooden. Preference was given to synthetic stocks for smaller calibres, and laminate-wood for large calibres to reduce the risk of cracking the stock (216).
[60] Whether an iron sight is included, the type of iron sight, whether the sights are protected.
[61] Mounts for optics such as a red-dot
[62] Preference given to being greater than 30-06, although 338 Win-Mag was downgraded because of precarious local availability, and the 45-70 because of the unsuitability of the locally available cartridge.
[63] At 4.5kg, the Tikka Arctic is a heavy rifle designed for an exceptionally long service life rather than field ergonomics.
[64] The shorter the rifle the better, to make it less cumbersome when moving over difficult terrane.
[65] The Tikka Arctic has a magazine capacity of 10 cartridges, however most dangerous animal encounters will allow time for only one or two shots (122). Preference was also given to recessed magazines so that there a fewer edges upon which a rifle may catch and slow its deployment.
[66] No weight was given to PF/CRF as conclusive evidence was not identified. This position is supported by the indifference demonstrated in the review process associated with the Canadian Ranger's Lee Enfield replacement program (128). However, as the PF/CRF is a major differentiator in firearm design, the feed type was recorded.

a dangerous animal firearm is on power and speed. In a purely group-defence situation the range may be beyond 50 m, but in the opinion of Greenfields, are unlikely to be at ranges that require optical magnification. For an average user, the effective range of an iron-sight may be around 150m[67] (151), which is adequate for the most likely emergency scenarios.

The most important aspect of dangerous animal defence with a firearm is not the gun itself, but the cartridge. Cartridges should be available within the logistical connections to Frontier, such as within Greenland and Iceland. Bullet construction should be such that it allows penetration to the vital organs of a large with strong muscles and dense bones, such as bear. The bullet should then be designed to impart as large a wound channel as possible. However, a cartridge should not be so powerful and the bullet so strong that it passes through the target without imparting most or all its energy.

While the minimum regulatory calibre is 30-06, this may be regarded as having marginal power. Shot placement is just as if not more important than absolute power, and as such there are many anecdotes of successful defence using smaller calibres. However, most of the literature on large-bear defence discusses cartridges of 338 or above. There is comparatively little discussion on the use of 9.3x62 in bear defence, however this appears to be a function of economic spheres of influence rather than cartridge performance.

While many cartridge types may be procured in Australia, moving them to Greenland would involve trans-shipping through at least three other jurisdictions. If ammunition were not available when required, an expensive field program would be jeopardised for the sake of a few hundred dollars' worth of ammunition. Consequently, it is identified that logistical certainty is a high priority.

A review of the ammunition available in Akureyri, the closest logistical hub to the Frontier, shows that there are three suitable cartridges

- **9.3x62** – "*a versatile workhorse but is often surrounded by far too much fantasy and hype. While some put it to good use on larger bodied game where it excels, there are many hunters who look to such cartridges for hunting light to mid weight deer species at bush / woods ranges where snap shots have to be taken*" (148). The 9.3x62 is the most widely available cartridge in Akureyri, although there appears to be only one that meets Greenfields' sectional density requirement.

- **338** – "*The .338 Winchester is a highly practical cartridge, performing extremely well on large bodied medium game. By using select projectiles, the .338 is highly versatile"* (152); *"A main detractor of this cartridge is its excessively sharp recoil"* (152) *as it is "sharp in many rifles, this factor is the major detractor from this cartridge's overall popularity and must be given due consideration*" (152). There is only one cartridge type available in Akureyri, and while having desirable qualities, it represents the highest logistical risk.

- **375 H&H** – *"a true all-round workhorse, neither overpowered or underpowered, working very well on a very broad range of game. Provided hunters continue to have access to a broad range of bullet styles and not just the tough numbers, this cartridge and its kin will continue to prove useful well into the future"*; and *"produces moderate recoil compared to faster bores or wider bores of equal speed. Having said this and depending on one's experience levels, first impressions when shooting the .375 at a range are often that of high*

[67] The maximum effective range of an iron-sight may be around 275m (146)



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*recoil. But as the shooter becomes more relaxed, isolating the muscle groups that need to be held at tension versus those that should be relaxed, the hunter can learn to roll comfortably with recoil*" (153). While there are only two cartridge choices in Akureyri, they are both suitable for defence from dangerous animals; and are widely available in a more global context.

