Resumption of Live-fire Training Exercises at XU022 – Eagle River Flats Impact Area, Operable Unit C
Joint Base Elmendorf-Richardson, Alaska

Prepared For: EPA, ADEC

Date: September 2015

1.0 INTRODUCTION

The purpose of this memorandum is to summarize information requested by the United States Environmental Protection Agency (EPA) and Alaska Department of Environmental Conservation (ADEC) in a letter dated May 27, 2015, regarding resumption of live-fire training exercises at XU022 – Eagle River Flats (ERF), Operable Unit (OU) C, Joint Base Elmendorf-Richardson [JBER]-Richardson [JBER-R]). Live-fire training exercises were performed April 1-3 and 13-14, 2015, to provide mandatory unit certification. EPA and ADEC requested the following information because live-fire training occurred outside the window of November 1 and March 31:

(1) Provide a map of the type of munitions used and area impacted by the live-fire training that occurred in February and April 2015 at ERF. If possible, provide the firing trajectories and resulting impact zones overlaid on a map of the known ERF contaminated sediments and capped white-phosphorus (WP) hotspot areas (i.e., Ponds 23 and 730, and approximately 34 gravel caps installed in Area C). Capping and filling operations have taken place in 2007, 2008, 2009, 2011, and 2013. Cap integrity monitoring/repair were scheduled in the 2012-2013 Remedial Action Summary Report (Table 2-1) for 2016 (verification and 2017 (repairs, if needed) (United States Air Force [USAF], 2013). The regulators believe this schedule may need to be accelerated so that verification activities occur in 2015 and cap repairs can be made if they are needed in 2016 or sooner.

(2) Provide the evaluation made by USAF to resume live-fire training outside of the restrictions established in the Environmental Assessment (USAF, 1991) and the OU C Record of Decision (ROD) (USAF, 1998). How was ice cover thickness determined prior to the live-fire exercises? Were waterfowl surveys conducted to determine the absence of migratory birds in the area in early April 2015?

(3) Provide a workplan or strategy to evaluate remedy integrity at OU C following resumption of live fire outside the restricted time lines. How will new impact craters be assessed and recorded? How will gravel cap integrity be determined? Will waterfowl mortality surveys be conducted in 2015 to determine potential exposure to WP-contaminated sediment?

2.0 BACKGROUND

The United States Army (Army) / USAF has used ERF for artillery and munitions training since the early 1940s, creating thousands of craters in the wetlands and associated mud flats. Unusually high mortality of dabbling waterfowl at ERF was discovered in the early 1980s. The primary contaminant of concern is WP deposited in the sediment during range firing activities. Although

ERF is a training area, it remains a productive wetland, serving as an important staging ground for migrating waterfowl during the spring and fall migrations.

In 1990, the Army banned the firing of smokes containing WP into the ERF. The following additional restrictions were also applied to training activities at ERF:

- A minimum of 6 inches of ice must cover the ERF before it can be used for firing.
- Firing is allowed only between November 1 and March 31.
- Only point-contact detonators may be used.

Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), remedial action objectives (RAOs) were established for the XU022 – ERF and XE023 – EOD Area in the OU C ROD (USAF, 1998), and a remedy was selected: draining ponds with pumps to treat WP in sediment, minimizing disturbance to wetlands habitat, capping of areas that do not dry sufficiently, and maintaining land use controls (LUCs). The following RAOs established in the ROD have been achieved, and the site is considered at response complete with ongoing monitoring (long-term management):

- **Short-Term RAO**: Within 5 years of the ROD being signed, reduce the dabbling duck mortality rate attributable to WP to 50 percent of the 1996 mortality rate attributable to WP (dabbling ducks were the group primarily affected). Radio tracking and aerial surveys suggest that about 1,000 birds died from WP at ERF in 1996. Therefore, the allowable number of duck deaths each year from WP is approximately 500.
- **Long-Term RAO**: Within 20 years of the ROD being signed, reduce the mortality attributable to WP to no more than 1 percent of the total annual fall population of dabbling ducks in the ERF. The 2010 dabbling duck population was about 5,000. Therefore, the allowable number of duck deaths from WP would be approximately 50. This long-term goal could be adjusted based on future population studies conducted during the monitoring program.

Approximately 1,900 square feet of sediment remains capped (less than 0.5 acre) because these areas were not effectively dewatered to treat/reduce WP concentrations to below 1 microgram per gram (µg/g). LUCs are also in place restricting site access, construction, and road maintenance, as well as requiring training for personnel who work at OU C source areas, as long as site conditions do not allow for unlimited use/unrestricted exposure. Although there were no immediate plans to resume warm-weather firing onto the ERF at the time the ROD was finalized, the ROD also notes that future changes to the mission of Fort Richardson could necessitate the use of the training area during the summer months.

Ongoing long-term management for XU022 includes sediment sampling, waterfowl mortality monitoring (ground-based mortality surveys and aerial waterfowl surveys), and habitat monitoring (vegetation plot analysis and aerial photography) in accordance with the revised monitoring schedule in the *Memorandum to the Site File for Operable Unit C – Eagle River Flats Impact Area, Joint Base Elmendorf-Richardson* (Memo to Site File) (USAF, 2011). Cap repairs and gravel cap integrity inspections are also completed, if needed.

In 1991, the Army completed an Environmental Assessment (USAF, 1991) and associated Finding of No Significant Impact under the National Environmental Policy Act. Firing was limited to "winter only" based on ice thickness (not specified in the EA) and absence of migratory birds. In 2001 and 2005, Record of Environmental Consideration (REC) Modified Firing Regimes (USAF, 2001; USAF, 2005) were also completed to provide flexibility for firing activities and ensure protectiveness of waterfowl. The modified firing regimes outline general timeframes for conducting training at ERF based on the actual waterfowl migratory patterns rather than a specified time period, and redefine the recommended ice thickness.

3.0 MUNITIONS USED AND IMPACT AREA

Live-fire training exercises conducted in April 2015 used the following munitions:

- April 1, 2015: Point detonated mortar (120 millimeters [mm])
- April 2, 2015: Point detonated mortar (81 and 120mm)
- April 3, 2015: Point detonated mortar (81 and 120mm), point detonated artillery rounds (105mm)
- April 4, 2015: Point detonated artillery rounds (105mm)

Figure 1 shows the locations of the target areas and points in relation to the locations of the caps that are currently in place to prevent waterfowl access to WP-contaminated sediment. The closest target point is more than 250 meters southeast of the nearest cap. Attachment 1 includes associated trajectories for each of the impact areas. Firing was not observed outside of the impact zones/targets.

4.0 EVALUATION TO RESUME LIVE-FIRE TRANINING

4.1 Ice Cover Thickness

The ice thickness required to protect underlying sediment from impact by various caliber munitions was initially determined during tests conducted during winter 1991, and was reported in *Winter Tests of Artillery Firing into Eagle River Flats, Fort Richardson, Alaska* (Collins and Calkins, 1995) (see Attachment 2). Subsequently, the 2001 and 2005 REC Modified Firing Regimes (see Attachment 3) have provided additional guidance on ice thickness requirements for firing in ERF.

The 2005 REC modified firing regime indicates that the new firing regime was to have begun in January 2005, remaining in place as long as the following adequate ice thickness conditions are present, and is predicated on the actual waterfowl migratory patterns rather than a specified time period (between November 1 and March 31):

- Point detonated mortar (60 and 80mm), Grenades (40mm): 2 inches of ice
- Point detonated artillery rounds (105mm), point detonated mortar (120mm): 5 inches of ice

Ice thickness was measured on March 30 and April 13, 2015, prior to the April 1-3 and April 14, 2015, firing events (respectively), in accordance with the *Standard Operating Procedure (SOP)* *for Measuring Ice Thickness at Eagle River Flats (ERF) Impact Area, Fort Richardson, Alaska (FRA)* (USAF, 2007) (see Attachment 4). The ice conditions for the firing events were characterized as "hard" with measured thicknesses of 24 and 12 inches on March 30 and April 13, 2015, respectively (see Table 1). In both events, the ice thickness was considered protective for the type of munitions fired. In addition, a Range Control Facility Operations Specialist verified that safety measures were in place and monitored initial firing to observe effects on the ice. A photograph of the ice thickness measurement at one of the three measured locations (EOD Area) on April 13, 2015, is provided as Figure 2.

Table 1: Ice Thickness

Location	Date	Ice Thickness (inches)	Sediment Encountered Below the Ice (Y or N)	Condition of Sediment (soft, partially frozen, or frozen)
EOD Pad	4-Nov-14	6.5	N	Frozen
EOD Pad	17-Nov-14	10.25	N	Frozen
EOD Pad	16-Mar-15	30	N	Frozen
EOD Pad	30-Mar-15	24	N	Frozen
EOD Pad	7-Apr-15	16	N	Frozen
EOD Pad	13-Apr-15	12	N	Frozen
EOD Pad	14-Apr-15	13	N	Frozen

4.2 Waterfowl Surveys

Prior to each firing event, the Unit Officer-in-Charge and Forward Observers verified that the down range area was absent of wildlife. The absence of migratory birds was further supported through JBER Bird/Wildlife Aircraft Strike Hazard (BASH) reports for areas around the flightline and cantonment area and was confirmed by the United States Department of Agriculture as follows:

> "We have a few new birds but you're right the migration hasn't started yet. Some geese have been seen in Fairbanks but thus far we haven't seen any. We have been watching out for the eagles to build a new nest but we haven't seen any activity yet. No snow or standing water this year so the birds might just bypass us on the way to the nesting grounds." (Morrill, 2015)

Between 0 and 25 mallards (a species that includes some year-round resident birds) were observed during each of the weeks ending March 28, April 4, and April 11, 2015 (see Attachment 5). In addition, the lack of open water, as evidenced by the measured 12 inches (or greater) of ice during the time of the events, would also make the area an unlikely stopping point for migratory waterfowl.

5.0 STRATEGY TO EVALUATE REMEDY INTEGRITY

Consistent with the ROD (USAF, 1998) and Memo to Site File (USAF, 2011), sediment sampling, gravel cap integrity inspections, and waterfowl mortality monitoring (ground-based mortality surveys and aerial waterfowl surveys), as described further below, will be completed as a part of long-term management of XU022 under CERCLA to evaluate the protectiveness of the remedy.

5.1 Sediment Sampling and Gravel Cap Integrity Inspections

Sediment sampling (multi-increment) will assess the following:

- Whether there is continued clean status of ponds previously drained to treat WP in sediment or whether there has been a rebound in concentrations
- Whether the gravel caps placed in 2012 adequately covered the WP-contaminated sediments (sampling of cap perimeters)
- Whether WP is present in sediment in areas where higher numbers of waterfowl deaths are concentrated (as observed during waterfowl mortality transect inspections)

Areas identified during sediment sampling with WP above the target concentration of 1 μg/g will be capped the following winter, to prevent waterfowl contact with sediment.

In areas where caps were expanded or augmented in 2013, the gravel cap integrity will be evaluated by inspecting the areas to determine whether the gravel layer settled over the contaminated site as predicted; and the cap perimeters will be surveyed.

Gravel cap integrity will also be evaluated by visual observation of the caps during the ground-based mortality surveys (see Section 5.2). Although the edges of the caps may be more difficult to observe, during lower tides much of the capped surfaces are visible above the water's surface.

5.2 Waterfowl Mortality Monitoring

Waterfowl mortality monitoring consists of both ground-based mortality surveys for waterfowl carcasses and aerial waterfowl surveys by the United States Fish and Wildlife Service (USFWS) during the fall migration. The ground-based mortality survey consists of monitoring 13 transects, which are modified and monitored at varying frequencies based on where mortalities have been recorded in recent years. A two-person observation team either walks or canoes each transect, visually scanning for waterfowl carcasses or feather pile remains.

The aerial surveys provide total population numbers to allow calculation of mortality rates when compared to the number of deaths resulting from WP poisoning. Consistent with the long-term RAO in the ROD, if the waterfowl mortality rate remains at or below 1 percent, then the remedy is considered protective.

5.3 Schedule

According to the revised monitoring schedule in the Memo to Site File (USAF, 2011), sediment sampling and a waterfowl mortality survey are required in 2016, with cap repairs, if needed, required in 2017. As indicated in the 2012-2013 Remedial Action Summary Report (see Table 2-1) (USAF, 2013), sediment sampling, gravel cap integrity inspections, and the waterfowl mortality survey are planned for 2016. If needed, capping will be completed in winter 2017.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Considering that ice thickness was measured at 12 to 24 inches on ERF, compared with the 5 inches considered protective for the type of munitions fired and the 6 inches noted in the ROD, and that minimal waterfowl were observed at JBER, site conditions during the live-fire training exercises from April 1-3 and 13-14, 2015, were considered protective of both migratory waterfowl and the gravel caps. In addition, the closest target point was more than 250 meters southeast of the nearest cap, and firing was not observed outside of the impact zones/targets. At this time, USAF does not intend to further accelerate long-term management activities for XU022 under CERCLA (i.e., sediment sampling, waterfowl mortality survey, and cap repairs), and considers any additional activities to monitor for potential impact craters from live-fire training exercises unnecessary. If long-term management activities completed in 2015 determine that the mortality rate has increased and the long-term RAO is no longer met, or that there has been a significant rebound in WP concentrations in areas previously remediated or capped, then further actions will be considered at that time.

