Human Health and Ecological Risk Assessment
for the Use of Wildlife Damage Management Methods
by APHIS-Wildlife Services

Chapter XXI

THE USE OF EXPLOSIVE MATERIALS IN WILDLIFE DAMAGE MANAGEMENT

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EXECUTIVE SUMMARY

The USDA-APHIS-Wildlife Services (WS) Program uses explosive materials, including multicomponent (binary and trinary) explosives, pyrotechnics, ammunition for firearms, propellants for rocket and cannon nets, and incidental explosive materials used to detonate explosives such as detonation cord, fuses, and primers. Most of the explosives WS uses are multicomponent explosives for removing beaver dams to reduce flooding and pyrotechnics for hazing wildlife from airports to avoid aircraft strikes and to keep them away from other resources such as agricultural crops. Other uses of explosives include ammunition, cannon and rocket net charges, and gas cartridges for fumigation. WS risk assessments have covered these methods, except for the use of smokeless powder for ammunition, propellants for nets, and fuses for gas cartridges. Finally, other incidental explosive materials are used to initiate explosives, such as detonation cord for multicomponent explosives, fuses for all types of explosives, electric matches for rocket and cannon nets, and primers for pyrotechnics and ammunition rounds.

Between FY16 and FY20, WS used 3,084 pounds of multicomponent explosives to remove 1,379 beaver dams, 357,184 pyrotechnics and firearm blanks to haze 22,115,160 wildlife from damage situations annually. In addition, WS used 15,042 gas cartridge fuses, 309 cannon and rocket net activations using 142 rocket and cannon net charges and 1,084 blanks to capture 1,527 wildlife, and an estimated 1,079,473 shots with firearms to take wildlife during wildlife damage management activities. The Animal and Plant Health Inspection Service evaluated the potential human health and environmental risks from WS proposed use of explosive materials and determined that the risks are negligible. WS personnel and the public are at risk of being injured or killed by the explosives analyzed. The greatest risks with explosives use is to WS personnel that use the devices, but the numbers of accidents and incidents have been minimal. To reduce those that occur, WS trains personnel properly to handle explosive materials to minimize the identified risks. WS and public exposure to potentially toxic gases and solids produced from explosives are negligible due to the minimal use by individual employees, use throughout the United States with relatively small numbers of devices, and use almost exclusively outdoors. Thus, exposure is limited and gases disperse quickly.

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1 INTRODUCTION

The U.S. Department of Agriculture (USDA), Animal and Health Plant Inspection Service (APHIS), Wildlife Services (WS) Program uses explosive materials for various wildlife damage management (WDM) activities, such as multicomponent explosives for beaver dam removal and pyrotechnics to haze wildlife such as European starlings[1] and gulls (Table 2 gives all wildlife hazed) that damage property, agriculture, or natural resources, or are a public safety threat. WS uses items classified as explosive materials by the Bureau of Alcohol, Tobacco, Firearms, and Explosives[2] (ATF) (see 27 CFR 555.23). As defined by ATF:

> *Explosive materials are any chemical compound, mixture, or device, the primary or common purpose of which is to function by explosion. The term includes but is not limited to, dynamite and other high explosives, black powder, pellet powder, initiating explosives, detonators, safety fuses, squibs, detonating cord, igniter cord, and igniters.*

WS uses materials classified as explosives by ATF, including multi-component explosives, pyrotechnics, rocket and cannon net charges, components of firearm ammunition, and incidental explosive materials such as fuses and primers that are integral to the other devices. WS uses multicomponent (i.e., binary, trinary) explosives for removing beaver dams where the water impounded by the dams is causing damage, such as flooding a crop field, road, or residence. WS uses pyrotechnics to haze wildlife, primarily birds, from damaging situations at airports (some of the risks were covered in *the Use of Firearms in Wildlife Damage Management Risk Assessment*). WS uses ammunition in firearms to take or haze wildlife from damaging situations. Take and risks with firearms are covered in *The Use of Firearms in Wildlife Damage Management Risk Assessment.* The use of lead in ammunition is covered in *The Use of Lead in Wildlife Damage Management Risk Assessment*, but the burning gunpowder was not and will be covered here. WS uses rocket and cannon net charges to deploy nets from their stands to capture wildlife, primarily birds. Other than risks associated with burning gunpowder and propellant, take and risks with rocket and cannon nets are covered in *the Use of Nets in Wildlife Damage Management Risk Assessment*). The explosion and potential for injury or death are the primary risks of using explosive materials. Though not as common today, fire from the use of explosives can occur. Another risk is the gases produced by an explosion or fire.

Federal, state, and local regulations may apply to the storage, transportation, and use of explosives materials. State and federal agencies and tribes may require permits or authorizations before using explosive materials to haze, capture, take, or remove wildlife, including beaver dams. For example, according to the Bald and Golden Eagle Protection Act, a United States Fish and Wildlife Service (USFWS) permit is required before using pyrotechnics to haze eagles from an airport. Under the Migratory Bird Treaty Act, using cannon nets to capture Canada geese would require a USFWS permit. Using a rocket net to capture wild turkeys may require a permit from a state wildlife agency. If the water impounded by a long-standing beaver dam creates an established wetland as defined by Section 404 of the Clean Water Act, a permit from the United States Army Corps of Engineers would be required to remove the beaver dam. Permits are typically not needed to haze most wildlife or control invasive species, but state and local

[1] Scientific names for species are given in the text only for species not discussed in the Wildlife Damage Management Methods Risk Assessment Introduction.

[2] A bureau of the U.S. Department of Justice having responsibility for the promulgation and enforcement of regulations related to the unsafe or insecure storage of explosives materials and the unlawful use of explosive materials under 18 U.S.C. Chapter 40, Section 847. Codes of Federal Regulations (CFRs), and rules and regulations that ATF guides the public can be found @ https://www.atf.gov/rules-and-regulations/rules-and-regulations-library. *Accessed 6/29/2022.* These will not be cited in the risk assessment but can be found on their website.

regulations may still apply. WS personnel abides by federal, state, and local laws and WS Directives for using these methods.