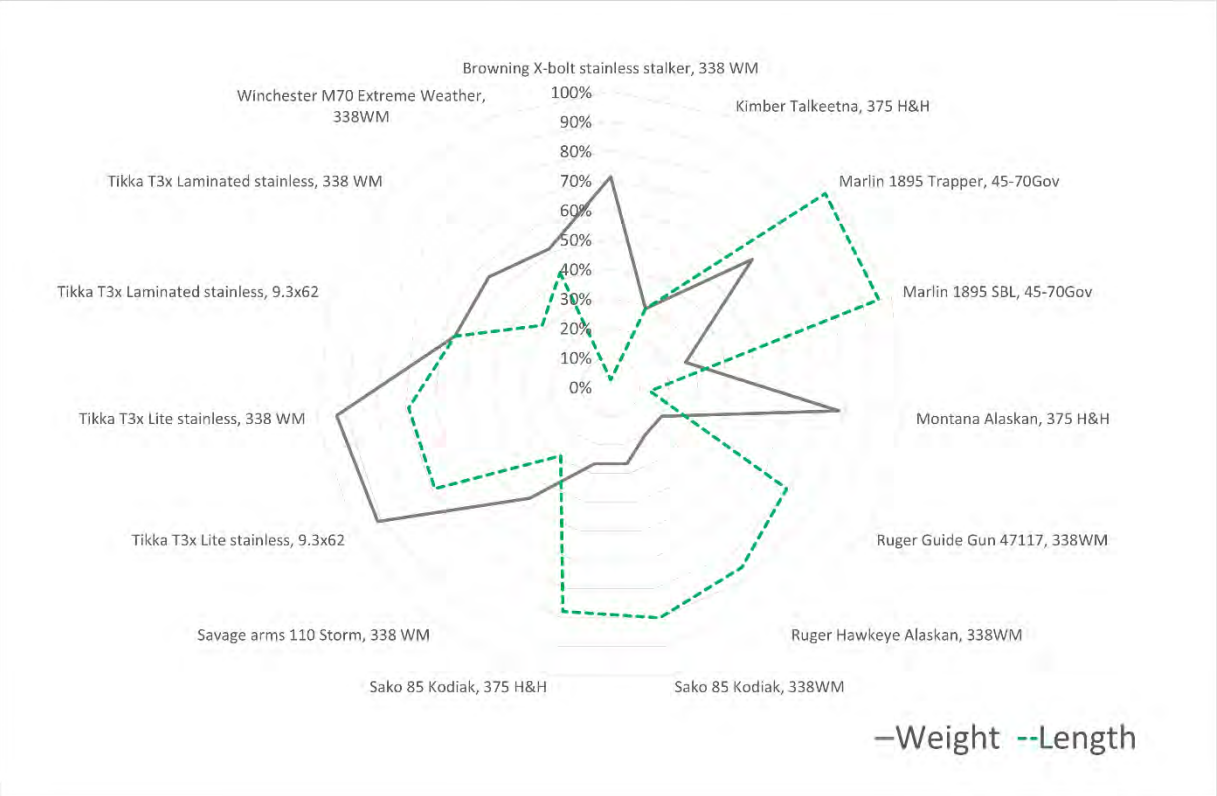
It is identified that the locally available 45-70 cartridge while meeting the regulatory requirements[68] and being physically imposing, has performance characteristics below than the 30-06. It is also identified that cartridges larger than a 375 H&H are likely to be excessive.

The firearms should be reliable under a range of operational conditions. A bad-case and plausible scenario is where a field-team being stranded in the field away from the basecamp, where a helicopter is grounded by inclement weather and a bear is encountered. A firearm should be reliable in such conditions, which includes being wet and dirty. Stainless-steel components are preferable to avoid rust, combined with iron-sights as they are not affected by rain or prone to fogging. Red-dot sights are attractive as they are faster, more accurate and importantly, provide higher situation awareness. The weakness of red-dot sights is that they may fog, be blurred by rain, and more prone to damage[69] than iron-sights. Stock material may be either synthetic or wood-laminate, however only high-quality synthetic stocks should be considered given the potential for the high-powered cartridges to crack inferior materials. As such, synthetics may be suitable for 9.3x62 chamberings but should be selected with caution if combined with a barrel chambered in 375 H&H. Greenfields opines that recoil should not be a key determinant in selecting a firearm for low-use, safety purpose. Furthermore, recoil controlling devices such as a muzzle brake may temporarily deafen the user or people nearby, which is highly undesirable in an emergency. Finally, while a safety rifle will probably never be used for its intended purpose, it is important that it is of high enough quality to ensure that it is easy to operate and reliable in high-stress situation where the user's skill may be compromised.