7.0 REFERENCES

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Figures

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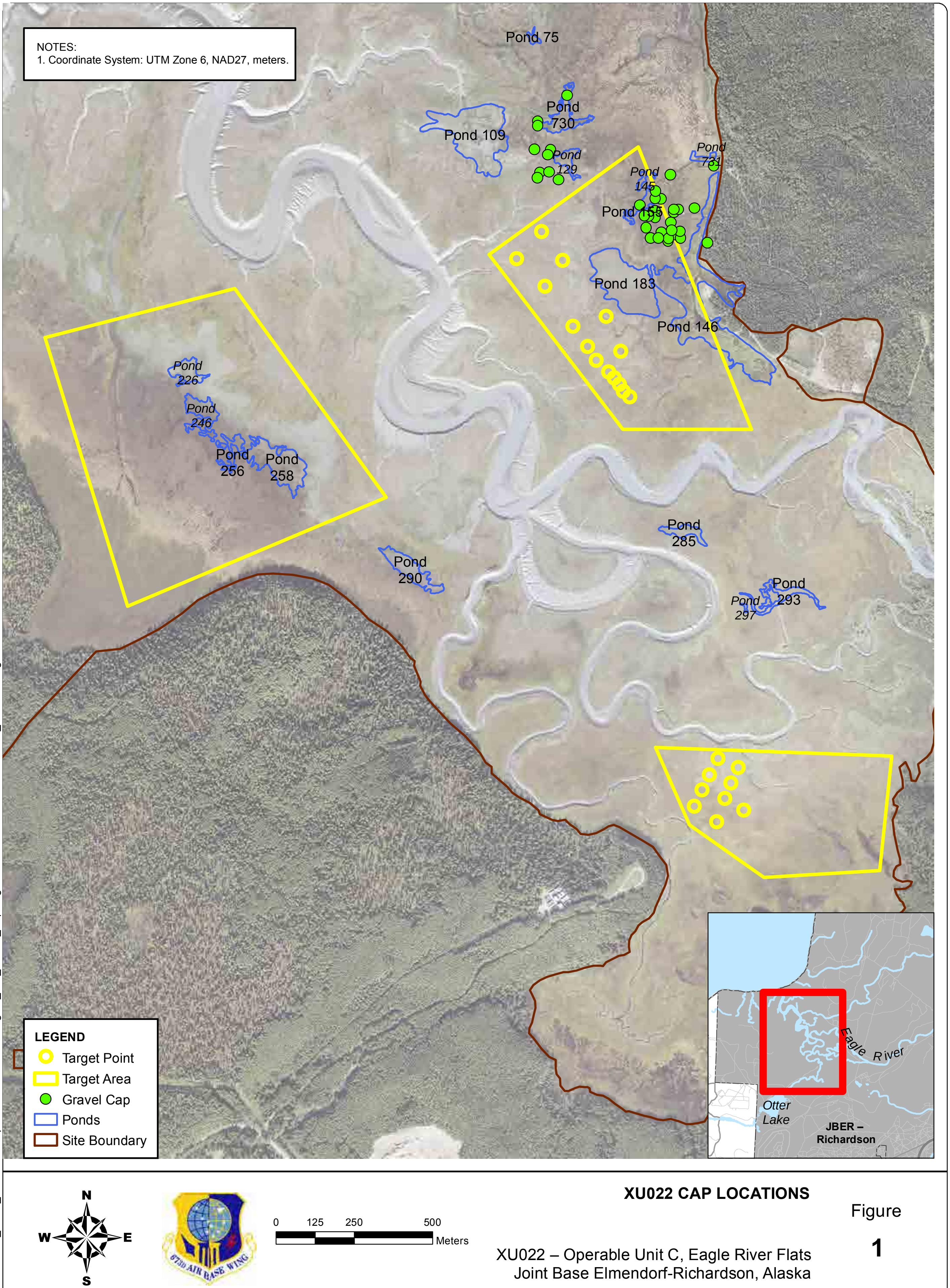

XU022 CAP LOCATIONS

XU022 – Operable Unit C, Eagle River Flats
Joint Base Elmendorf-Richardson, Alaska

Figure
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673D AIR BASE WING

ICE THICKNESS
XU022 – Operable Unit C, Eagle River Flats
Joint Base Elmendorf-Richardson, Alaska

Figure 2

Attachment 1
Firing Trajectories

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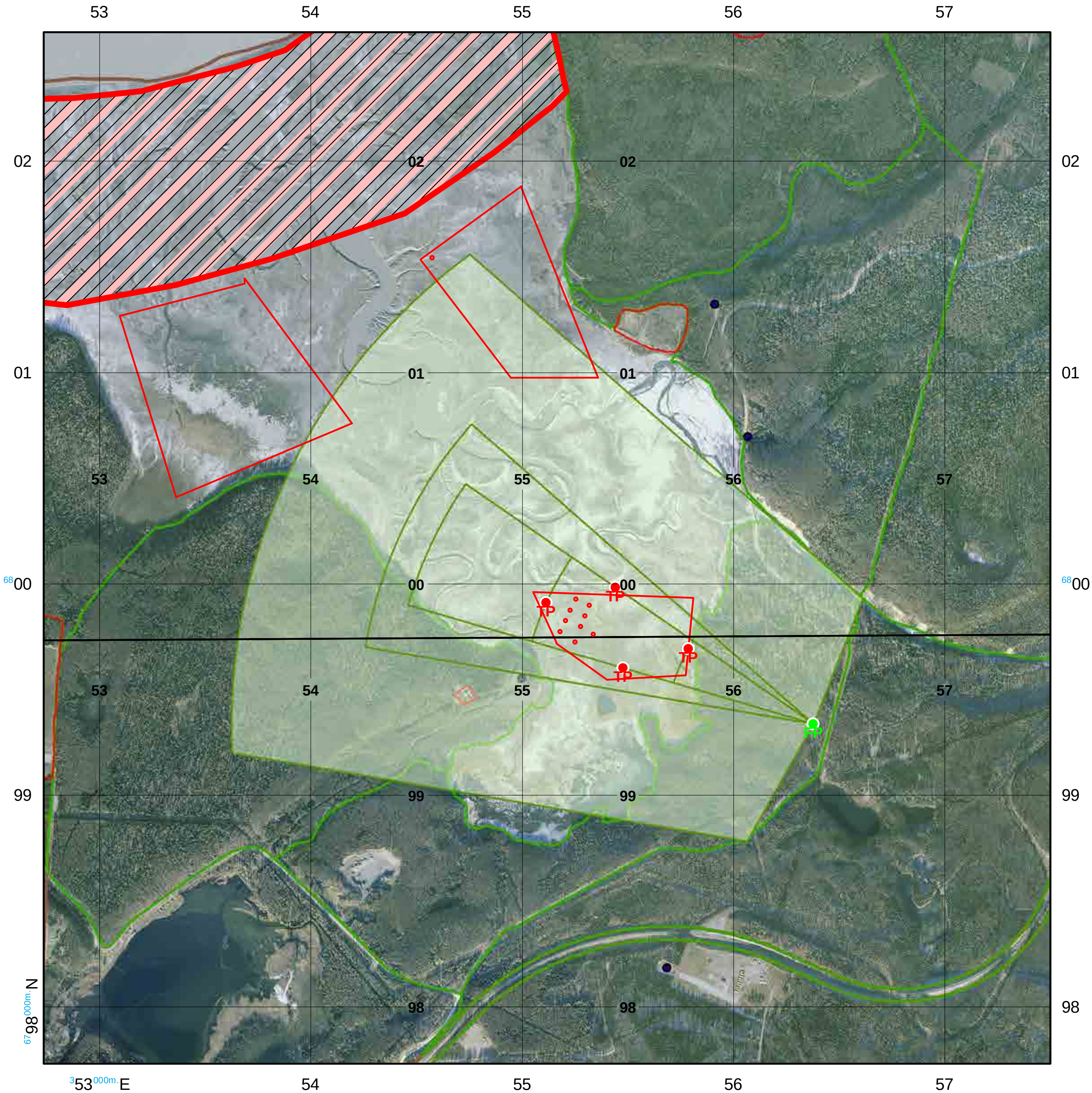
Map Scale: 1:25,000
Layout Date: 04/28/2015

RMTK Build: 10.2.0.0.1
RMTK Build Date: 07/01/2014

Weapon Type: MORTARS AND ARTILLERY

Weapon Caliber: 120mm:HE M934 w/ MOF M734



Range Manager Signature Authority:	Date:		
Approving Authority:	Date:		

SDZ Created By: Bryers	Date: 04/28/2015	Unit:	Phone:	Email:

SDZ Name: 120mm_HE M934 L Fox 2 Installation: JBER Range Name: None Range Officer: Deflection Probable Error: 15.00 m Range Probable Error: 19.00 m Min Target Dist: 690.00 m	Max Target Dist: 1,389.00 m Charge: 2 Indirect Fire Ground Target Distance X: 2,000.00 m Area A: 600.00 m Area B: 600.00 m	Angle A: 70.00 deg Lt GTL Azi: 286.33 deg Rt GTL Azi: 304.58 deg FP: 06VUN5637899337 TP: 06VUN5511299911 TP: 06VUN5544099984 TP: 06VUN5547799601	TP: 06VUN5578699692

Map Scale: 1:25,000
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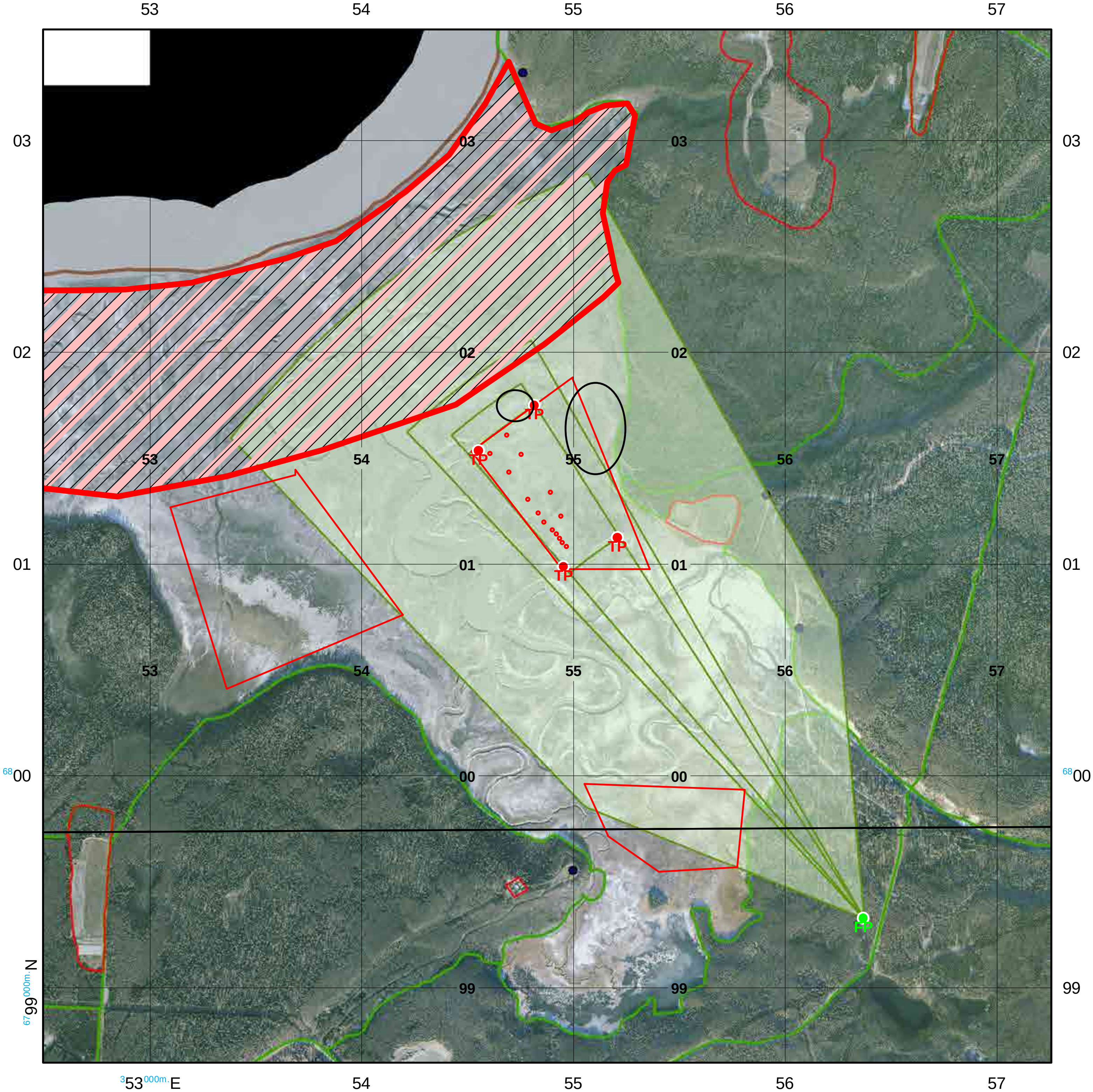
RMTK Build: 10.2.0.0.1
RMTK Build Date: 07/01/2014



Range Manager Signature Authority:	Date:		
Approving Authority:	Date:		

SDZ Created By: Bryers Date: 04/28/2015 Unit: Phone: Email:

SDZ Name: 120mm_HE M934 Fossil Installation: JBER Range Name: None Range Officer: Deflection Probable Error: 15.00 m Range Probable Error: 19.00 m Min Target Dist: 2,141.00 m	Max Target Dist: 2,878.00 m Charge: 2 Indirect Fire Ground Target Distance X: 3,000.00 m Area A: 600.00 m Area B: 600.00 m	Angle A: 25.00 deg Lt GTL Azi: 319.54 deg Rt GTL Azi: 327.34 deg FP: 06VUN5637099326 TP: 06VUP5455301534 TP: 06VUP5481701749 TP: 06VUP5495300987	TP: 06VUP5520701124

Attachment 2
Winter Tests of Artillery Firing into Eagle River Flats

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SPECIAL REPORT 95-2

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Winter Tests of Artillery Firing into Eagle River Flats, Fort Richardson, Alaska

Charles M. Collins and Darryl J. Calkins

January 1995

Abstract

Winter tests of artillery firing were conducted in the Eagle River Flats impact range to determine the physical effects of exploding high-explosive (HE) projectiles on the ice-covered terrain. Eagle River Flats is an estuary at the mouth of the Eagle River used as the artillery impact range for Ft. Richardson. The Army suspended use of the impact range following the discovery that white phosphorus (WP) deposited in the salt marsh was responsible for large numbers of waterfowl deaths each summer. The purpose of these tests was to assess if seasonal firing of HE projectiles from 60- and 81-mm mortars and 105-mm howitzers into Eagle River Flats could be resumed without significantly disturbing the sediments contaminated with WP. The results of the test firings indicated that a minimum of 25 cm of ice over frozen sediment or a minimum of 30 cm of floating ice over shallow water was required to prevent disturbance of the WP-contaminated sediment by exploding 105-mm howitzer projectiles. Only 10 cm of ice was required to prevent disturbance by exploding 60- and 81-mm mortar projectiles.