1.1 WDM Methods that Use Explosive Materials

WS uses several methods that contain explosive materials when conducting WDM activities including multicomponent explosives, black powder (pyrotechnics and rocket nets), smokeless powder (cannon nets and ammunition), and incidental material needed to do this work (e.g., detonating cord, fuses, primers, and electric matches).

1.1.1 Multicomponent Explosives

Multicomponent explosives consist of two or more components that, individually packaged, do not meet the classification for explosive materials but the individual components when mixed create a high explosive. Depending on the manufacturer, these high explosives consist of either two (binary – Figures 1) or three (trinary – Figures 2) components. The binary explosives that WS uses consist of either ammonium nitrate (solid component) and nitromethane (liquid component), or aluminum powder (activator) and nitromethane (liquid component) packaged separately. WS also recently started using trinary systems consisting of ammonium nitrate (solid component), nitromethane (liquid component), and aluminum powder (activator), which are also packaged separately. When mixed, two and three-component systems are classified as Division 1.1 explosives. Division 1.1 explosives are explosive materials defined by the United Nations (UN) and the United States Department of Transportation (USDOT) as a mass explosion hazard.

WS personnel only use multi-component explosives to breach beaver dams, and generally, only those beaver dams that are too large to remove or breach using hand tools or where the deployment of heavy equipment is impractical (Figures 3a, b). WS personnel are prohibited from transporting mixed components and can only mix the explosive components at the blasting site. WS Directive 2.435 provides procedures and accountability for WS use of explosives to breach beaver dams and the

Figure 1a. Mixing ammonium nitrate with nitromethane, a binary explosive.

Figure 1b. Attaching a detonator to detonating cord that leads to explosive charges.

Figure 1c. Placing an explosive charge attached to detonating cord.

Figure 2a. Trinary explosives consist of ammonium nitrate powder, nitromethane liquid, and aluminum powder.

Figure 2b. Mixing liquid nitromethane into ammonium nitrate powder.

Figure 2c. Mixing aluminum powder into the mixture of first two and shook.

Figure 2d. Attaching a detonating cord to the mixed explosive. A knot is added to the detonating cord to ensure that it is not pulled free from the canister.

Figure 2e. An explosive ready to be placed. The container is pointed to allow it easily to be pushed into place in a dam, made of plastic to eliminate the possibility of creating a spark, and the top fits easily into a specially made placement rod that allows it to be pushed without the detonating cord getting sheered.

Figure 2f. A hole in the dam is created with a ramrod and then the explosive is seated in the hole created.

Figure 3a. Blowing up a beaver dam with explosives. Blasts are intentionally directed to minimize potential damage to nearby structures.

Figure 3b. Beaver dams can cause many different damage types such as flooding residences and crops. Restoring normal flow of the creek minimizes such occurrences.

training requirements for WS personnel to use explosives. In addition, WS has established an Explosives Safety Subcommittee responsible for developing safety and security procedures for WS, conducting training, and certifying WS personnel in the use of multicomponent explosives. WS has also developed an explosives safety manual that establishes procedures and accountability for the safe and secure storage, transportation, procurement, and use of multicomponent explosives. The manual also ensures WS use of multicomponent explosives conforms to applicable federal, state, and local laws and regulations.

1.1.2 Pyrotechnics

WS uses several commercially available pyrotechnics that produce a loud noise after being fired to haze wildlife. Most pyrotechnics used by WS are defined by ATF as Explosive Pest Control Devices (EPCDs) and are shot from a pistol launcher or shotgun. Some pyrotechnic rockets that are like fireworks, make noise while traveling, followed by a report. People may refer to some of these common EPCD pyrotechnics as "*screamers,*" "*bangers,*" "*shell crackers,*" "*CAPA*[3] *cartridges*" (Figure 4), and "*screamer banger rockets*." Pyrotechnic bangers use black powder, which is made with 75% potassium nitrate or saltpeter (KNO_3), 15% carbon (C), and 10% sulfur (S). KNO_3 chemically provides oxygen for the reaction; C is the fuel, and S is the fuel that lowers the ignition temperature of the mixture to increase the rate of combustion. The three components are mixed and coated with graphite to prevent static electric discharge. Additionally, graphite may be added in various quantities to 1% and is essentially carbon. Flash powder for screamers and whistlers is a pyrotechnic mixture of oxidizer and metallic fuel, which burns quickly and, if confined, produces a loud noise. The oxidizer for screamers is potassium perchlorate ($KClO_4$) and likely an aluminum powder as the metal as this is the most common flash powder mixture.

Figure 4. CAPA cartridge pistol launcher and cartridges.

The pyrotechnic industry, which includes EPCDs, consumer, and display fireworks, is one of the last primary users of black powder. The most common pyrotechnics are those that people fire from a pyrotechnic launcher or shotgun, which travel approximately 50 to 1,000 feet downrange. Some types of pyrotechnics emit a loud whistle as they travel, while some travel downrange and then explode with a bang. Pyrotechnics that whistle as they travel and those that explode with a bang after traveling downrange generally emit a 100-decibel to 150-decibel report that can startle target animals. A long-range pyrotechnic commercially available rocket can travel approximately 1,000 feet downrange and produce a 150-decibel report (CAPA cartridges and rockets). Pyrotechnics are a primary method that WS personnel use to haze and disperse wildlife. WS Directive 2.627 establishes procedures and accountability for the safe and secure handling and use of pyrotechnics for WS employees. The UN and USDOT classify EPCDs and most consumer

[3] CAPA = *cartouche anti peril aviaire* (French meaning anti-avian scare cartridge) manufactured by the Etienne LaCroix Company of France

pyrotechnics as Division 1.4 explosives. Division 1.4 explosives are explosive materials with a minor explosion hazard, primarily confined to the shipping container (no mass detonation hazard).