A review of the firearms available in 93x62, 338 and 375 H&H shows that there are surprisingly few in these chamberings that come in stainless steel construction and have iron-sights. Red-dot sights are faster and more accurate that iron-sights. Furthermore, their ease of use may be a significant factor when the user is experienced. The ease of use is important given that operator error contributed to additional harm in 25% of all documented polar bear attacks (54). However, while red-dots excel in many situations, they do not have the breadth of reliability demonstrated by iron-sights. It is also noted that there is a variety of different iron-sight configurations and that 'express' sights are the fastest and most suited to dangerous animal situations.

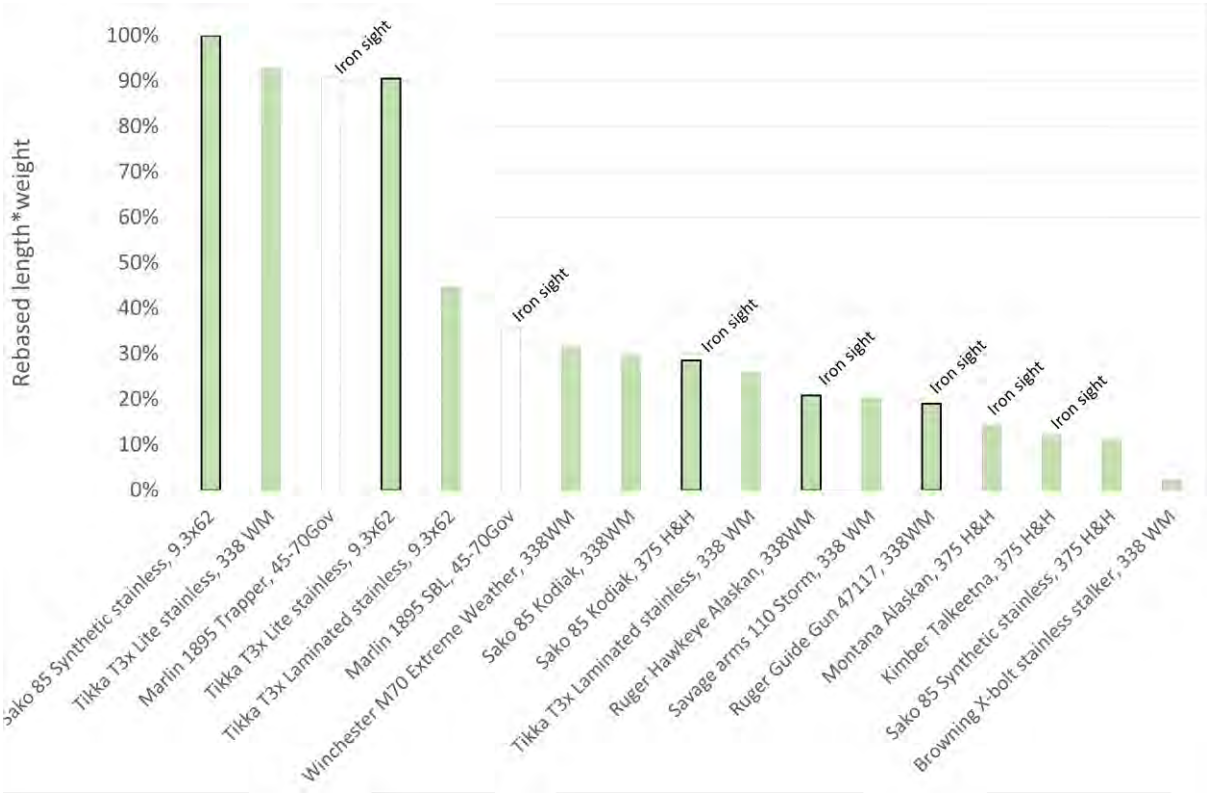
[68] Greenfields is aware that lever-action firearms chambered in 45-70 have previously been carried on the Ymer Licence within the Frontier. Greenfields cautions against the use of this cartridge, as it is inherently low-powered and large-for calibre bullets that have adequate sectional density may be undesirably slow.
[69] Red-dot sights are hardy and are frequently used by security and military forces. Red-dot sights are more fragile than iron-sights in a relative sense.