For conversion of SI metric units to U.S./British customary units of measurement consult ASTM Standard E380-89a, *Standard Practice for Use of the International System of Units,* published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.

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Special Report 95-2

US Army Corps
of Engineers
Cold Regions Research &
Engineering Laboratory

Winter Tests of Artillery Firing into Eagle River Flats, Fort Richardson, Alaska

Charles M. Collins and Darryl J. Calkins

January 1995

Prepared for
DIRECTORATE OF PUBLIC WORKS
FT. RICHARDSON, ALASKA

Approved for public release; distribution is unlimited.

PREFACE

This report was prepared by Charles M. Collins, Research Physical Scientist, and Darryl J. Calkins, Chief, Geological Sciences Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory.

Funding for this effort was provided by the Directorate of Public Works, Sixth Infantry Division (Light), Ft. Richardson, Alaska.

The authors acknowledge William Gossweiler, Directorate of Public Works, Ft. Richardson, for his support in helping to arrange the test firing. The authors thank Bruce Brockett, Geological Sciences Branch, for his assistance in the field measurements of craters. The authors also thank Edward Chacho and Paul Sellmann for technically reviewing the manuscript. Finally, they thank the members of the 176th Explosive Ordnance Disposal Detachment for escorting them into the Eagle River Flats impact area and assisting them in the field measurements of craters.

CONTENTS

ILLUSTRATIONS

Figure

TABLES

Table

Winter Tests of Artillery Firing into Eagle River Flats, Fort Richardson, Alaska

CHARLES M. COLLINS AND DARRYL J. CALKINS

INTRODUCTION

The objective for the winter tests of artillery firing into the Eagle River Flats (ERF) impact area was to determine the physical effects of exploding rounds on winter terrain. The winter ground conditions of interest include snow cover, ice cover, frozen and unfrozen sediments and to some extent water beneath the ice covers in the pond areas. Observations were based on the disturbance of the snow, ice and sediment layers caused by exploding 105-, 81- and 60-mm high-explosive (HE) projectiles with both point detonation and delay fuses. To determine the effects of these projectiles, test firings using 105-mm howitzers and 60- and 81-mm mortars were conducted in a small portion of ERF during March 1991.

The purpose of these tests was to assess if seasonal firing of HE projectiles into ERF could be resumed without significantly disturbing contaminated sediments. Firing only during the winter, when the salt marsh is covered by a seasonal cover of snow, frozen ground and ice, might significantly reduce the disturbance of the sediments, compared to the previous practice of year-round firing.

BACKGROUND

Historical perspective

In 1990 white phosphorus (WP) was identified as the cause of waterfowl mortality in Eagle River Flats, a U.S. Army artillery impact range at Ft. Richardson, Alaska (Racine et al. 1992, 1993). Waterfowl use ERF as a resting, feeding and staging area during the spring and fall migration periods. In the past ten years, thousands of waterfowl have died annually in ERF. The WP particles found in the sediments of the shallow ponds were derived from WP smoke projectiles fired into the impact area over the years. The sediments are anoxic, allowing the particles of white phosphorus to persist for many years, posing a continual risk to waterfowl feeding in the ponds.

Firing into the impact area was suspended in February 1990. However, there is a continuing need to conduct artillery training at Ft. Richardson, and Eagle River Flats is the only feasible impact range available. Renewed artillery firing would only use high-explosive (HE) projectiles; the use of white phosphorus would be discontinued. Continued firing into ERF during the summer would cause redistribution and mixing of the bottom sediments in the shallow ponds and make buried WP particles accessible to feeding waterfowl. Winter firing into ERF has been proposed as a solution. The purpose of this study was to determine if the snow cover, ice cover and frozen ground that exist over extensive areas of ERF during the winter would isolate the sediments containing white phosphorus particles and prevent them from being disturbed or brought nearer to the surface by the explosion of artillery projectiles.

Environmental setting

Eagle River Flats, at the mouth of the Eagle River, is an 860-ha estuarine salt marsh on the south side of Knik Arm in upper Cook Inlet (Fig. 1). It is approximately triangular in shape, 2.75 km wide near the coast and 4 km long in an inland direction. It is bounded inland by a sharp topographic and vegetation boundary of spruce- and birch-covered uplands. The salt marsh is composed of a complex of landforms and vegetation zones. Natural levees occur along the banks of the river, with large expanses of sparsely vegetated mudflats along either side of the river and near the shore of Knik Arm. The backwater areas away from the river consist of zones of low sedge meadow, tall coarse sedge marsh and shallow open-water ponds (Racine

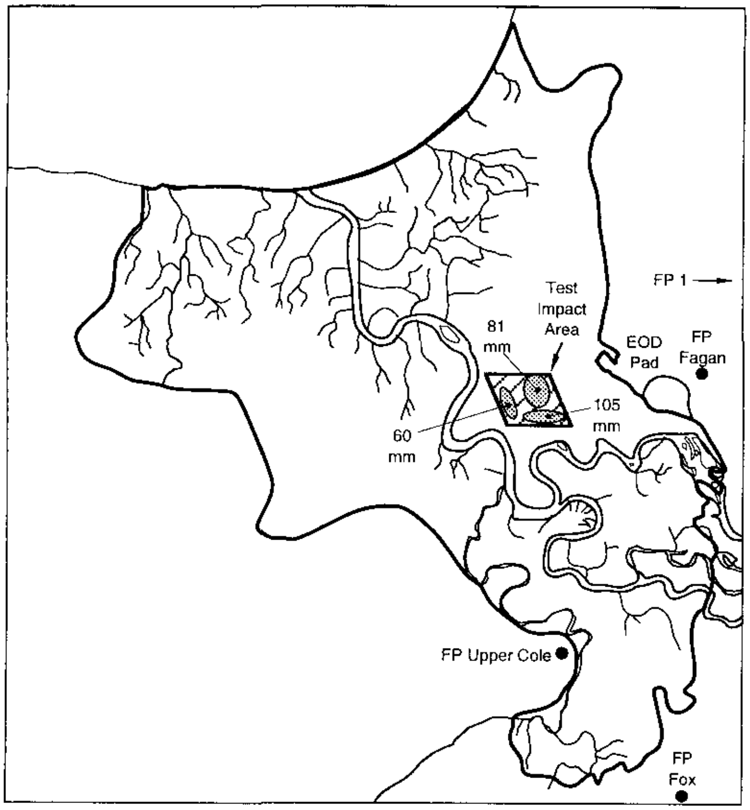


Figure 1. Eagle River Flats, showing the firing points and impact areas.

et al. 1993). The ponds, used by feeding waterfowl, are mainly located along the eastern and western perimeters of ERF. A 10-ha gravel pad (the EOD pad) is located along the eastern edge of ERF (Fig. 1). The EOD pad is a former open-burn, open-detonation disposal site.

Seasonally frozen ground

In areas of ERF without standing water, such as the mudflats, the natural levees and the tall coarse sedge marsh area adjacent to the EOD pad on the east side, the ground freezes each winter. The soils are generally saturated, and their properties generally do not vary appreciably. The soils consist of a mixture of silt and clay with a very small sand-size fraction (Racine et al. 1992). The depth of seasonal freezing primarily depends on the depth of the overlying snow cover, the frequency of tidal flooding and the seasonal air temperatures. Sediments underlying the shallow ponds along either side of the flats may or may not freeze, depending on the depth of the overlying water and whether the ice freezes completely to the bottom during the winter. In March 1991 the ground was frozen as deep as 40 cm in the tall coarse sedge marsh area adjacent to the EOD pad.

Ice cover conditions

The duration, extent and properties of the ice cover that forms over much of ERF during each winter are governed by meteorological conditions, snow cover, tidal effects, vegetation and local hydrology. The number and peak heights of high tides during the winter determine the extent of periodic inundations and the rate of ice buildup. Observations and measurements of the ice cover on a portion of ERF during the 1990-91 winter indicate a very complex situation (Taylor et al. 1994).

The extent and thickness of the ice cover are initially governed by the water surface elevations in the pond areas. The open ponds are normally the first areas to freeze over, forming congelation ice. Standing-water areas with heavy sedge and bulrush vegetation normally freeze later due to the insulating effect of the vegetation. Without tidal influences the growth of the ice sheet in the ponds will be a function of the heat loss (primarily radiation cooling and sensible heat conduction, both of which are affected by the snow cover thickness). A thin or nonexistent snow cover will promote rapid freezing; a thicker snow cover will reduce both radiative cooling and sensible heat conduction, thus reducing the rate of freezing. The weight of an even thicker snow cover, however, will exceed the buoyancy of the ice sheet, causing flooding of the sheet, saturation of the overlying snow cover and rapid ice thickening.

The role of the tides is important to both the continued growth of the existing ice sheets and extension of the area of ice cover. During a flooding high tide, water will back up in the channel of the Eagle River and then back up into the series of distributary channels and gullies that drain ERF into the Eagle River. The tide water floods out of the channels onto the mudflats and onto the ice-covered ponds; the water depth of the tide depends on the tidal elevation and the terrain features. When the water flows over an existing snow-free ice sheet or bare frozen ground when the air temperature is below freezing, a thin layer of ice is formed on the surface. This superimposed ice can be built up in multiple layers by succeeding flooding tides.

The extent and thickness of the existing snow cover also play a role in the rate of ice buildup due to tidal flooding. When snow is present, the tidal water moves laterally through the snow cover and wicks upward several centimeters into the overlying snow pack, either partially or totally saturating the snow, depending on its thickness. Water under the snow that has only partially saturated the snow cover can remain unfrozen for a considerable length of time due to the insulating properties of the overlying snow. The saturated snow, when it freezes, produces a characteristic bubbly or white "snow ice" that is less dense than the clear congelation ice. This frozen saturated snow produces a thicker ice layer than would be produced if no snow cover had been present. Most high tides do not flood the entire flats. Rather, tidal flood water spreads out from the heads of tidal distributary channels as lobes or splays of water that saturate the snow cover, freeze and build up a layer of ice several centimeters thick over a limited area. These lobes of superimposed ice are then slightly higher than the surrounding non-flooded areas. Flooding water from the next high tide will then be displaced slightly, building up a lobe of ice adjacent to the previous ice lobes. Over time, much of the area of ERF can be covered by an ice sheet built up from successive multiple lobes of ice. An occasional extreme tide may flood the entire area, adding an additional ice layer.

During the 1990-91 winter, sparsely vegetated mudflat areas that are normally subaerially exposed in the summer had 30–60 cm of superimposed ice by March. The ice thickness in the ponds ranged from 40 to 70 cm, with the ice surface of the ponds as much as 20 cm above the normal summer water surface elevation due to the superimposed ice. In the mudflat areas where a superimposed ice sheet had formed, frozen sediments were found under the ice sheet, and in some cases the sediments were frozen greater than 40 cm. The brackish water from the tidal flooding did not appear to significantly alter the ice growth rate relative to freshwater behavior. The salinity gradient in ice samples ranged from brackish (20 ppt) near the river channel to fresh (<2 ppt) in the pond near the east edge of ERF. Petrographic and chemical analysis of the ice and sediment cores taken during the 1990-91 field season indicate a complex buildup of ice from tidal flooding and some freshwater runoff (Taylor et al. 1994).

The ice cover in the Eagle River within ERF continually moves up and down because of the tidal fluctuations. The surface of the ice sheet along the banks and extending into the channel was very smooth because of the constant flux of water from successive flooding. Ridges of broken ice, 2–4 m wide, in the centerline of the channel extend over a major portion of the river reach. Wide hinge cracks were evident along both shorelines at low tide. Ice chunks and flows up to several meters in diameter were scattered along either riverbank and extended a short distance from the channel. During the high tides, parts of the ice cover detached from the bank support, broke into small floes and floated onto the Flats for a short distance, depending on the terrain topography and water depth.

Impact area description

The impact area for the test was located on the east side of the Eagle River, about 500 m west of the EOD gravel pad, and covered an area of approximately 700 × 700 m (Fig. 1). Prior to the artillery tests, we characterized the site by measuring ice thicknesses and snow depths. Six ice cores were obtained using a hand-held 7.62-cm-diameter SIPRE core barrel. Ice thicknesses varied from 30 to 60 cm, with a minimum of 25 cm and a maximum of 40 cm of frozen sediment below the ice. The snow depth ranged from 15 to 20 cm within the test impact area, with an estimated snow density of 0.3 g cm^{-3}.

Previous research on cratering

Little information is available in the literature on the cratering and demolition effects of artillery fire on ice. A few 105- and 155-mm projectiles were fired onto the Imjin River in 1977 to determine their effectiveness in breaking floating ice covers; they were not effective. Several authors have looked at the effects of explosions in ice and snow (Livingston 1960, Mellor 1965), in frozen ground (Livingston 1956, 1959, Mellor and Sellmann 1970) and in and under floating ice sheets (Mellor 1982, 1986a, 1986b). Mellor (1986a) summarized the guidelines for blasting on ice sheets and gave estimates for the sizes of craters that will form, depending on the weight of the explosive charge and its position in the ice sheet.