1.1.3 Ammunition for Firearms

Firearms with various ammunition, which almost exclusively use smokeless gunpowder and are regulated by ATF, are used by WS personnel in WDM. However, ATF exempts most ammunition manufactured for personal use from regulations for explosives. Gunpowder comes in many different brands, and the brand dictates the weight of gunpowder used in a cartridge or shell to get the desired ballistics. Smokeless powders consist of propellants (the energetic compound that propels the bullet), deterrents (plasticizers that slow the burn rate down), stabilizers (the propellant nitrocellulose deteriorates over time and produces acidic byproducts, which increases the rate of deterioration; this process releases heat and can cause self-ignition, thus additives include chemicals to stabilize the nitrocellulose), flash reducers (to minimize the flash from the end of the gun), and other minor additives (Gore et al. 2016). The mixture of chemicals in gunpowder varies by brand, and different chemicals are used to get the desired mix. One brand of smokeless powder could use half the amount needed to get the same ballistics from another powder. Therefore, it is very difficult to assess the amount of actual chemicals and smokeless powder used by WS with accuracy, but it can be assumed.

The .22 caliber bullet was propelled initially using 5 grains (0.065 g) of black powder. When .22 ammunition was converted to smokeless gunpowder, about 2.5 grains were typically used, depending on brand and bullet grains (usually about 40 grains of lead). A 150-grain bullet uses a max of 7.5 grains of smokeless powder in a .40 pistol depending on the brand of gunpowder used. Shotgun shells use a maximum of 20 grains of powder. Rifle cartridges tend to carry the most powder, often as much as 60 grains. Using these parameters, along with parameters outlined in *The Use of Lead in Wildlife Damage Management Risk Assessment* for the number of shots fired per animal taken, the gunpowder used nationally by WS can be estimated.

Several types of smokeless powders are available and contain several ingredients, including propellants, deterrents, stabilizers, decoppering chemicals, flash and wear reducers, and other additives (Gore et al. 2016). The most important factors related to ballistic performance are the shape, density, and burn rate of the powder. Pistol powder is flake powder that burns fast; rifle powder is a ball powder, and sometimes stick powder, which burns slower. Shotgun powder usually consists of flattened ball powder, which burns slowly, usually slower for heavier loads.

Smokeless powders are single-, double-, and triple-based, meaning they have one, two, or three propellants as the primary ingredients. Nitrocellulose is the primary propellant, nitroglycerine in double- and triple-based powders, and nitroguanidine in triple-based smokeless powder (Table 1). Other propellants could include diethylene glycol dinitrate (sometimes used in single-based powder – Table 1), diethanolamine dinitrate ($C_4H_8N_4O_8$), fivonite 2,2,5,5-tetramethylol-cyclopentanone tetranitrate ($C_9H_{12}N_4O_{13}$), and acetyl cellulose ($[C_6H_7O_2(OH)_3]_n + 3_n(CH_3CO)_2O$). Deterrents typically include centralites, dibutyl phthalate, and polyester adipate (Table 1) and have also included Arkadite II ($C_{14}H_{14}N_2O$) and ortho-tolyl-urethane. Stabilizers include diphenylamine, calcium carbonate, and N-nitrosodiphenylamine (Table 1) and have included petroleum jelly, magnesium oxide (MgO), sodium bicarbonate ($NaHCO_3$), and beta-naphthyl methyl ether (2-methoxynaphthalene – $C_{11}H_{10}O$). Flash reducers include potassium nitrate and potassium sulfate and have included potassium chloride (KCl) (Table 1). Decoppering additives, which hinder the buildup of copper in the barrel, are tin oxide and bismuth trioxide (Table 1), and wear reducers typically include wax, talc, and titanium dioxide. Finally, some additives are related to the shape, size, and adhesiveness of the powder and include ethyl acetate (used in

manufacturing to make spherical shaped pellets), rosin (a surfactant to hold flake shape), and graphite (a lubricant to keep flakes separate and dissipate static so the flakes do not ignite) (Table 1).

Under explosives regulations, ATF does not regulate smokeless gunpowder used as the propellant in small arms ammunition. Black powder is associated with some firearms commonly known as muzzleloaders, but WS does not use these in the field. Smokeless powders designed for use in small arms ammunition are exempt from regulation under 18 U.S.C. Chapter 40 and the regulations in 27 CFR Part 555. Packaging that readily identifies the smokeless powder as being designed for use in small arms ammunition may help determine whether it is entitled to the exemption. Smokeless powder designed for use other than in small arms ammunition, and explosive products such as squibs, fireworks, theatrical special effects, or other articles that may contain smokeless powders, are regulated and must be stored pursuant to the regulations at 27 CFR 555, Subpart K – Storage. It should be noted that people engaged in the business of importing or manufacturing smokeless powder designed for any use must have a Federal Explosives license. Further, importers of smokeless powder designed for use in small arms ammunition must also possess an ATF firearms importers license (Type 08 or 11) and must register with ATF under the provisions of the Arms Export Control Act. They must submit (to ATF) and receive an approved ATF Form 6 – part I (5330.3A), Application and Permit for Importation of Firearms Ammunition and Implements of War.

Table 1. Smokeless powder components, specific ingredients, their basic chemical formula, and percentage of generic ingredients in single-based, double-based, and triple based formulations (every brand of gunpowder contains different elements and amounts).