## Figure 12: Shortlisted firearm weight, length and chamberings




*Source: Generated by Greenfields using publicly available information*

**Figure 13: Product of weight*length rankings**




*Source: Generated by Greenfields using publicly available information*

# 8 RECOMMENDATIONS

Having reviewed the literature it identified; Greenfields recommends that for the Frontier:

1. Field teams **must** comprise at least three persons that are nearby at all times. If a team of less than three is unavoidable, both persons must carry a firearm. If that deterrence measure is lowered, the defence **must** be increased;
2. Firearms and cartridges should be locally available;
3. Rifles should have a bolt-action, be light, short and where possible, have recessed magazines. These qualities reduce ergonomic risk, and mishandling risk under stress;
4. Calibres should be either 9.3x62 or 375H&H. The 338 has desirable performance characteristics but it has less logistical certainty than the preferred cartridges. The 30-06 is acceptable but not optimal;
5. Bullets **must** have a sectional density close above 0.27 and preferably 0.30;
6. Controlled expansion bullets are preferred assuming the above two points are satisfied;
7. If the only available bullets have sectional densities less than 0.27, an FMJ construction is preferable;
8. Where available, homogenous-copper bullets should be used providing that there is no material advantage to lead-core alternatives.
9. If the cartridge is high-powered, the purchaser **must** be cognizant of the potential for a strongly constructed bullet to pass through the target without imparting enough of its energy;
10. Full wad-cutter flat-nosed bullets **must not** be used as they increase the tendency to cause a cartridge feeding jam;
11. Firearms chambered in 45-70 cartridges should not be used due to their likely inferior sectional density, power, and speed. If this cartridge type is chosen, the purchaser **must** clearly demonstrate how these shortcomings have been overcome;

12. Firearms **must** have a stainless-steel construction. This provides certainty of operation in the field but does not reduce the need for maintenance;
13. Hooded express iron-sights are the preferred means of aiming a firearm. However, red-dot sights being acceptable providing there is additional inspection to ensure alignment;
14. Optical scopes **must not** be used; and
15. Rifles **must not** have fixed muzzle brakes, and if removable they **must not** be used outside of a tightly controlled training situation where bystanders are appropriately protected.
16. Easily removable slings should be used in preference to carry straps.

This whitepaper recommends five suitable firearms for the Frontier:

- **Sako 85**[70] **Kodiak** chambered in 375 H&H. This firearm is available in both Greenland and Iceland and has all the desirable design features identified in this whitepaper. This rifle has an express sight with a long tubular hood over the front-sight that may help the speed and precision of target acquisition in short range emergencies. This Sako 85 Series, to which the Kodiak belongs, is marketed as CRF, but is a hybrid and is closer to PF (154). The Sako 85 series has a 70° bolt throw. The drawback of the Kodiak is that it is heavier than some of the non-iron sight iron alternatives, and its minimum chambering is 375 H&H which is at the upper end of the muzzle energy guidance for large dangerous animals such as bears.

- **Sako 85 Synthetic Stainless** chambered in 9.3x62. This hybrid PF/CRF has the equal best logistical supply line in terms of both firearm and cartridge. Of the shortlisted firearms, it has the best weight-length combination and given the smaller chambering and shorter action length (65) than the Kodiak, the recoil may still be tolerable despite the reduced weight[71]. Furthermore, as it uses a standard-length bolt, there is a lower risk of short-stroking and it has faster action. However, this firearm is not available with iron-sights and a (non-battery) red-dot optic is necessary[72].

- **Tikka T3x Lite Stainless** chambered in 9.3x62. This PF firearm has a 70° bolt rotation (155), is the lightest[73] and has the best logistical supply lines. However, the only identified T3x series that have iron-sights do not come in stainless steel construction. Consequently, this rifle also requires a red-dot sight.

- **Ruger Guide Gun**[74] – This firearm is very similar to the Kodiak, except that it doesn't have a hooded front sight and is a traditional CRF with a 90° bolt rotation. The drawback of this firearm is that that it has a 338 chambering that has the weakest supply line to the Frontier.