The traditional analysis for determining the apparent scaled radius R_a and the scaled depth D_a of craters formed by explosions uses cube-root scaling (Mellor 1986a) to remove the effect of charge size (all linear dimensions are divided by the cube root

Table 1. Predicted apparent scaled radius and depth of craters.

	*Snow**	*Ice†*	*Frozen silt***
R_a	$0.87\,M_c^{1/3}$	$0.71\,M_c^{1/3}$	$0.56\,M_c^{1/3}$
D_a	$0.3\text{–}0.5\,M_c^{1/3}$	$0.24\,M_c^{1/3}$	$0.28\,M_c^{1/3}$

M_c is the mass of the explosive charge in kilograms.
Radius and depth of craters are in meters.
*Mellor (1965)
†Mellor (1986a)
**Mellor and Sellmann (1970)

of charge mass), allowing comparisons of craters formed by explosive charges of various sizes. For surface explosions, that is, explosions with a depth ratio of zero, the predictions in Table 1 can be made for the size of craters formed in snow, ice and frozen silt using the equations presented in Mellor (1965, 1986a) and Mellor and Sellmann (1970).

For example, a 105-mm howitzer M1 projectile, containing 2.3 kg of HE, has predicted apparent radii of the craters resulting from a contact burst for snow, ice and frozen silt of 1.15, 0.94 and 0.74 m, respectively. The predicted apparent depths would be 0.40–0.66, 0.32 and 0.37 m, respectively. The differences between the apparent crater formed by an explosion vs. the true crater may be substantial; they depend on whether the charge depth is zero (i.e. at the surface) or at some depth below the surface. The apparent crater is the excavation as it appears to an observer immediately after a blast (Livingston 1960). It often contains fall-back material, defined as the loose material thrown up by the explosion that has fallen back into the crater. Excavation of the fall-back material in the crater reveals the true crater.

ARTILLERY TESTS

The test firing onto the ice of Eagle River Flats took place on 20 March 1991. The test firing was conducted in three phases. The first phase consisted of firing a series of 105-mm howitzer HE projectiles with point-detonating fuses, the type of fuse and projectile normally fired into the ERF impact area for training. A series of HE projectiles with time-delay fuses was also fired to determine if the slight delay before detonation would allow the projectile to penetrate the ice cover before exploding. The HE projectiles were fired from M101A1 105-mm howitzers of the 4th Battalion, 11th Field Artillery. The howitzers were set up at Firing Point One (FP1), 4 km east of the impact area (Fig. 1). The second phase of tests used 81-mm mortar projectiles, using both point-detonating and delay fuses, into an area just north of the 105-mm impact area. The 81-mm mortars were set up at FP Fox, 1500 m southeast of the impact area. The third phase of tests consisted of 60-mm mortar projectiles with point-detonating fuses fired into an area west of the 105-mm impact area. The 60-mm mortars were set up at FP Upper Cole, 1000 m south of the impact area. The tests were observed and photgraphed from Observation Point Fagan, 1000 m east of the impact area. Firing information for the weapons used is presented in Table 2.

After the firing we photographed and measured the apparent diameters and apparent depths of the craters. Samples of snow were collected from around the craters to analyze for explosive residues.

All the dimensions given in this report are apparent crater diameters and depths. Because of the safety constraints and time limitations, none of the craters were excavated to measure true crater dimensions. However, except for the broken ice observed in the bottom of some 105-mm-howitzer craters, most craters appeared to have little loose material in them.

The analyses of our crater measurements assume that all explosions were contact bursts. A contact burst is one in which the center of mass of the exploding charge is at the surface, giving a depth ratio of zero. In actuality, the projectile with a point-detonating fuse may penetrate the surface by some unknown amount before exploding,

Table 2. Firing information for weapons used in the tests.

Weapon	*Round*	*Barrel angle*	*HE weight*
105-mm howitzer M101A1	105-mm HE M1	350–354 mils = 19.7–19.9°	2.3 kg (5.0 lb)
81-mm mortar M252	M374-A-3-81 mm	1217–1289 mils = 68.5–72.5°	0.95 kg (2.1 lb)
60-mm mortar M224	M49-A-4-60 mm	1166 mils = 65.6°	0.19 kg (0.42 lb)

because of the small time delay between the impact on the surface and the detonation of the explosion. In softer material such as mud or deep snow, where there is no hard surface to initiate the detonation, the point-detonating fuse will detonate once it senses a loss of momentum.

Based on the results of the March 1991 test, Eagle River Flats was reopened as an impact range in January 1992. Training began again in ERF on 7 January 1992, when the 4th Battalion, 11th Field Artillery fired a series of 105-mm howitzer projectiles into the impact range as part of a training exercise. Most projectiles impacted on the ice-covered levee and mudflats near the river. Several projectiles impacted on the ice-covered shallow ponds near the east side of the impact area. After the firing was completed we were able to measure several of the craters formed in the ice of the shallow ponds. We wanted to compare the effects of exploding 105-mm howitzer projectiles on a floating ice sheet with our previous observations on the effects on grounded ice and frozen ground. We also compared the measured crater parameters with the predicted parameters for explosives on floating ice.

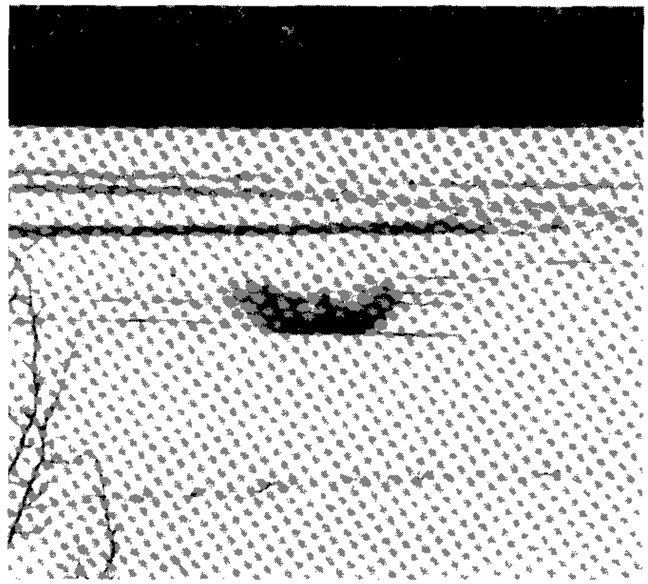


Figure 2. Explosion of a 105-mm HE projectile in the test area.

RESULTS

105-mm howitzer test firing

Eight high-explosive 105-mm projectiles with point-detonating fuses were fired into the impact area. Seven of the eight projectiles detonated on contact with the ice (Fig. 2). The impact area had a 20-cm snow cover on the ice sheet, and the ice thickness varied from 0.30 to 0.60 m. The measurements of seven craters are included in Table 3 (craters no. 1–6 and 9); all values are for the apparent craters. All seven measured craters were oblong in shape, probably due to a low impact angle caused by the low firing angle (19.7–19.9°). The longest axis of the craters ranged from 2.26 to 3.63 m, and the shortest axis ranged from 1.89 to 3.05 m. The mean lengths for maximum and minimum axes were 3.17 and 2.45 m, respectively. This gives a mean apparent diameter of 2.81 m, or a mean apparent radius R_a of 1.41 m. The seven measured craters were shallow, between 0.2 and 0.44 m, with a mean apparent depth of 0.32 m. In all but one case, the ice sheet was still intact, with only a 0.6- to 1.0-m-diameter area of broken ice in the center of the crater (Fig. 3).

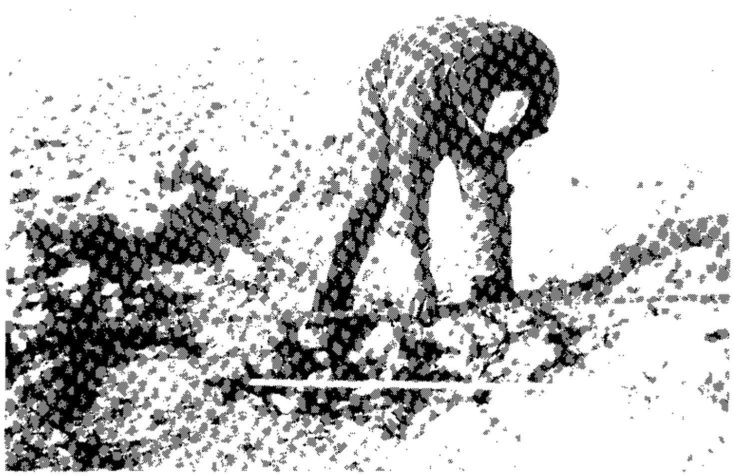


Figure 3. Crater formed by a 105-mm HE projectile.

Table 3. Measurement data from craters.

Crater no.	Description	Maximum axis (m)	Minimum axis (m)	Center depth (m)	Snow depth (m)	Notes
105-mm howitzer						
1	PD	2.26	1.89	0.30	0.20	
2	PD	2.90	2.10	0.44	0.20	1.2- × 0.6-m area of ground exposed at bottom of crater.
3	PD	3.29	2.50	0.37	0.20	
4	PD	3.38	2.32	0.39	0.20	
5	PD	3.20	2.77	0.30	0.20	
6	PD	3.63	2.50	0.27	0.20	0.6-m area in center where ice shattered.
7	D	1.07	0.61	—		Point where projectile ricocheted.
9	PD	3.54	3.05	0.20	0.20	0.6-m area of shattered ice in center.
8	D	7.62	2.44	0.20	0.20	Shallow, elongated crater. Ricocheted projectile blew up near surface.
10	D	3.00	2.40	0.35	0.20	
81-mm mortar						
1	PD	2.59	2.29	0.15	0.15	Bottom of crater is on top of ice sheet.
2	PD	2.49	2.29	0.16	0.15	
3	PD	2.26	1.86	0.16	0.15	
4	D	1.83	1.83	0.17	0.15	
5	D	Camouflet				Not measured.
6	D	Camouflet				0.6- × 2-m mound of ice rubble. 0.6-m-diam × approx. 1.8-m-deep crater hidden under rubble.
60-mm mortar						
1	PD	1.83	1.83	0.21	0.21	Depth of crater is equal to depth of snow on ice sheet, i.e. bottom of crater is top of ice sheet.
2	PD	1.83	1.52	0.15	0.15	
3	PD	1.80	1.89	0.18	0.18	0.10-m-diam × 0.08-m-deep hole in ice in exact center. Fuse parts in hole.
4	PD	1.83	1.52	0.22	0.20	
5	PD	1.83	1.83	0.17	0.17	

* PD = point-detonating fuse
D = delay fuse.

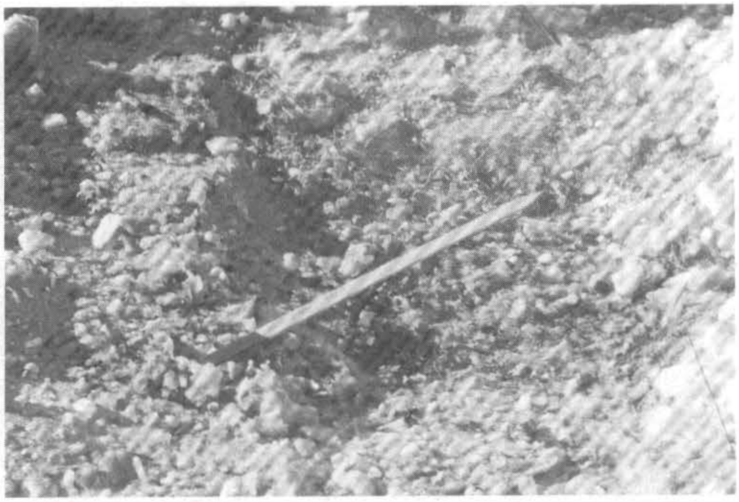


Figure 4. Ice lifted out of the bottom of crater no. 2, exposing frozen ground.

In one crater (no. 2 in Table 3), a 1.2- × 0.6-m area of the 0.25-m ice sheet was completely lifted and blown out of the crater, exposing the frozen ground underneath. The exposed frozen ground was not visibly disturbed or removed by the explosion (Fig. 4). There was no cratering of the frozen ground beneath the ice. One of the eight point-detonating projectiles was a dud, creating only a white plume of snow and ice when it hit the ice surface. The dud projectile produced a small crater estimated to be less than 1 m in diameter and of unknown depth; we did not measure this crater for safety reasons.

Figure 5. Ricocheting projectile exploding near the ice surface. The white plume of snow and ice shows where the projectile initially hit, and the explosion was just beyond it.

Four 105-mm projectiles with delay fuses were fired into the test area; three ricocheted off the ice before exploding, and one detonated in the snow and ice cover similar to the point-detonating projectiles. Figure 5 shows one ricocheting projectile exploding near the ice surface. This explosion produced a shallow elongated crater (no. 8) in the snow (Fig. 6), approximately 2.4 m wide at the near end, narrowing down to 0.6 m wide at the far end and 7.6 m long. Two ricocheting projectiles exploded in the air. Figure 7 shows the white plume of snow and ice where the projectile first hit and the dark explosion cloud high in the air (50 m?), near the skyline. The ricocheting projectile produced a small crater (no. 7), 1.07 × 0.60 m. The one delay-fused projectile that appeared to detonate normally produced a crater (no. 10) similar to those of the point-detonating fused projectiles, measuring 3.0 × 2.4 × 0.35 m.