COMPONENT	INGREDIENT	CHEMICAL FORMULA	PRODUCT % (-based)		
			Single	Double	Triple
PROPELLANTS - Energetic Compounds	Nitrocellulose	$3HNO_3$+ $C_6H_{10}O_5$	50-90%	50-85%	26-30%
	Nitroglycerine	$C_3H_5(NO_3)_3$	none	8-42%	20-24%
	Nitroguanidine	$CH_4N_4O_2$	none	none	46-48%
	Diethylene Glycol Dinitrate	$C_4H_8N_2O_7$	0-1.5%	none	
DETERRENTS – Plasticizers, Slow Burn Rate	Ethyl Centralite	$C_{17}H_{20}N_2O$	0-10%	none	1-3%
	Dibutyl Phthalate	$C_{16}H_{22}O_4$	0-10%	0-8%	none
	Polyester Adipate	$(C_6H_{10}O_4.C_2H_6O_2)_x$	0-10%	none	none
STABILIZERS - Slow Self-Decomposition	Diphenylamine	$C_{12}H_{11}N$	0-1.5%	0.7-1.7%	none
	Calcium Carbonate	$CaCO_3$	0-1%	0-1%	none
	N-Nitrosodiphenylamine	$C_{12}H_{10}N_2O$	0-1%	none	none
	Potassium Nitrate - Saltpeter	KNO_3	0-3%	0-1.5%	none
	Potassium Sulfate	K_2SO_4	0-3%	none	none
DECOPPERING - Hinder CU Buildup	Tin Oxide	O_2Sn	0-1.5%	none	none
	Bismuth Trioxide (Cryolite)	Bi_2O_3	none	none	0.3%
OTHER ADDITIVES – For Consistency and Safety	Ethyl Acetate – spherical	$C_4H_8O_2$	0-2%	none	none
	Rosin - surfactant	$C_{15}H_{20}O_6$	0-5%	none	none
	Graphite – lubricant	C	0-1%	none	1-3%

In addition to gunpowder, ammunition cartridges use primers to ignite the gunpowder. In firearms, the primer is the chemical or device responsible for initiating the propellant combustion to push the projectiles out of the gun barrel. Center-fire cartridges (rifle and shotgun ammunition, and larger calibers of pistols) use a cap, which can be pulled to reload and rim-fire cartridges, used in small caliber rounds such as .17 and .22 caliber ammunition, are struck on the rim, which is like a centerfire cap or primer. Because of the dent, rim-fire rounds cannot be reloaded. WS can estimate the primers used annually.

1.1.4 Rocket Nets and Cannon Nets

Explosive-activated projectiles carry rocket and cannon nets over targeted species that are attracted to a specific area, usually a baited or natural feeding site (Dill and Thornsberry 1950, Schemnitz et al. 2009). These can be rather large areas, covering 15 ft. x 30 ft. to 30 ft. x 60 ft. or larger. Rocket and cannon nets are accordion folded nets pulled rapidly by explosive-driven projectiles to cover a predetermined area to capture target animals present before they can escape (Figures 5 and 6). The net can be placed directly on the ground in a line or folded and placed in a specially designed box (Grubb 1988). The projectiles are attached to the net, usually with small cords. The two netting systems differ in basic hardware and speed, which equates to the capacity to pull larger nets and the height of deployment.

Most cannon nets utilized by WS are smoothly bored-out heavy projectiles placed on launch rods, usually directed at about a 20-degree angle over the target area (Figure 5a). A charge of smokeless powder or black powder is placed inside the projectile atop the launch rod. The powder is ignited with an electric match with leg wires that run from the end of the launch rods, along grooves in the launch rod, or through holes (Figure 5b, 5c) and is connected to a small gauge wire firing line. The wire firing line is usually spooled out to an area where WS personnel wait hidden from the target animal(s).

Rocket nets use heavy pipe projectiles, typically three or more, on “L-shaped“ or “Pi-shaped” (Figure 6a) stands. Rockets have a twist-off cap on the bottom where an explosive is inserted with holes for gas created by the blast to escape, propelling the rocket in the opposite direction (Figure 6b). The explosive is usually a bag containing M6 howitzer propellant (mostly compressed nitrocellulose, otherwise known as guncotton, and this ingredient makes it a true explosive) and black powder with an electric match. The electric match is attached to a leg wire run out of the projectile and then attached to a small gauge wire firing-line, which is used to initiate the rockets from a remote location. These

Figure 5a. A cannon stand and smooth-bore projectile.

Figure 5b. Cannon net projectile attached to net being placed on launch rod which has a groove for the match leg wires.

Figure 5c. Taping the electric match leg wires to the launch rod to keep it in place.

are often used with heavier netting for larger birds or mammals, especially those that can quickly get out of the way, and for nets of larger dimensions (Figure 6c). Rocket nets typically require the use of three or more projectiles.

Projectiles are reusable but require frequent cleaning as black powder and, to a lesser extent, smokeless gunpowder cause fouling. In addition to the rocket net, other specialty equipment is necessary for safely firing and storing rocket nets and their charges. A blasting galvanometer, capacitor-discharge machine, and electrical firing line are recommended for the safe use of this equipment.

Figure 6a. Preparing rockets and net for a tundra swan banding project.

Until recently, the UN and USDOT classified rocket net charges (mixture of black powder and M6 howitzer propellant) as Division 1.3 explosives, which are a fire or projection hazard but do not pose a mass explosion hazard. Following a packaging redesign and other related modifications made by the manufacturer, the rocket net charges used by WS have been reclassified as Division 1.4 explosives. WS Directive 2.625 provides procedures and accountability for the secure handling and safe use of net propellants. The WS Explosives Safety Subcommittee is responsible for developing safety and security procedures for WS, conducting training, and certifying WS personnel in the use of rocket and cannon nets. The WS Explosives Safety Subcommittee has developed a rocket and cannon net safety manual that establishes procedures and accountability for the safe and secure storage, transportation, procurement, and use of rocket and cannon nets, including net propellants. The manual also ensures WS's use of net propellants conforms to applicable federal, state, and local laws and regulations.

Figure 6b. One of 6 rockets used for project with electric match leg wire coming from an opening where black powder and M-6 propellant are stored.

Figure 6c. A rocket net deployed to capture about 40 tundra swans for a banding project.

1.1.5 Incidental Explosive Materials

Several explosive components are associated with the use of multicomponent explosives, net propellants, pyrotechnics, and ammunition to enable their use. Examples may include nonelectric, electric, and fuse detonators, detonating cord, nonelectric shock tube, safety fuse, pull-wire fuse lighters, electric matches, and primers. Pyrotechnics and ammunition are mostly actuated by primers (some pyrotechnics are

actuated by a lit fuse, though they are used rarely compared to other pyrotechnics). Both rocket and cannon nets use electric matches to ignite smokeless gunpowder or black powder, respectively, which launches projectiles attached to a net with cords.