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[70] The 85 Series Sako's are variable, with some being very precise and others leaving much to be desired (81). However, precision is not a key factor for the Frontier operational requirements. Some Sako 85s are also known to have ejection issues where the spent cartridge hits a mounted scope and may fall back into the action (168). However, scopes are not recommended for the Frontier and this potential issue is not considered material.
[71] Decreased weight directly translates into increased felt recoil (110). A rifle of this weigh chambered in a 375 H&H, for example, could make for brutal handling.
[72] The Trijicon dual-illuminated sights (220) use fibre optics paired with tritium to illuminate the reticule. The fibre-optics inherently self-adjust for the prevailing light conditions, while the tritium provides additional light in poorly lit/night time conditions. Battery dependent red-dots are not recommended.
[73] 2.8kg compared to 3.6kg for the Sako Kodiak, Ruger Guide Gun, and Ruger Hawkeye Alaskan. In general, Tikka has cornered the light-weight affordable rifle market and requires little to no work from the point of purchase. However, for long-range shooting the light weight may be consideration, however this is not a likely requirement for the Frontier (81 p. 178).
[74] The Ruger Guide Gun and Alaskan are part of the 77 Series (169). These rifles can have good accuracy, but generally require gunsmithing before being used in a precision hunting situation (81 p. 165). While precision is not a major consideration for the Frontier, the tendency to have rough machining and burring is not confidence inspiring even though the rifles are solid and well-engineered.



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- **Ruger Hawkeye Alaskan** – This CRF firearm is like the Guide Gun but its main difference is that it has a synthetic stock, instead of a laminated stock. Surprisingly, there is no weight advantage over the Guide Gun despite it being shorter and having a synthetic instead of laminate stock.

There are trade-offs associated with all the firearms identified above and it is not possible to make a conclusive recommendation for a single rifle.

While this whitepaper sets out recommendations for firearms that may be suitable for the Frontier's operational requirements, it is important to emphasise that the "**user is no safer because they carry a gun than they are a musician because they own a guitar**'[75]. This sentiment is borne out in the statistics which show that in 25% of the documented polar bear attacks, stress and mishandling resulted in the firearm contributing to further human injury or death (54). For this reason, this whitepaper **strongly recommends** that all Frontier personnel undergo training, but that firearms are primarily carried by individuals with extensive firearm experience, such as ex-military personnel.

[75] Apologies to, and adapted from, Taylor, Williamson, and Clark, 1990 (79).