All of these test firings of point-detonating and delay-fused 105-mm projectiles were done at a low angle of fire (19.7–19.9°). This is the standard procedure for firing into the impact range for training, with the projectiles reaching the target in the shortest time. A target can also be engaged from the same firing point with a high angle of fire, producing a high parabolic flight path, a longer flight time and a more vertical impact angle. Delay-fused 105-mm projectiles fired at a high angle would not

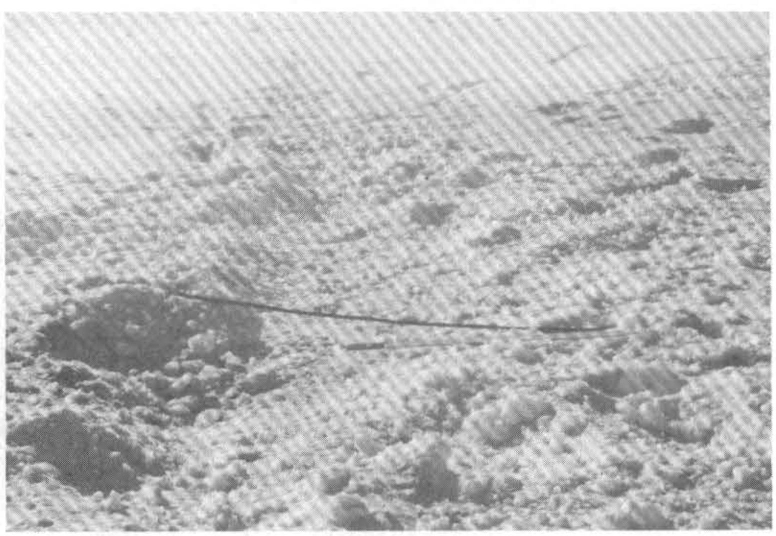


Figure 6. Shallow elongated crater produced by a ricocheting delay-fused projectile.

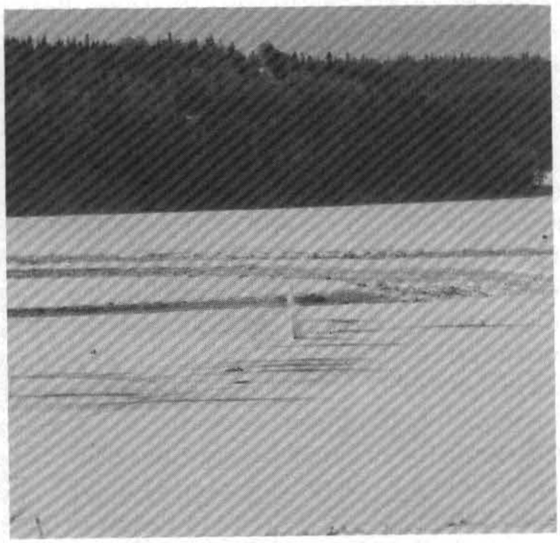


Figure 7. Ricocheting delay-fused projectile exploding high in the air.

be expected to ricochet but would penetrate the ice sheet before exploding, similar to the 81-mm delay-fused mortar projectiles discussed below.

81-mm mortar test firing

Both point-detonating and delay-fused 81-mm projectiles were fired during the test. Several of the mortar projectiles fell in the river and were inaccessible to us. We measured three craters formed by point-detonating projectiles. These craters averaged 2.45 × 2.15 m in diameter (Table 3), and they were more nearly circular than the howitzer craters, probably because of the higher trajectory of the mortar projectile. The mean apparent radius of the craters was 1.15 m.

The mean depth of the craters was 0.16 m, with most of the depth caused by removal of the 0.15-m-thick snow cover. A shallow depression was blown in the underlying ice cover in the center of the craters,

Figure 8. Crater formed by a point-detonating 81-mm mortar projectile on grounded ice.

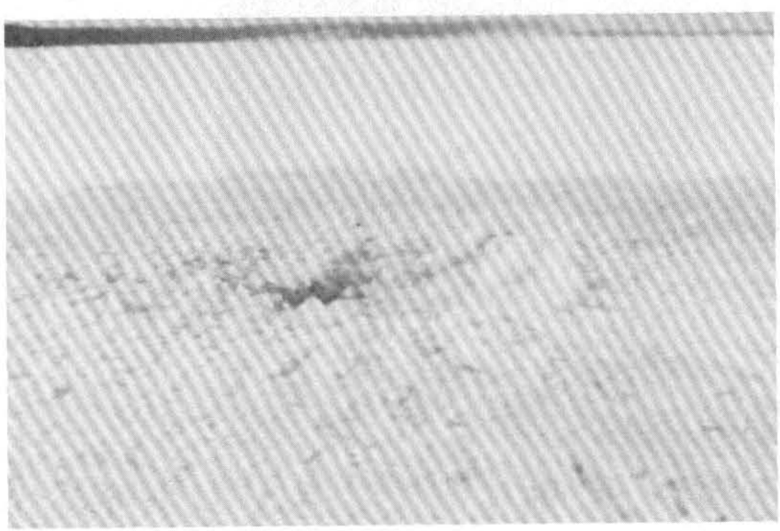


Figure 9. Crater formed by a point-detonating 81-mm mortar projectile on a floating ice sheet.

but the ice was not broken or penetrated by the explosions (Fig. 8).

One of the point-detonating projectiles landed on the ice of a shallow pond north of the main impact area. The ice cover on the pond was 40 cm thick over about 30 cm of water. The crater (no. 1) produced by this projectile (Fig. 9) looked no different from the craters (no. 2 and 3) produced by projectiles landing on areas of grounded ice over frozen ground (Fig. 8).

Three delay-fused 81-mm projectiles (no. 4–6) landed in an area of grounded ice over frozen ground in the center of the test impact area. The cloud produced by the explosion of the 81-mm mortar projectiles was noticeably smaller than that produced by the 105-mm howitzer projectiles. The crater (no. 4) produced by the first projectile was similar to the 81-mm point-detonating projectiles but smaller and slightly deeper.

The second and third delay-fused projectiles each produced a camouflet, or a hidden crater. The projectiles penetrated the ice cover and the underlying frozen and unfrozen sediments before exploding. The confining strengths of the ice, the upper seasonally frozen sediment and the underlying saturated unfrozen sediment allowed the explosion to be confined and prevented it from ejecting material and producing a surface crater. The only evidence of the two camouflets was conical mounds of broken ice rubble, one of which measured 0.6 m high and 2 m in diameter (Fig. 10). Closer inspection and judicial digging into the mound by the EOD escort revealed a nearly vertical hole 30 cm in diameter and 1.5 m deep (Fig. 11).

Figure 10. Camouflet formed by a delay-fused 81-mm mortar projectile.

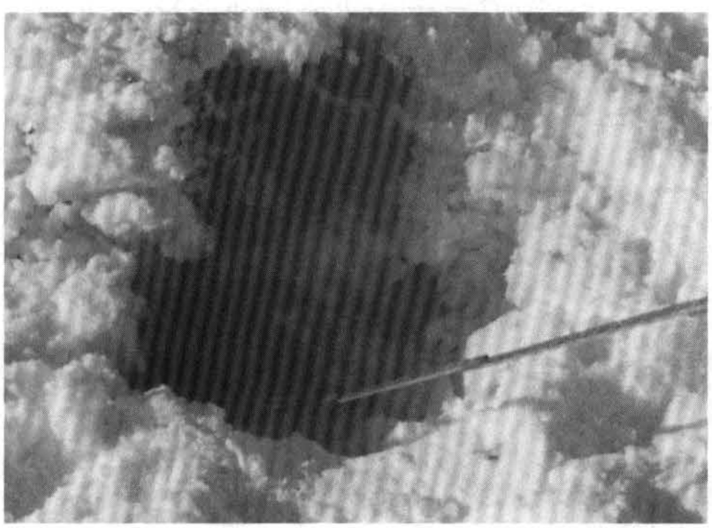


Figure 11. Nearly vertical hole in the camouflet.

seven craters was 1.07 m/kg$^{1/3}$. This is considerably larger than the predicted R_a of 0.71 m/kg$^{1/3}$ for ice and is out of the range of the scaled crater radius data for ice (Mellor 1986a). If we use the estimates for the scaled apparent radius of a crater in snow (Mellor 1965) instead of ice, we get closer agreement between the predicted and measured crater radii. The predicted value would be 0.87 m/kg$^{1/3}$ vs. the measured 1.07 m/kg$^{1/3}$.

The size of a crater created by an explosion increases as the depth of the explosive charge below the surface increases up to a certain depth, known as the critical depth. If we assume that the projectile did not explode at the surface but penetrated through the snow and a short distance into the ice (<0.05 m) before exploding, then the data would be within the maximum range of experimental data for ice presented by Mellor (1986a). However, there is no field evidence that the projectiles did penetrate into the ice before exploding.

The seven measured craters had a mean apparent depth of 0.32 m. This gives a scaled apparent depth of 0.25 m/kg$^{1/3}$, much shallower than the predicted depth for snow but almost the same as the predicted value given by Mellor (1986a) for ice. Obviously these comparisons are complicated by several factors. The experimental data used by Mellor in developing the scaled radius relationships were produced by static spherical explosive charges placed on the snow or ice surface. The artillery tests used a cylindrical projectile traveling at high velocity. The experimental data were for a single, uniform, semi-infinite-depth medium; we had a relatively thin, multiple-layered medium with quite different densities and structural properties.

The interaction of the snow and ice layer may explain the differences in crater size. As the 105-mm HE projectile penetrates the snow cover and the point-detonating fuse contacts the ice surface, the projectile explodes, producing a shock wave. The shock wave collapses the snow cover as it propagates downward and outward. Snow is a very good absorber of shock wave energy (Johnson et al. 1991, 1992), so the snow cushions part of the explosion. Part of the shock wave propagating downward will be reflected back off the snow–ice interface; this may increase the radius of the crater formed in the snow layer. Part of the shock wave will continue downward through the ice layer, hitting the ice–frozen soil interface. Part of the wave will then be reflected back up. This reflected wave, traveling back upward through the ice, can pop portions of the ice layer out of the crater without damaging the underlying frozen ground, as seen in one of the craters (Fig. 4). These reflected waves, traveling upward through the ice, may reduce or cancel later shock waves penetrating downward, thus reducing the total effect of the explosion.

81-mm mortar test results

The mean apparent radius of the three craters formed by point-detonating fused projectiles was 1.15 m, resulting in a scaled radius of 1.17 m/kg$^{1/3}$. The craters were almost entirely confined to the snow layer on top of the ice. The measured scaled radius is higher than the predicted scaled radius of a crater in snow from a surface-placed explosive.

The mean depth of the craters was 0.16 m, giving a scaled depth of 0.16 m/kg$^{1/3}$. Because the snow layer was shallow (0.15 m) and the crater was almost entirely confined to this layer, the scaled depth may be low because of the reflection of the shock wave off the ice layer, inhibiting the crater depth development.

60-mm mortar test results

Craters formed by the 60-mm mortar projectiles had a mean apparent radius of 0.88 m, or a scaled apparent radius of 1.53 m/kg$^{1/3}$. The craters were entirely confined to the snow layer. The measured scaled apparent radius was much higher than the predicted scaled radius of 0.87 m/kg$^{1/3}$. The measured scaled depth was 0.33 m/kg$^{1/3}$; this is very close to the predicted scaled depth for snow.

January 1992
105-mm howitzer firing results

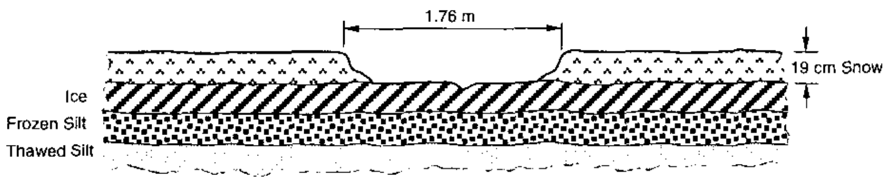
The mean apparent radius of the outer craters formed in the snow on the ice sheet of shallow ponds was 1.72 m. The mean scaled apparent radius of the six craters was 1.30 m/kg$^{1/3}$. This is considerably larger than the predicted R_a of 0.87 m/kg$^{1/3}$ for snow, even larger than the differences noted in the March 1991 test firing. The mean apparent radius of the six inner craters or holes formed in the ice sheet of shallow ponds was 0.68 m. The mean scaled apparent radius of these inner craters is 0.90 m/kg$^{1/3}$, very close to the predicted scaled apparent radius of 0.94 m/kg$^{1/3}$ for ice.

The mean depth of the inner craters was 0.68 m, or a scaled depth of 0.52 m/kg$^{1/3}$. It is difficult to compare this to a predicted depth, since the inner crater completely pierced the ice sheet and extended into the soft pond bottom sediments below the ice.

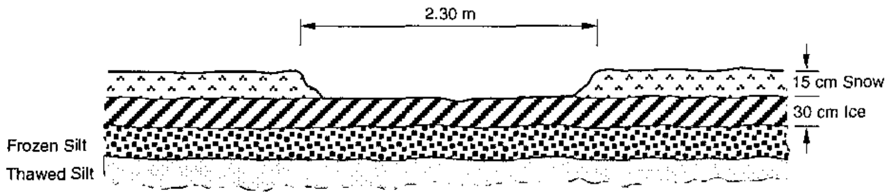
CONCLUSIONS

The sizes of craters we measured during these tests were all larger than predicted from previous data for static spherical explosive charges set on the snow or ice surface. The mean scaled apparent radius of the craters formed by 105-mm point-detonating projectiles was 23% greater than predicted for a crater in snow and 50% greater than predicted for ice, 1.07 vs. 0.87 and 0.71 $m/kg^{1/3}$. The mean scaled apparent radius of the 81-mm point-detonating projectile craters was 1.17 $m/kg^{1/3}$, 34% larger than the predicted scaled apparent radius in snow and 65% larger than the predicted radius in ice. The 60-mm mortar projectiles produced craters confined to the shallow snow layer, with a mean scaled apparent radius of 1.53 $m/kg^{1/3}$, fully 76% larger than the predicted scaled radius in snow. The equations developed by Mellor (1986a) for predicting the scaled radius from experimental data greatly underestimate the radius of craters in layered snow and ice produced by artillery projectiles. On the other hand, the scaled depths of the artillery craters were similar to or less than the predicted depths; 0.25 vs. 0.4 and 0.24 $m/kg^{1/3}$ in snow and ice for the 105-mm projectiles, 0.16 vs. 0.4 and 0.24 $m/kg^{1/3}$ in snow and ice for the 81-mm mortars, and 0.33 vs. 0.40 $m/kg^{1/3}$ in snow for the 60-mm mortars.