- **Detonators**

  Detonators frequently referred to as blasting caps, are small explosive devices generally used to detonate a larger, more powerful secondary explosive. Detonators can initiate secondary explosives chemically, mechanically, or electrically, with mechanical and electrical initiation being the most common. The primary explosive compound found in detonators is a combination of lead azide ($Pb(N_3)_2$), lead styphnate ($C_6HN_3O_8Pb$), and aluminum (Al), which is commonly referred to as the compound ASA. The ASA compound is pressed against the base charge within the detonator, which usually consists of pentaerythritol tetranitrate (PETN or pentrite) ($C_5H_8N_4O_{12}$). Some detonators designated as lead-free use diazodinitrophenol ($C_6H_2N_4O_5$) instead of lead azide and lead styphnate to reduce the amount of lead emitted into the atmosphere.

  WS may use electric detonators, nonelectric shock tube detonators, and fuse detonators. A small electric current activates an electric detonator. A nonelectric shock tube detonator does not require an electric current or safety fuse to function but initiates by a spark or flash from a shock tube initiation device. A shock tube consists of a small diameter laminated plastic tube coated with a very thin layer of energetic material known as HMX ($C_4H_8N_8O_8$) that ignites at approximately 6,500 feet per second. A detonation wave transmitted through the shock tube initiates the detonator. A fuse detonator is initiated by a safety fuse, consisting of a flexible cord containing an internal black powder burning medium whereby a fire or flame is conveyed at a continuous and uniform rate from the point of ignition to the point of the fuse detonator.

- ***Detonating Cord***

  Detonating cord is a flexible plastic cord with a center core of high explosives (PETN) used to initiate other explosives. PETN detonates at approximately 23,000 feet per second or 4 miles per second. The detonation rate of detonating cord allows users to synchronize multiple charges to detonate almost simultaneously, even if the explosive charges are different distances from the initiation point. The PETN is enclosed in multiple polypropylene yarn, over-extruded with a polyethylene jacket and high-strength textile yarns. The covering ensures that the cord is water and abrasion-resistant, has high tensile strength, and is not sensitive to extraneous current. Several colors are available to ensure easy identification of different types like white, pink, bright green, yellow, and red (e.g., Figures 1b and 2e).

- ***Fuses***

  In an explosive or pyrotechnic device, a fuse is the part of the device that initiates the function of another product. Fuses are typically colored dark green, black (military), or fluorescent orange (commercial) to distinguish them from detonating cords, which are brightly colored or transparent. There are several types of fuses that WS could use, including safety fuse, Visco fuse, quick match, black match, and slow match, which are described below.

  - **Safety Fuses**, made with potassium nitrate (saltpeter, KNO_3), charcoal (carbon, C), and sulfur (S), are the agent through which the burning reaction is conveyed at a relatively uniform rate to the ignition area of the blasting cap. It burns at its core, not at its surface; thus, the exterior signs of burning follow behind the interior burning. Safety fuses consist

of a black powder core in a textile tube, covered with a waterproofing agent such as asphalt (asphaltum), plastics, or nitrocellulose lacquer, and having an outer wrapper of tough textile or plastic. They are made in a standard diameter designed to be crimped into blasting caps. Safety fuses are typically green, black, or orange, but not bright to distinguish them from detonating cord. Once ignited, safety fuses have no external flame, so they will not ignite any flammable material or gases in their path and can burn underwater. Safety fuses are manufactured with specified burn times per foot (30 cm), e.g., 40 seconds, which means that a foot-long fuse will take 40 seconds to burn. Air pressure determines the burn rate. The greater the confinement or pressure is on the fuse, the faster the fuse's burn rate (low elevation - faster vs. high elevation –slower). Manufacturers warn that although every effort is made to ensure uniform burn times, safety fuses are subject to variation depending on conditions and should be used with adequate safety measures in place. The core can be affected by water absorbed through cracks or at the end of the fuse.

- **Visco Fuses** are like a safety fuse with a core of black powder with one or more textile overwraps but differ in that a flame is visible. The outer layers may be coated with wax or nitrocellulose lacquer for water resistance. These fuses are widely used in modern pyrotechnics because they burn at a uniform rate with an easily visible external flame. Depending on their outer treatment, Visco fuses are water-resistant and can burn reliably underwater once lit because the black powder core provides both its own fuel and oxidant. In rodent and predator damage management, gas cartridges use Visco fuses to ignite the gas cartridge. *The Use of Carbon Monoxide from Gas Cartridges and Forced Gas Fumigation Systems in Wildlife Damage Management* considered the carbon monoxide and take associated with gas cartridges, but not fuses.

- **Quick Matches** or piped matches are a type of black powder fuse that burns very quickly, some hundreds of feet per second. They are a black match covered with a loose paper wrap (pipe). When lit, the flame propagates quickly down the paper pipe from the hot gases produced by the burning powder. Quick matches are used in professional fireworks displays to pass fire nearly instantly between devices that must be physically separated while firing simultaneously, such as a finale rack. Devices that should fire in sequence can be branched from a single master fuse, consisting of quick match spliced onto a Visco fuse of various lengths for time delays.

- **Black Matches** are a type of fuse consisting of cotton string coated with a dried slurry of black powder and glue. This fuse acted as a simple pass fire and was used to fire ancient cannons. They are used today in fireworks construction. An igniter safety fuse electric (ISFE), a black match or quick matches, lights a main fuse or device when activated by an electric current. Black matches burn many feet per second.

- **Slow Matches** are very slow-burning fuses consisting of a hemp or cotton rope saturated with an oxidizer such as KNO_3 (most widely used). Slow matches were used as a source of fire for manually lighting other devices such as pyrotechnics (M-80 firecrackers). These were frequently used prior to 2000 (Neff and Mitchell 1955). Other pyrotechnic devices have replaced these, including propane cannons and electronic sounds. WS will not likely use these again.

- ***Electric Matches***

  Electric matches typically consist of a pair of wires leading to a thin resistance wire that heats when an electrical current is applied. The resistance wire is covered by a bit of pyrotechnic composition that ignites from the wire heating, providing enough fire to reliably ignite the main fuse via a mechanical connection or the device directly. Cannon and rocket net explosives are lit by a type of electric match.