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# 10 APPENDIX 1

**Table 5: List of reviewed firearms**

| Manufacturer | Model | Caliber | Weight | Overall length | Recessed magazine | Iron sight | Barrel material | Stock material | Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Variable | kg | mm | Binary | Binary | Binary | Binary | Variable |
| **Browning** | X-bolt stainless stalker | 338 | 3.1 | 1187 | Yes | No | Stainless | Synthetic | Push feed |
| **Kimber** | Talkeetna | 375 H&H | 3.5 | 1130 | Yes | Yes | Stainless | Carbon fiber | Hybrid |
| **Marlin** | 1895 Trapper | 45-70 | 3.2 | 889 | Yes | Yes | Stainless | Synthetic | Lever-action |
| **Marlin** | 1895 SBL | 45-70 | 3.6 | 940 | Yes | Yes | Stainless | Laminate | Lever-action |
| **Montana** | Alaskan | 375 H&H | 3.1 | 1168 | Yes | Yes | Stainless | Synthetic | Controlled-feed |
| **Ruger** | Guide Gun 47117 | 338WM | 3.6 | 1080 | Yes | Yes | Stainless | Laminate | Controlled-feed |
| **Ruger** | Hawkeye Alaskan | 338WM | 3.6 | 1067 | Yes | Yes | Stainless | Synthetic | Controlled-feed |
| **Sako** | 85 Kodiak | 338WM | 3.6 | 1065 | Yes | Yes | Stainless | Laminate | Hybrid |
| **Sako** | 85 Kodiak | 375 H&H | 3.6 | 1066 | Yes | Yes | Stainless | Laminate | Hybrid |
| **Savage arms** | 110 Storm | 338 | 3.3 | 1130 | Yes | No | Stainless | Synthetic | Push-feed |
| **Tikka** | T3x Lite stainless | 9.3x62 | 2.8 | 1080 | Yes | No | Stainless | Synthetic | Push-feed |
| **Tikka** | T3x Lite stainless | 338 | 2.7 | 1080 | Yes | No | Stainless | Synthetic | Push-feed |
| **Tikka** | T3x Laminated stainless | 9.3x62 | 3.2 | 1080 | Yes | No | Stainless | Laminate | Push-feed |
| **Tikka** | T3x Laminated stainless | 338 | 3.2 | 1130 | Yes | No | Stainless | Laminate | Push-feed |
| **Winchester** | M70 Extreme Weather | 338WM | 3.2 | 1111 | Yes | No | Stainless | Synthetic | Controlled-feed |
| | | | | | | | | | |
| **Browning** | X-bolt stainless stalker | 30-06 | 3.1 | 1086 | Yes | No | Stainless | Synthetic | Push feed |
| **Kimber** | Mountain Ascent | 30-06 | 2.4 | 1111 | Yes | No | Stainless | Carbon fiber | Hybrid |
| **Kimber** | Montana | 30-06 | 2.6 | 1111 | Yes | No | Stainless | Carbon fiber | Hybrid |
| **Mauser** | M18 | 30-06 | 2.9 | 1060 | Yes | No | Stainless | Synthetic | Push-feed |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Remington** | 700 Mountain SS | 30-06 | 3.5 | 1080 | Yes | No | Stainless | Synthetic | Push feed |
| **Ruger** | Guide Gun 47118 | 30-06 | 3.7 | 1080 | Yes | Yes | Stainless | Laminate | Controlled-feed |
| **Savage arms** | 110 Storm | 30-06 | 3.2 | 1072 | Yes | No | Stainless | Synthetic | Push-feed |
| **Tikka** | Arctic | 308 | 4.5 | 1020 | No | Yes | Stainless | Laminate | Push-feed |
| **Tikka** | T3x Laminated stainless | 30-06 | 3.1 | 1080 | Yes | No | Stainless | Laminate | Push-feed |
| **Winchester** | M70 Extreme Weather | 30-06 | 3.1 | 1111 | Yes | No | Stainless | Synthetic | Controlled-feed |
| | | | | | | | | | |
| **CZ** | CZ 550 American Safari Magnum | 30-06 | 4.3 | 1181 | Yes | Yes | Black | Wood | Controlled-feed |
| **CZ** | CZ 550 American Safari Magnum | 375 H&H | 4.3 | 1181 | Yes | Yes | Black | Wood | Controlled-feed |
| **Mauser** | M98 | 30-06 | 3.7 | 1105 | Yes | Yes | Black | Wood | Controlled-feed |
| **Mauser** | M98 | 375 H&H | 4.6 | 1180 | Yes | Yes | Black | Wood | Controlled-feed |
| **Montana** | X3 | 30-06 | 3.2 | 1143 | Yes | No | Black | Synthetic | Controlled-feed |
| **Montana** | X3 | 338 | 3.1 | 1143 | Yes | No | Black | Synthetic | Controlled-feed |
| **Mossberg** | Patriot 27906 | 30-06 | 3.2 | 1086 | Yes | Yes | Black | Wood | Controlled-feed |
| **Mossberg** | Patriot 27908 | 338 | 3.2 | 1086 | Yes | Yes | Black | Wood | Controlled-feed |
| **Ruger** | American Rifle Ranch 6901 | 30-06 | 2.8 | 1080 | Yes | No | Black | Synthetic | Push feed |
| **Ruger** | American Rifle Ranch 26927 | 30-06 | 3.0 | 1067 | Yes | No | Black | Synthetic | Push feed |
| **Ruger** | American Rifle Ranch 16913 | 338 | 3.4 | 1130 | No | No | Black | Synthetic | Push feed |
| **Sako** | 85 Black Bear | 30-06 | 3.3 | 1027 | Yes | Yes | Black | Synthetic | Hybrid |
| **Savage arms** | Axis | 30-06 | 2.9 | 1114 | Yes | No | Black | Synthetic | Push-feed |
| **Savage arms** | 110 Brush Hunter | 338 | 3.3 | 1041 | Yes | Yes | Black | Synthetic | Push-feed |
| **Steyr** | CL II SX Mountain | 30-06 | 3.3 | 1041 | Yes | Yes | Black | Synthetic | Controlled feed |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Steyr** | CL II SX Magnum | 375 H&H | 3.4 | 1176 | Yes | Yes | Black | Synthetic | Controlled feed |
| **Tikka** | T3x Battue Lite | 30-06 | 2.8 | 1020 | Yes | Yes | Black | Synthetic | Push-feed |
| **Weatherby** | Vanguard Dangerous Game | 375 H&H | 3.5 | 1130 | Yes | Yes | Black | Laminated | Push feed |
| **Winchester** | M70 Alaskan | 375 H&H | 3.9 | 1162 | Yes | Yes | Black | Wood | Controlled-feed |