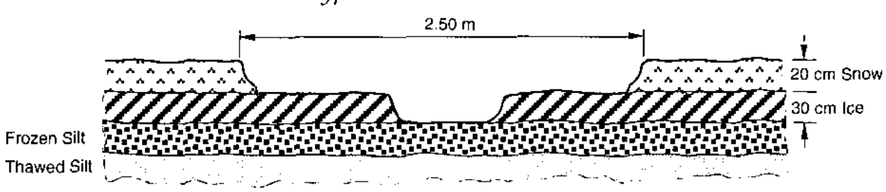
The shapes of the craters formed were influenced by the multiple-layered medium of snow, ice and frozen ground into which the firing took place (Fig. 14). The greater-than-predicted radii of the craters



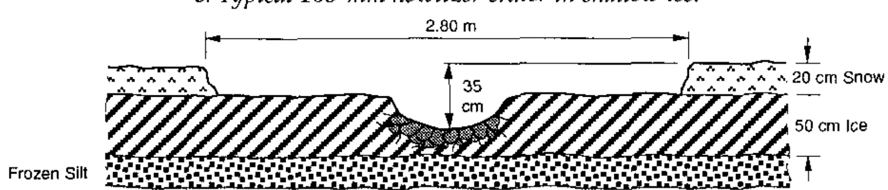
a. Typical 60-mm mortar crater.



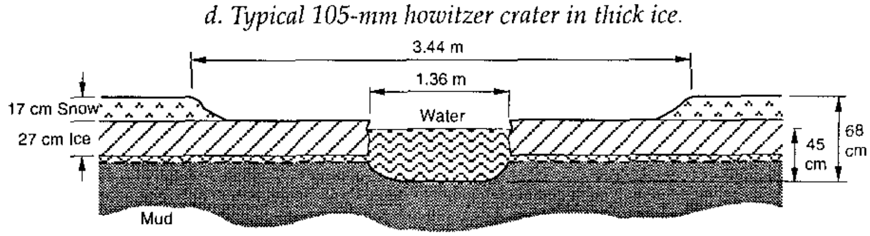
b. Typical 81-mm mortar crater.



c. Typical 105-mm howitzer crater in shallow ice.



d. Typical 105-mm howitzer crater in thick ice.



e. Typical 105-mm howitzer crater in a floating ice sheet.

Figure 14. Typical crater cross sections.

can be attributed to the multiple-layered medium. The reflections of the shock waves off the multiple interfaces tended to decrease the depths of the craters, especially in the ice layer, and increase the radii of the craters in the snow layer.

In all cases the underlying frozen sediments were not disturbed when point-detonating projectiles were fired into Eagle River Flats with the ground frozen and covered with a 0.30- to 0.60-m ice sheet and 0.15- to 0.20-m of snow. The craters formed by point-detonating projectiles of both mortars and 105-mm howitzers were confined to the overlying snow and ice sheet. With the exceptions of one 105-mm and one 60-mm dud, all of the point-detonating projectiles performed satisfactorily. Delay-fused projectiles operated very erratically in areas with frozen ground and an ice cover.

The mean scaled apparent radius of craters we measured in January 1992 formed by 105-mm point-detonating projectiles in the ice sheet of shallow ponds were very close to those predicted from previous data for static spherical explosive charges set on the ice surface, 0.90 vs. 0.94 $m/kg^{1/3}$. However, the measured vs. scaled apparent radius of the outer crater in the shallow snow cover was 50% greater than predicted, again indicating the difficulty in predicting crater size in a shallow, multi-layered medium such as a thin snow layer over ice (Fig. 14).

In summary, based on the results of the test firing and observations of subsequent firing, winter firing into Eagle River Flats under conditions similar to those during the tests will not disturb the underlying sediments containing white phosphorus particles. For 105-mm howitzers, a minimum of 25 cm of ice over frozen sediment or a minimum of 30 cm of floating ice over shallow water is required. For 60- and 81-mm mortars, minimums are much less, on the order of 10 cm of ice. Winter firing with point-detonating projectiles when a sufficiently thick snow and ice cover is present appears to be the best approach to training in Eagle River Flats to prevent disturbance and mixing of the WP-contaminated sediments.

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REPORT DOCUMENTATION PAGE

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1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
January 1995

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
Analysis of Artillery Winter Test Firing into Eagle River Flats, Fort Richardon, Alaska

5. FUNDING NUMBERS

6. AUTHORS
Charles M. Collins and Darryl J. Calkins

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Cold Regions Research and Engineering Laboratory
72 Lyme Road
Hanover, New Hampshire 03755-1290

8. PERFORMING ORGANIZATION REPORT NUMBER
Special Report 95-2

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Directorate of Public Works
Sixth Infantry Division (Light)
Fort Richardson, Alaska

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

Available from NTIS, Springfield, Virginia 22161

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

Winter tests of artillery firing were conducted in the Eagle River Flats impact range to determine the physical effects of exploding high-explosive (HE) projectiles on the ice-covered terrain. Eagle River Flats is an estuary at the mouth of the Eagle River used as the artillery impact range for Ft. Richardson. The Army suspended use of the impact range following the discovery that white phosphorus (WP) deposited in the salt marsh was responsible for large numbers of waterfowl deaths each summer. The purpose of these tests was to assess if seasonal firing of HE projectiles from 60- and 81-mm mortars and 105-mm howitzers into Eagle River Flats could be resumed without significantly disturbing the sediments contaminated with WP. The results of the test firings indicated that a minimum of 25 cm of ice over frozen sediment or a minimum of 30 cm of floating ice over shallow water was required to prevent disturbance of the WP-contaminated sediment by exploding 105-mm howitzer projectiles. Only 10 cm of ice was required to prevent disturbance by exploding 60- and 81-mm mortar projectiles.

14. SUBJECT TERMS
Artillery
Eagle River Flats
High-explosive projectiles
Ice-covered terrain

15. NUMBER OF PAGES
21

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

Attachment 3
2001 and 2005 Record of Environmental Consideration Modified Firing Regimes

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RECORD OF ENVIRONMENTAL CONSIDERATION

TITLE: Modified Firing Regime for the Eagle River Flats Impact Area, Fort Richardson, Alaska

DESCRIPTION OF PROPOSED ACTION: The proposed action will afford the USARAK command more flexibility for conducting necessary firing activities within the Eagle River Flats (ERF) Impact Area. The following is a list of restrictions as they pertain to specific types of ammunition fired into the ERF Impact Area:

a. Helicopter Door Gunnery (Small Arms)

1. No firing activities will be conducted while any waterfowl are present in the ERF (normally November through April).
2. No Wildlife will be purposely killed, injured or targeted.

b. High Explosive Proximity Fuse (VT) Rounds

1. No firing activities will be conducted during ERF Clean-up and monitoring operations when equipment and personnel are actively deployed (normally from April to mid October).
2. No firing activities will be conducted in the spring once waterfowl begin arriving (as determined by DPW Environmental Department and Range Control). This normally occurs in early April.
3. No firing activities will be conducted in the fall until the majority of waterfowl have departed (normally from mid to late October) as determined by DPW Environmental Department and Range Control. This determination will be made when no more than 25 swans and 100 ducks are sighted in the ERF for three consecutive days.

c. Illumination Rounds

No firing activities will be conducted during ERF Clean-up operations when equipment and personnel are actively deployed for the **remediation phase** (normally May through September).

d. High Explosive Point Detonated Rounds

Mortar (60mm & 80mm)

No firing activities will be conducted when there is less than two inches of ice cover on water bodies within the ERF.

Artillery (105mm)

No firing activities will be conducted when there is less than five inches of ice cover on water bodies within the ERF

ANTICIPATED DATE AND / OR DURATION OF PROPOSED ACTION: The new firing regime for the ERF Impact Area is anticipated to begin Fall 2001 and remain in place until the situation or changing conditions dictate.

MITIGATION AND / OR SPECIAL CONDITIONS: The aforementioned stipulations for this modified firing regime are based on conditions and activities normally associated with the ERF Impact Area. In the event that such conditions change, firing activities will conform to whatever schedules may be necessary to insure safety, regulatory compliance and environmental protection.

CATEGORICAL EXCLUSION: This action is determined to be adequately covered in an Environmental Assessment entitled: Resumption of Firing in the Eagle River Flats Impact Area, Fort Richardson, Alaska, December 1991.

Prepared by: William A. Gossweiler
WILLIAM A. GOSSWEILER
Environmental Resources Department
Fort Richardson, Alaska

Reviewed by: Crystal Fosbrook
DOUGLAS W. JOHNSON, Chief
Environmental Resources Department
Fort Richardson, Alaska

Proponent: ______
LAWRENCE E. FUSSNER
LTC, GS
Director of Plans, Training, Security, and Mobilization
Fort Richardson, Alaska

Approved by: ______
DAVID B. SNODGRASS
LTC (P), EN
Directorate of Public Works
Fort Richardson, Alaska

OCT 9 2001

RECORD OF ENVIRONMENTAL CONSIDERATION

TITLE: Modification of Munitions Firing at Eagle River Flats Impact Area, Fort Richardson, Alaska.

DESCRIPTION OF PROPOSED ACTION: Since 1945, the Army has used Eagle River Flats (ERF) as an impact area for artillery, mortars, rockets, grenades, illumination flares, and aerial door gunnery. In the 1980s high numbers of dead waterfowl were discovered at ERF. The high waterfowl mortality rate was initially assumed to be associated with munitions firing. Based on the assumption that munitions were the cause of waterfowl mortality at ERF, the Army temporary suspended firing at ERF in 1990.

In 1991 the Army identified white phosphorus (WP) as the cause of waterfowl mortality at ERF and banned the use of WP in wetland areas, including ERF. Additionally, in 1991 the Army completed an Environmental Assessment (EA) for the Resumption of Firing in the Eagle River Flats Impact Area, Fort Richardson, Alaska and associated Finding of No Significant Impact (FNSI) to resume firing munitions (except WP) at ERF. The "Winter Firing Alternative" was selected as the preferred alternative for resumption of firing at ERF. This alternative restricted firing at ERF to winter periods when sufficient ice was present to protect (prevent disturbance of) underlying WP-contaminated sediments. The EA did not specify ice thicknesses for specific munitions, but instead indicated that sufficient ice thickness would be determined through evaluation. The selected alternative also restricted the types of munitions used at ERF to those that had been previously used prior to the temporary firing suspension. New munitions were to be evaluated for impacts to WP-contaminated sediments prior to use at ERF.

Live fire exercises were conducted at ERF in 1991 and 1992 to evaluate the impact of mortars (60-mm and 81-mm) and artillery (105-mm) on WP-contaminated sediments. Initial testing indicated that the mortars (both 60-mm and 81-mm) had minimal impact to frozen sediments and/or ice. The 105-mm howitzer rounds created craters in the ice that were about five inches deep.

The current firing restrictions at ERF include a requirement for two inches of ice formation prior to firing point-detonated mortars (60-mm and 81-mm) and five inches of ice formation prior to firing 105-mm point-detonated artillery rounds. The sole reason these restrictions are in place is to prevent WP-contaminated sediments (where present in ERF) from being disturbed or redistributed, resulting in potential waterfowl mortality. It is critical to note that after six years of WP cleanup work at ERF approximately 95 percent of the area has been remediated. Thus, for about 95 percent of the ERF area potential disturbance of WP-contaminated sediments is no longer a concern.

The Army proposes to initiate firing of 40-mm grenades and 120-mm mortars at the ERF Impact Area. These munitions have not been previously used or tested at ERF. The net explosive weight (NEW) of the new munitions was compared to the NEW of the previously tested munitions (60-mm and 81-mm mortars; 105-mm artillery) to determine potential impacts.
The 40-mm grenade (M383 LNKD) has a NEW of 0.1402 pounds (lbs), much less than the NEW of an 81-mm mortar (M374/A3), which has a NEW of 2.428 lbs. As mentioned previously, the 81-mm mortars had no impact to sediments covered with a minimum of two inches of ice. Thus, based on the NEW of the respective munitions, firing 40-mm grenades at ERF will not cause disturbance of WP-contaminated sediments under conditions suitable for firing point-detonated mortars.

The 120-mm mortar (M933) has a NEW of 7.9177 lbs, slightly less than the NEW for a 105-mm howitzer round (M1) that is 7.96 lbs. Testing conducted in 1991 using 105-mm howitzer rounds indicated that five inches of ice cover over frozen sediments was adequate to prevent disturbance of any underlying WP contamination. Since the 120-mm mortars have a lower NEW than the 105-mm howitzer rounds, the 120-mm mortar will create a smaller crater than the 105-mm howitzer rounds and would result in no adverse effect.

RECORD OF ENVIRONMENTAL CONSIDERATION (continued)

TITLE: Modification of Munitions Firing at Eagle River Flats Impact Area, Fort Richardson, Alaska.

ANTICIPATED DATE AND/OR DURATION OF THE PROPOSED ACTION: The new firing regime for the ERF Impact Area is anticipated to begin in late January 2005 and remain in place as long as adequate ice thickness conditions are present (two inches for the 40-mm grenades and five inches for the 120-mm mortars).

ENVIRONMENTAL FACTORS AND CONSIDERATION: The potential impacts associated with the firing of the 120-mm mortars and 40-mm grenades are comparable with the 105-mm howitzer rounds and the 81-mm mortars that were analyzed in the Resumption of Firing in the Eagle River Flats Impact Area, Fort Richardson, Alaska Environmental Assessment (December 1991). This document thoroughly evaluated the potential environmental impacts associated with the types of firing activities that are being contemplated under this action. Accordingly, the proposed action does not represent any activity of which the potential environmental impact has not been thoroughly evaluated.