- ***Primers***

  Primers, including percussion and blasting caps, are made with a detonator mixture of lead styphnate (lead 2,4,6-trinitroresorcinate, $C_6HN_3O_8Pb$) and lead azide ($Pb(N_3)_2$). Lead azide is a less sensitive primary explosive for initiating other explosives such as ammunition, blanks, pyrotechnics, and blasting caps than other compounds that have been used, such as mercury fulminate (Lundgaard et al. 2019). Lead styphnate is the most widely used initiating compound; but possibly could be replaced due to the toxicity of lead (Fronabarger 2011, Csernica et al. 2016, Klapotke et al. 2016). A new initiating compound for primers would have to pass stringent requirements for use in military applications. Requirements would include reliability, shelf-life, stability, and commercial application safety since primers are used in ammunition for many activities, such as shooting sports and law enforcement. Lead styphnate has a 5.2 km/second detonation velocity and an explosion temperature of 265-280° C after five seconds. Lead styphnate is a primary explosive with gunpowder but will not ignite upon a simple impact but rather a heavy impact such as that from a firing pin.

  Lead styphnate is used in primers and produces a minimal amount of gas when fired, which in large doses would be toxic owing to the heavy metal poisoning, as with other lead-containing compounds. Lead styphnate, whose name is derived from styphnic acid, is only slightly soluble in water and methanol but can be neutralized with sodium carbonate. It is particularly sensitive to fire. There are two forms of lead styphnate crystals, six-sided monohydrate crystals, and small rectangular crystals. When dry, longer and narrower lead styphnate crystals are more susceptible to static electricity and can readily detonate by static discharges from the human body. Lead styphnate does not react with metals and is less sensitive to shock and friction than mercury fulminate or lead azide. It is stable in storage, even at elevated temperatures. Lead styphnate is only slightly soluble in water and methyl alcohol and may be neutralized by a sodium carbonate solution.

  Primers are highly reliable and rarely misfire, maybe 3 in a million (Guns and Ammo 2018). The most common cause of misfires is an "insufficient indent," meaning the primer was not struck with sufficient force to initiate an explosion. It should be noted that primers are set at a very precise orientation of component parts, and its sensitivity decreases if it is indented but does not go off; the primer chemical mix, called a pellet, may be cracked with an insufficient indent and moved out of the way from between the cup and the anvil, which will not detonate with further strikes. Causes of insufficient indent are numerous, including a damaged firing pin (e.g., one that has either a bent or chipped tip), a firing-pin spring that has weakened, excessive headspace making the cartridge further from the firing pin, and a firing-pin spring that may be dragging on the interior of the bolt body or impeded by grease in the bolt, especially under cold conditions. Improper loading techniques can cause perfectly good primers to perform poorly. For best sensitivity, the primer should be seated firmly to the bottom of the primer pocket but not unduly crushed into place. Contamination of the primer by moisture or oil can also desensitize the primer, resulting in a misfire. These causes are not

typically seen in factory-loaded ammunition due to quality-control procedures (Guns and Ammo 2018). Still, they can be seen in primers used for pyrotechnic launchers and hand-loading ammunition, which are loose or may be exposed to the elements prior to use. Another common cause for misfires from a perfectly functioning rifle and good ammunition is the failure of the operator to close the bolt completely before firing. While all U.S. primers are made to an industry specification, the specification is a range. Thus, an identical performance may not be obtained from every primer, though differences may not be noticeable. Some brands of primers are more sensitive than others, not due to quality differences but rather to their design. Primer sensitivity is a concern for problems such as “slam fires” when closing the bolt, causing a premature detonation, which could result in gases escaping from the breech area next to a shooter's face.

1.2 Laws, Regulations, Policies, and Safe Use of Explosives

WS follows all applicable laws, regulations, policies, and directives for the safe use of explosives. WS personnel must report all accidents and incidents to their supervisors and others as required. Explosive use involves inherent risks, which are minimized by following training and safety guidelines. Safe use of explosives also requires appropriate storage, inspections, and security, and these guidelines inherently reduce risks to WS personnel and the public. Some rules and regulations overlap among the various types of explosives, especially storage requirements.

1.2.1 Multicomponent Explosives

WS personnel that handle and use explosives to breach beaver dams abide by the policies in WS Directive 2.435, the WS Explosive Safety Manual, ATF Federal Explosives Laws and Regulations (ATF P 5400.7), Occupational Safety and Health Administration (OSHA) regulations, state regulations, the Institute of Makers of Explosives (IME) safety recommendations (IME 2021), and product manufacturer instructions. WS only uses multicomponent explosives to breach beaver dams to release water impounded behind the dam. WS personnel transport and store the explosive components unmixed. WS safety guidelines and directives prohibit the transport or storage of mixed components by WS personnel. WS personnel mix the components of explosives at the dam site and then attach a detonating cord lead line to the plastic container containing the mixed components. WS personnel place the mixed components into the dam with the lead line extending out of the dam. When placing explosives inside a beaver dam, WS personnel use a pole made of wood or other non-sparking material to create a channel to insert the container containing the mixed components. WS personnel run a detonating cord trunk line across the top of the beaver dam and then attach the lead line(s) from the explosive container(s) at right angles to the trunk line. During blasting activities, detonators and initiation devices must remain in the possession of the WS Explosives Specialist-In-Charge.

From the WS Explosive Safety Manual, the following rules apply to the use and handling of multicomponent explosives by WS employees:

Rule - Specific instructions for the safe handling and use of all explosives, including multicomponent explosives, will be adhered to by all WS personnel certified to use explosives.

Rule - Mixing of multicomponent explosives will occur only at the blasting site. The blasting site is defined as the area where explosive material is handled during loading and 50 feet in all directions from loaded holes or holes to be loaded (i.e., the individual beaver dam to be removed and the surrounding 50-foot area). Any unused, mixed explosives will be deactivated at the blasting site in a timely manner, following the manufacturer’s recommended procedures.

Rule - Warning signs must be placed at conspicuous entrances to the blasting area as appropriate. Other safety measures to prevent unwanted access to the blast area should be taken as appropriate.

Rule - Night blasting or blasting under conditions requiring an artificial light source or under adverse weather conditions is prohibited.

Rule - Safety hats (hard hats) will be worn during blasting activities. The WS Explosives Specialist-in-Charge is responsible for ensuring that all persons present at the blasting site are wearing safety hats.

Rule - Smoking, open flame producing devices (matches and cigarette lighters), and firearms use are prohibited around explosive materials.

Rule - Before blasting operations are conducted in the vicinity of gas, electric, water, sewage, fire alarm, telephone, or other utilities, the Explosives Specialist-in-Charge will contact the Dig Safe One-Call Center # 811 or go to the website call811.com to obtain local utility locations and utility contact information. Operators of utilities will be notified at least 24 hours in advance of blasting and asked to provide exact locations of any utility close enough to the blast site to be of concern. The Explosives Specialist-in-Charge will ensure blasting activities are conducted a safe distance from utilities and other property to avoid damage.

Rule - Conducting blasting operations within 300 feet of a structure or utility is not permitted without authorization from the WS State Director.

Rule - Mobile radio transmitters and cell phones will be turned off during blasting operations involving electric detonators.

Rule - No explosive materials will be abandoned.

Rule - Tamping will be done only with poles made of wood or other non-sparking material.

Rule - At the discretion of the Explosives Specialist-in-Charge, noncertified individuals may provide assistance with moving explosives from the transport vehicle to the blasting site and preparing the blasting site. Only the Explosives Specialist-in-Charge is authorized to carry, handle, and prepare detonators. Noncertified assistants must be a safe distance from the blasting site when the detonator is being prepared and attached to the detonating cord. The Explosives Specialist-in-Charge is responsible for ensuring that all assisting persons are in a safe location (250 foot minimum) before the blast is initiated.

Rule - It is the responsibility of the Explosives Specialist-in-Charge to adhere to all state regulations pertaining to the handling and use of explosives.

Rule - During blasting operations, unattended explosives and binary components must be appropriately secured and locked in or on the vehicle (e.g., in locked IME-22 (IME 2007), toolbox, or camper shell or topper).

Rule - During blasting operations, the initiation device (capacitor discharge machine, shock tube ignition device, or pull-wire lighter) will always remain in the possession of the Explosives-Specialist-In-Charge.

Rule - Before preparing a shot, the Explosives Specialist-in-Charge will ensure that a back-up device or initiation system is available for use if the primary system malfunctions. If using fuse detonators as the primary system, an additional electric or nonelectric shock-tube system must be carried as a back-up system.

Rule - Multiple detonator shots will only be made by Advanced Explosives Specialists except that double capping is mandatory for all fuse detonator-initiated shots. An Advanced Explosives Specialist

is a Certified Explosives Specialist who has successfully completed the WS advanced explosives training course on multiple and delay detonator techniques.

Rule - All misfires will be reported on WS Form 23, Site Blasting Record, and within 72 hours, to the Explosives Safety Subcommittee Chair.

Occasionally, misfires may occur during the use of multicomponent systems (i.e., when mixed explosive components fail to detonate). The WS Explosives Safety Manual provides step-by-step procedures WS personnel must follow when misfires occur. The step-by-step procedures for misfires vary depending on the type of detonator WS personnel used. When using fuse detonators and a misfire occurs, WS personnel must wait at least 60 minutes before returning to the blasting site and must keep the area clear of people. After at least 60 minutes, WS personnel must approach the dam cautiously and look for smoke. If WS personnel detect smoke, WS personnel must retreat immediately. Before approaching the dam, WS personnel must prepare two detonators and fuse assemblies following the checklist procedures for the use of fuse detonators and tape the detonators to a minimum three-foot length of detonating cord. If possible, WS personnel should approach the dam on the opposite side from where the original detonators were attached to the trunk line and must not disturb the misfired detonators. WS personnel would then tie the detonating cord with two new detonators and fuse assemblies to the trunk line running across the dam. WS personnel would check and clear the blasting area and repeat the appropriate warning signal before igniting the fuses. Once personnel light the fuses, they would retreat to the preselected area of safety. If the explosive system fails a second time, WS personnel must use an alternative initiation system to detonate the explosives using the appropriate checklist.

When using shock tube detonators or electric detonators and a misfire occurs, WS personnel must examine the initiation device to determine a potential problem. If the cause of the misfire was a faulty initiation device or connection, then WS personnel must correct the problem and re-initiate the detonation. For example, when using electric detonators and a misfire occurs, WS personnel would check the wires at the blasting machine to determine if a short occurred. If the wires are shorted, WS personnel would correct the problem, ensure the blasting area is clear of people, and then initiate detonation again. In another example, when using nonelectric shock tube detonators and a misfire occurs, WS personnel would check the shock tube initiation device for moisture, mud, or other debris that may have prevented the shock tube from firing. If the cause of the misfire was not associated with the initiation device WS personnel must wait at least 30 minutes before returning to the blast site and must keep the blasting area clear of people. WS personnel then inspect lines and connections leading to and at the blasting site and make any necessary corrections to re-initiating the detonation, If the problem cannot be corrected, WS personnel must use a backup initiation device or prepare a second detonator and detonating cord assembly as described above or use an alternative initiation system to detonate the components of the mixed explosive.

WS personnel must also adhere to storage requirements of explosives below and in Section 1.2.6. When storing multicomponent explosives, WS personnel must store the liquid and solid components in separate locked buildings or store the liquid and solid components locked up separately in the same building. In addition, WS personnel must store nitromethane (liquid component) a minimum of 50 feet away from explosive materials. The solid components may be stored in the same building as explosives that are properly stored in indoor magazines. WS personnel must follow several rules when storing incidental explosives and multicomponent explosives overnight:

Rule - Never store explosives in a residence.

Rule - All explosive materials must be stored in accordance with ATF and OSHA regulations (ATF: Law and Regulations, ATF P 5400.7 and 29 CFR, Part 1910.109) as well as meet state and local requirements.