MITIGATION AND/OR SPECIAL CONDITIONS: An initial test firing will be conducted with 120-mm mortars and 40-mm grenades to validate the ice crater depth comparisons made with the 60-mm and 81-mm mortars and the 105-mm artillery on the ice at ERF. Initial testing will be conducted in mid to late January 2005. Current ice thickness data from ERF (12 January 2005) indicate that the ice thickness is about varies from about 12 to 20 inches, much greater than the current requirement for firing 105-mm howitzer rounds at ERF. Because the 120-mm mortars are expected to have less impact (smaller craters) than the 105-mm howitzer rounds, the current ice conditions will ensure that WP-contaminated sediments are not disturbed during the initial test firing. Subsequent to the testing, the Army will establish formal ice thickness for firing 120-mm mortars and 40-mm grenades at ERF. All firing activities associated with this action will be conducted in accordance with Army range regulations. Changes or modifications to the scope of this project require further coordination with the USAG-AK Environmental Office.

CONCLUSIONS: This action is determined to be adequately addressed in an Environmental Assessment entitled: Resumption of Firing in the Eagle River Flats Impact Area, Fort Richardson, Alaska, December 1991. The environmental impacts associated with the firing of the 120-mm mortars and 40-mm grenades are comparable in degree or type from those analyzed in the 1991 EA. The proposed action would not degrade the existing environment and it would not adversely affect environmentally sensitive resources.

RECORD OF ENVIRONMENTAL CONSIDERATION (continued)

TITLE: Modification of Munitions Firing at Eagle River Flats Impact Area, Fort Richardson, Alaska.

Prepared by:

JAN 14 2005

FOR VICTORIA L. REARDON
Research Associate
Environmental Department, DPW

Reviewed by:

14 JAN 05

TERRY BOONE
Chief, Environmental Department
Directorate of Public Works

Approved by:

Allan D. Lucht JAN 18 2005

ALLAN D. LUCHT
Director
Directorate of Public Works

Attachment 4
Standard Operating Procedure for Measuring Ice Thickness at Eagle River Flats Impact Area

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DEPARTMENT OF THE ARMY
INSTALLATION MANAGEMENT COMMAND
HEADQUARTERS, U.S. ARMY GARRISON, ALASKA AND FORT RICHARDSON (PROV)
724 POSTAL SERVICE LOOP #6000
FORT RICHARDSON, ALASKA 99505-6000

REPLY TO
ATTENTION OF:

IMPC-FRA-PWE

MEMORANDUM FOR RECORD

SUBJECT: Standard Operating Procedure (SOP) for Measuring Ice Thickness at Eagle River Flats (ERF) Impact Area, Fort Richardson, Alaska (FRA)

1. **Purpose**: The purpose of this directive is to establish standard procedures and proponents for measuring ice thickness within the ERF Impact Area. Ice thickness data will be used to determine whether adequate conditions exist to proceed with the firing of explosive munitions into the ERF Impact Area in accordance with existing policy and restrictions.

2. **Objective**: Ensure that consistent and representative ice thickness measurements are obtained to determine adequacy of ice cover prior to firing explosive munitions into the ERF Impact Area.

3. **Procedure for obtaining access to range and impact areas**:

a. ERF is an active impact area (dud-contaminated) where there is a high probability for encountering unexploded ordnance (UXO). All personnel entering the ERF Impact Area are required to be thoroughly briefed on the hazards of UXO and comply with all regulatory guidance in U.S. Army, Alaska (USARAK) Regulation 350-2, Army Regulation 385-63, DA Pam 385-63, and other governing regulations and certifications.

b. For safety reasons, at least two (2) personnel must be present during ice thickness assessment activities. Personnel entering the permanent impact area will be accompanied by a member of the USARAK Explosive Ordinance Disposal (EOD) unit or by other similarly qualified personnel in accordance with USARAK Regulation 350-2. Cold weather and dangers associated with accessing areas with unknown ice cover present potential hazards to personnel.

c. Testing will be initiated at the request of, and coordinated with, the Installation Range Officer (IRO) or his designee. Ice thickness testing must be conducted in advance of the first training event of the winter season that includes the use of point-detonating-fuzed ammunition. The IRO (or designee) will provide sufficient advance notice to the party performing the testing to allow the necessary planning and coordination with EOD. EOD availability is dependent on its manpower resources and established priorities.

d. The access roads and survey areas must be surface-cleared of UXO and/or other safety hazards prior to entry. This surface-clearing must be conducted before substantial snow cover is present. All UXO survey work must be performed by qualified personnel in accordance with USARAK Regulation 350-2.

4. **Location of Ice Thickness survey sites**:

a. Three locations have historically been used to assess ice thickness within the ERF impact area. Those locations are shown on Figures 1A and 1B and are designated locations Alpha, Bravo and Charlie. All three locations can be easily accessed from the trail system, provide adequate characterization of the ERF area and must be cleared by EOD prior to personnel entering the Permanent Impact Area. All three sites are located over ponds that are representative of open water conditions elsewhere in the ERF Impact Area. The ponds, when flooded, are at least five feet deep.

b. Global Positioning System (GPS) coordinates for the locations are as follows: Alpha (A) – (N)6765824.69, (E)358074.79; Bravo (B) – (N)6765983.14, (E)358006.09; and Charlie (C) – (N)6766334.54, (E)357968.52.

5. **Procedure for measuring ice thickness**:

a. Locations at which ice thickness is to be measured must be surface-cleared to ensure that the site is clear of UXO and/or other safety hazards. All UXO survey operations must be conducted by qualified personnel in accordance with USARAK Regulation 350-2.

b. The basic procedure is to cut holes in the ice at the locations indicated in Section 3. A hand axe or ice auger is used to make a hole in the ice large enough to insert the measuring device. At least two holes are to be drilled at each site to ensure adequate coverage for an accurate assessment.

c. An L-shaped measuring tool, shown in Figure 2, is inserted through the hole and hooked under the bottom edge of the ice. Any surface snow cover is removed and the measuring tool is pulled up against the bottom of the ice sheet and the thickness of the ice is determined by recording the reading of the ruled edge corresponding to the top surface of the ice (see Figure 2). The proponent agency is responsible for procurement/fabrication of the required tool.

d. If frozen or partially frozen sediments are encountered immediately under the ice, determine the location of the boundary between the ice and sediments. Place the top surface of the bottom L portion of the L-formed tool at the boundary and record a thickness measurement as indicated previously.

e. Record all applicable data on the Ice Thickness Testing Report form. Indicate findings in the appropriate area in the Conclusions section.

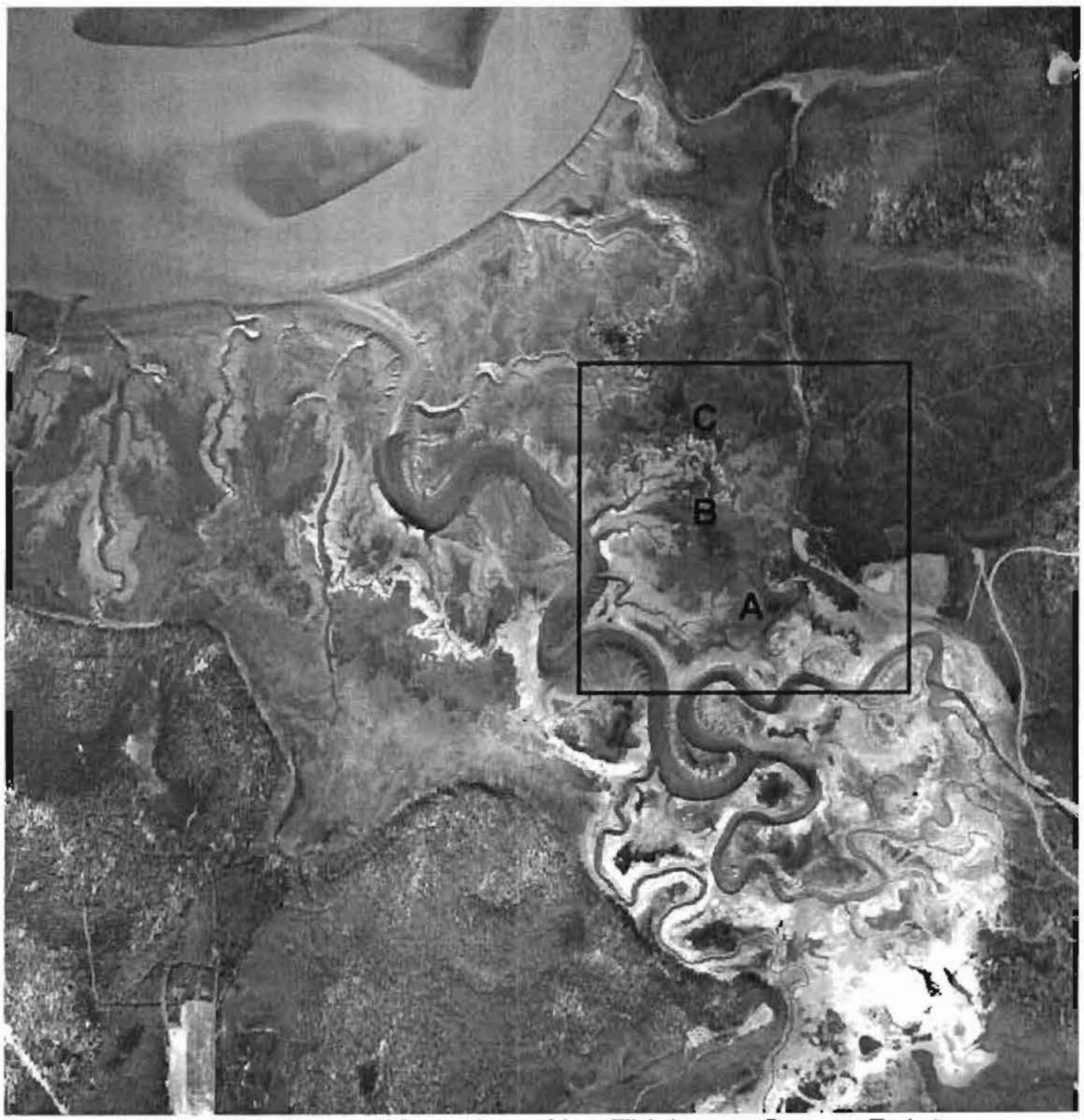


Figure 1A: General Location of Ice Thickness Survey Points.

Figure 1B: Location of Ice Thickness Survey Points

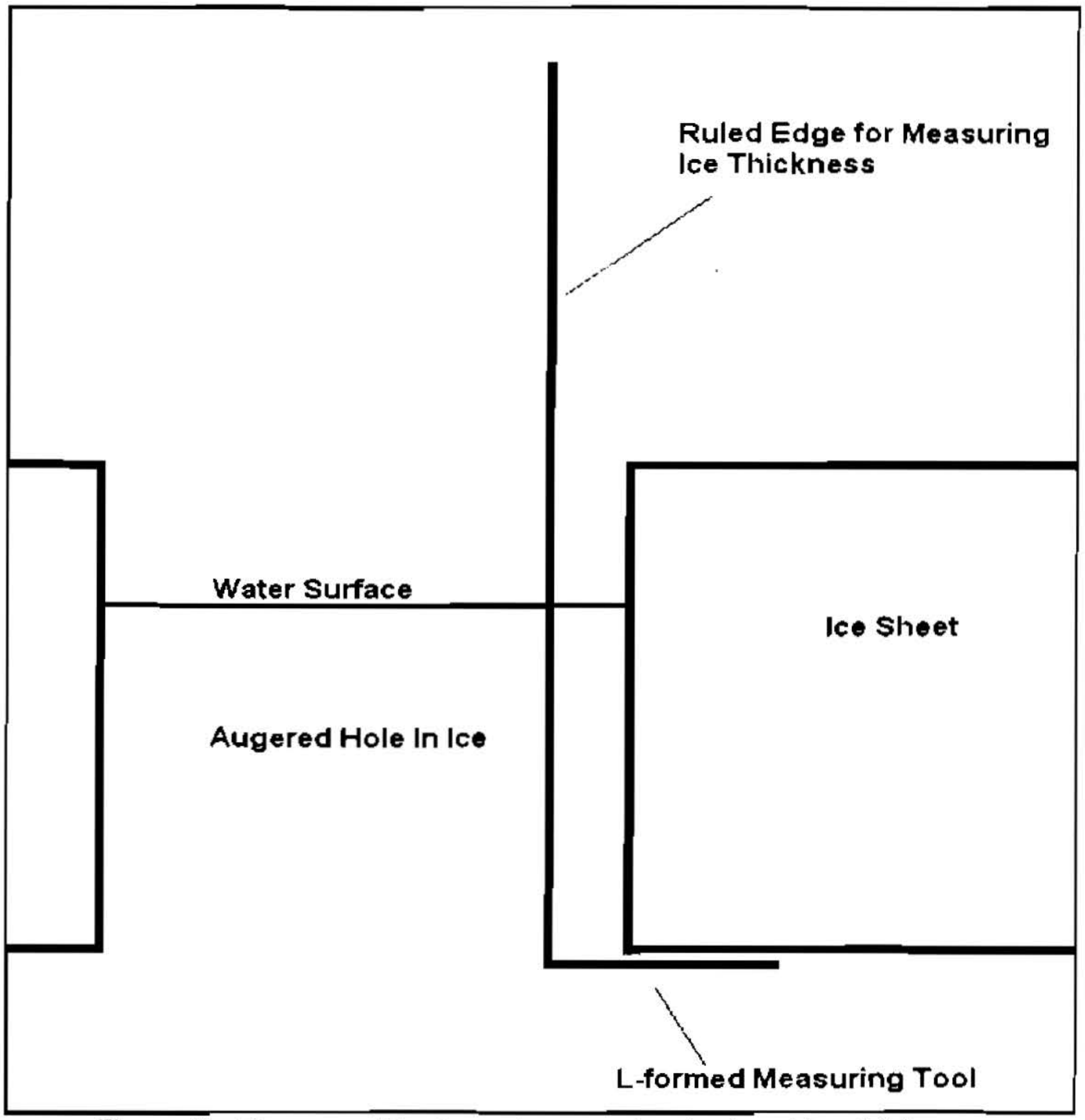


Figure 2: Diagram of L-shaped measuring tool and ice thickness measurement scenario

6. **Timing, frequency, and reporting of measurements**:

a. Ice thickness testing will not begin until weather patterns indicate that freezing conditions are predominate at the ERF, generally in late October. Weather conditions and patterns vary from year to year, so it is not possible to establish a start or end date for monitoring. Testing need not begin until unit training requests have been scheduled, and testing must precede the first training event of the winter season. The IRO will provide sufficient advance notice to the party performing the testing.

b. Once adequate ice conditions are present, monitoring events may be suspended unless weather warming trends indicate a need to conduct further monitoring to insure requisite ice thickness for firing still exists.

c. As warm weather conditions develop during the spring (generally late March), ice thickness testing must again be conducted as frequently as necessary to ensure that training does not take place when minimum ice thickness is not attained.

d. The party performing the testing will submit ice thickness reports to the IRO who will maintain the reports for three years.

7. **Duties and responsibilities**:

a. During winter of 2006 and 2007, the Directorate of Public Works (DPW) Environmental office will be responsible for conducting testing, and will validate the testing procedures. DPW Environmental will contract and coordinate appropriate EOD services to conduct testing and provide information to the IRO.

b. By spring 2007, DPW Environmental and the Installation Range Management Department will jointly conduct ice thickness testing for mutual training purposes.

c. By fall 2007, the Installation Range Management Department will be responsible for conducting all testing.

8. **Effective date**: This SOP takes effect upon publication.

9. Point of contact for this memorandum is Cristal Fosbrook, Chief Clean Up Branch for DPW at (907) 384-2713.

Encls
Ice Thickness Testing Report
ERF Impact Area Map

APPROVED BY: D L Shutt
DAVID L. SHUTT
COL, AR
Commanding

Range Control determines where ice will be tested. DLS

DISTRIBUTION:
IMPC-FRA
DPTSM
DPTSM Range Control

DISTRIBUTION CONT:
DPW
DPW Environmental
SJA Office
Garrison Commander

ERF Ice Thickness Testing Report

Report Date ____________________________

To Installation Range Management Department
ATTN: APVR-RPTM-R (Mr. Fussner)

Purpose To meet the requirements of the of the 1991 Environmental Assessment for firing into the Eagle River Flats Impact Area, Fort Richardson, Alaska

Reference Standard Operating Procedure for Measuring Ice Thickness at Eagle River Flats Impact Area (June 2006)

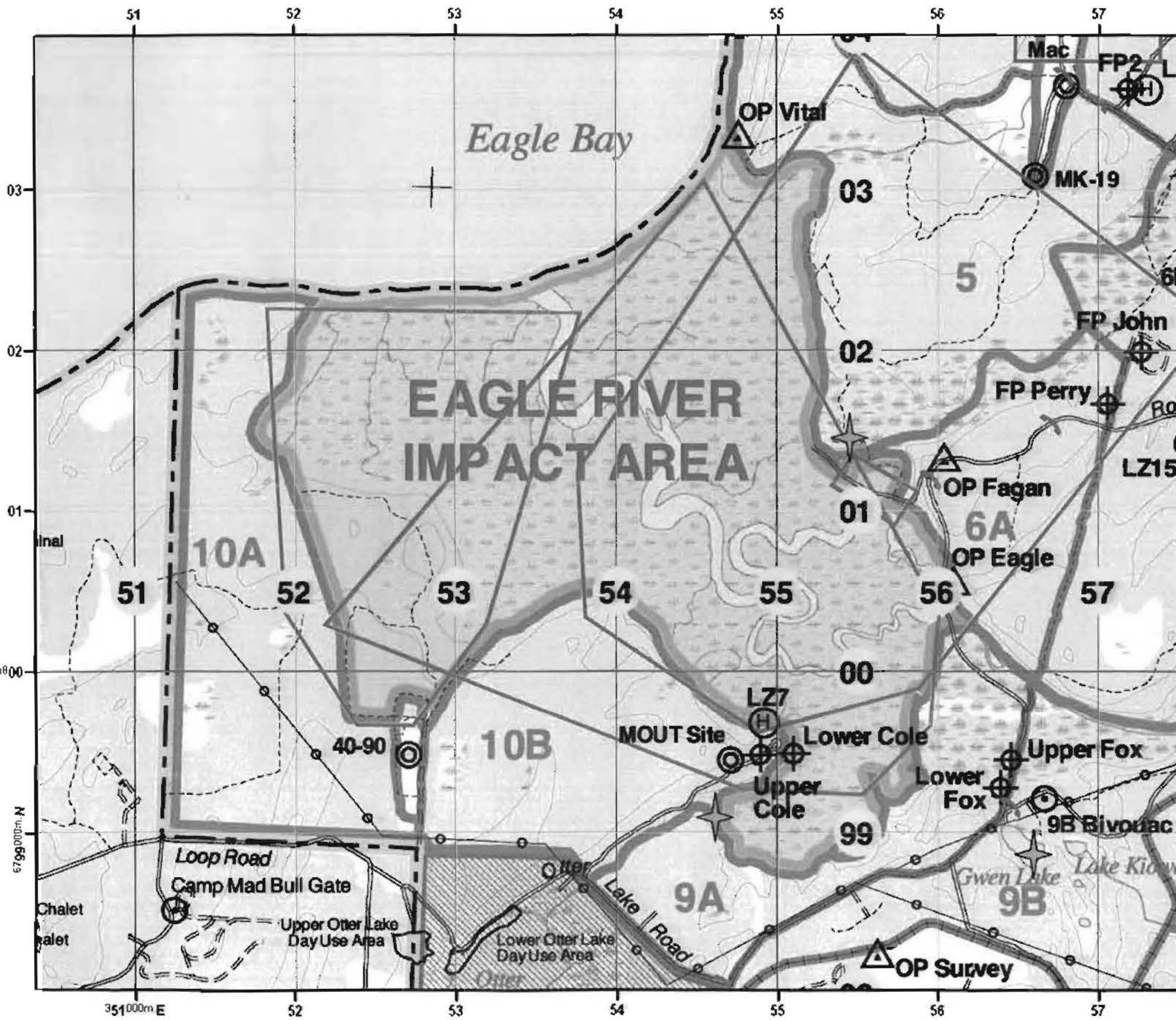
Results
Ice thickness was measured on _______________ (date). Ice thickness varied from ____ to ____ inches:

Area	Ice Thickness (inches)
A1	
A2	
B1	
B2	
C1	
C2	

No exposed sediment conditions were noted in non-ponded areas. Some areas of overflow were noted near the test areas but thick ice conditions were prevalent.

Conclusions
In accordance with established requirements, the munitions *checked* below can now be used at ERF and until further notice:

Helicopter door gunnery (small arms) October 16 to March 31, and No waterfowl present	
High explosive proximity fuse (VT) rounds October 16 to March 31, and No waterfowl present	
Illumination rounds October 16 to March 31, and No waterfowl present	
Point Detonating Mortar & Rifle Grenade Rounds Minimum Ice Thickness 2 inches	
Point Detonating Artillery Rounds Minimum Ice Thickness 5 inches	


Eagle Bay
OP Vital
Mac
FP2
MK-19
03
5
02
FP John
EAGLE RIVER
IMPACT AREA
FP Perry
LZ15
OP Fagan
01
6A
10A
OP Eagle
51
52
53
54
55
56
57
00
LZ7
MOUT Site
Lower Cole
40-90
10B
Upper Fox
Upper
Cole
Lower
Fox
9B Bivouac
99
Loop Road
Camp Mad Bull Gate
Otter
Lake
Road
9A
Gwen Lake
9B
Chalet
Upper Otter Lake
Day Use Area
Lower Otter Lake
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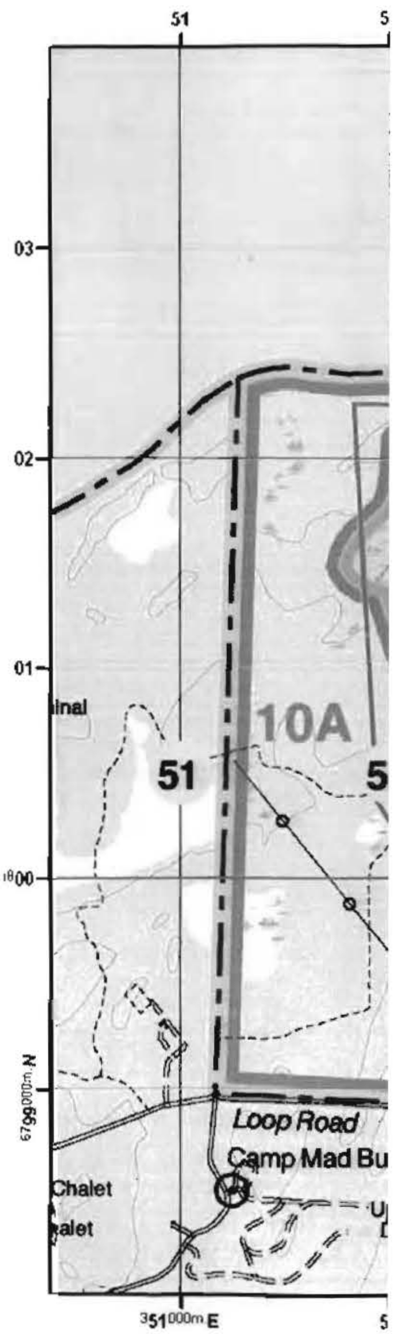
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STAFF SUMMARY

DATE 10 Jan 07

TO	FROM	
Garrison Commander	DPW Environmental	

SUBJECT	ACTION OFFICER (SIGNATURE)	SUSPENSE
ERF Remedial Action – Ice Thickness testing Standard Operating Procedure (including ERF Ice Thickness Testing Report form)	TYPED NAME, RANK & PHONE **Cristal Fosbrook, Chief, Clean Up, 384-2713**	31 Jan 07

Reason for Action Obtain signature on report cover letter

FACTS/DISCUSSION

This SOP will establish a clear and reproducible procedure for determining and reporting the thickness of ice cover on the Eagle River Flats Impact Area. Minimum ice thickness over the ERF Impact Area is one of several prerequisites to the use of point detonating-fused mortar, artillery, and other explosive ammunition in training. The ice thickness standards (for mortars and for artillery) are specified in a Record of Environmental Consideration for ERF Impact Area.

RECOMMENDATIONS Approve and sign document

COORDINATION

OFFICE	SIGNATURE	CONCUR	NONCONCUR
Chief, Environmental Division	SEE ATTACHED		
DPW Director	SEE ATTACHED		
DPTSM Larry Fussner	SEE ATTACHED		
SJA Office	SEE ATTACHED		
Deputy Garrison Commander	corrections expedite	[signature]	

ENCLOSURES	APPROVED (SIGNATURE)	DISAPPROVED (SIGNATURE)
	[signature]	
	TYPED NAME & RANK **DAVID L. SHUTT** **COL, AR** **Commanding**	TYPED NAME & RANK **DAVID L. SHUTT** **COL, AR** **Commanding**

USARAK Form 407

1 Nov 94

07-001

3744

Cristal-
Good work- I added a comment to ensure clarity
Thanks!

Attachment 5
JBER Bird/Wildlife Aircraft Strike Hazard Reports for Weeks ending March 28, April 4, and April 11, 2015

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Wildlife Management Report

Joint Base Elmendorf Richardson 2015

3/22/2015 - 3/28/2015

Federal Permit#
MB748033-0
State Permit#
15-110

Species	Number of Events	Dispersed	Eggs Destroyed or Removed	Captured /Relocated	Destroyed	Observed
bird						
Bald Eagle	2					0
Common Raven	6	5				3
Northern Shrike	1	1				
Sub Totals:	9	6				3
Grand Totals:	9	6				3

This report is a summary of data gathered from Direct Control activities during the selected time period.

Wildlife Management Report

Joint Base Elmendorf Richardson 2015

3/29/2015 - 4/4/2015

Federal Permit#
MB748033-0
State Permit#
15-110

Species	Number of Events	Dispersed	Eggs Destroyed or Removed	Captured /Relocated	Destroyed	Observed
bird						
American Dipper	1					1
Bald Eagle	6	3				4
Common Raven	15	5				26
Herring Gull	1					1
Mallard	6	10			1	
Red-tailed Hawk	2	1				1
Sub Totals:	31	19			1	33
mammal						
Black Bear	2					8
Coyote	1	1				
Red Fox	1	1				
Sub Totals:	4	2				8
Grand Totals:	35	21			1	41

This report is a summary of data gathered from Direct Control activities during the selected time period.

Wildlife Management Report

Joint Base Elmendorf Richardson 2015

4/5/2015 - 4/11/2015

Federal Permit#
MB748033-0
State Permit#
15-110

Species	Number of Events	Dispersed	Eggs Destroyed or Removed	Captured /Relocated	Destroyed	Observed
bird						
Bald Eagle	5	1				4
Barrow's Goldeneye	5	6				
Black-billed Magpie	1	1				
Common Goldeneye	4	7				
Common Raven	8				1	9
European Starling	1					20
Mallard	12	22				9
Red-tailed Hawk	2	2				
Rough-legged Hawk	1	1				
Sub Totals:	39	40			1	42
mammal						
Coyote	4	5				
Porcupine	1			1		
Sub Totals:	5	5		1		
Grand Totals:	44	45		1	1	42

This report is a summary of data gathered from Direct Control activities during the selected time period.