Rule - Type 1 and Type 2 outdoor explosives magazines must comply with the distance requirements of the American Table of Distances for Storage of Explosives (ATF: Explosives Law and Regulations, ATF P 5400.7, Subpart K, 555.218 and 29 CFR, Part 1910.109(c)(vii)). Indoor magazines must also comply with 555.218, as possible, and always comply with the Table of Distances for Storage of Low Explosives (555.219).

Rule - Overnight storage of explosive materials will be in a magazine which meets one of the following:

a. An outdoor magazine can be used if it meets ATF Type 1 or 2 and OSHA standards (ATF: Explosives Law and Regulations, ATF P 5400.7, Subpart K, 555.207 and 29 CFR, Part 1910.109(c)(3)(i) If a Type 2 outdoor magazine is used, it must have a metal floor, placed on a well-drained site, and be substantially anchored, preferably to a concrete slab.

b. Indoor magazine must meet ATF Type 2 Indoor and OSHA Class II magazine standards. The IME-22 container constructed with 1/2" plywood inside liner and 1/8" low carbon steel surface laminates with a lid that has a 1-inch overhang meets these standards and can be used as an indoor storage magazine (IME 2007). Storage of explosives in any other magazine type, container, or in a different manner is not authorized.

Rule - Indoor magazines are limited to a 50-pound maximum gross weight of explosive material per magazine, or 50 pounds per building when more than one indoor magazine is stored in the same building.

Rule - Indoor magazines must be placed in a secure, locked building for overnight storage and located within 10 feet of an exterior, ground level doorway. When two or more indoor magazines are in the same building, 10 feet should be maintained between magazines, as possible. The door on indoor explosives storage magazines must be equipped with two ATF approved hooded locks, except indoor magazines need only be secured with one steel padlock having at least five tumblers and a case-hardened shackle of at least 3/8 inch diameter, without a hood, if they are located in rooms or buildings for which the doorway(s) is secured by the same locking system required for a magazine; that is, two hooded padlocks, two mortise locks, a combination of a hooded padlock and a mortise lock, a mortise lock that requires two keys to open, or a three point lock. For ATF approved lock specifications, see ATF: Explosives Law and Regulations, ATF P 5400.7, Subpart K, 555.208(b)(4) for indoor magazines and 555.207(a)(9) for outdoor magazines.

Rule – Each indoor magazine must be provided with substantial wheels or casters with the recommendation of an unattached, flat, 4-wheel furniture-type dolly. As a result, all sides of indoor magazines, the front, top, and all sides must be painted red and have in 3" high white lettering reading:

EXPLOSIVES - KEEP FIRE AWAY

Rule - Packages of explosives must not be unpacked or repacked in any type of magazine or near any other explosives.

Rule - Magazine stock and binary components must be rotated so that the oldest material is always used first. The inventory needs should be planned to avoid storing explosive materials for extended periods of time.

Rule - Each magazine storage facility will have an assigned WS Explosives-Specialist- In-Charge who is responsible for the enforcement of safety precautions, security, weekly and biannual inspections, physical inventories, records and reporting requirements, and maintenance.

Rule - Grounds around outdoor magazines and buildings housing indoor magazines must be kept clear at a 25-foot minimum distance of brush, vegetation, and other combustible materials which could pose a fire hazard.

Rule - Smoking, matches, open flames, and spark or flame-producing devices are not permitted inside of or within 50 feet of a magazine. Persons approaching magazines must be warned verbally or by warning signs posted at appropriate locations. Firearms, ammunition, and spark-producing metal tools are prohibited in or near explosive magazines.

Rule - No flammable liquids or other flammable materials will be stored within 50 feet of explosive materials or magazines.

Rule - Signs reading "**Explosives - Keep Off**" are optional on property upon which outdoor magazines are located and on buildings housing indoor magazines. Signs should not be posted at magazine locations where security risk is a concern. If signs are not posted, persons approaching magazines must be warned verbally not to approach within 50 feet of magazines with firearms, ammunition, and spark or flame-producing devices.

Rule - Explosives Specialists will notify (or ensure that their supervisors notify) local law enforcement agencies and the local and/or State Fire Marshall in writing with the location(s) of explosives storage magazines and the types and general amounts of explosive materials stored in the magazine(s).

Rule - Explosives Specialists will restrict access to explosive materials by unauthorized persons by keeping their magazines locked when not adding or removing explosives and by providing proper security to magazine keys.

Rule - The storage of Division 1.1 explosive materials is prohibited.

WS personnel must also transport multicomponent and incidental explosives to and from a beaver dam. An IME-22 container is necessary for the safe transportation of explosive material, and an explosives magazine is required for long-term storage (IME 2007). USDOT regulates transportation of explosives, OSHA (Part 1910.109), and other state and local agencies. and IME Safety Library Publication (SLP) Numbers 1 (IME 2017), 3 (IME 2021), 4 (IME 2016), 12 (IME 2018), 14 (IME 2019), and 22 (IME 2007). WS vehicles that transport explosives materials, including multicomponent explosives, detonating cord, detonators, safety fuse, safety fuse lighters, and nonelectric lead lines, are exempt from USDOT placarding requirements (49 CFR 172.504) and commercial driver's license requirements (49 CFR 383) when the aggregate gross weight of the explosive materials is less than 1,001 pounds. In addition, the following rules apply when WS personnel are transporting explosives materials

Rule - Each vehicle used to transport explosives must be inspected daily before loading explosives. The inspection must be recorded on a daily vehicle inspection log and carried onboard the vehicle (see explosives safety manual).

Rule - The quantity of each explosive material type and binary components being transported must be recorded on an inventory list and carried onboard the vehicle (see explosives safety manual).

Rule - IME-22 containers must be locked and permanently or temporarily secured to the vehicle at all times when explosives are not being loaded or unloaded.

Rule - No persons are allowed to smoke or carry matches or any other flame-producing device while in or near a vehicle transporting explosives. Smoking within 50 feet of explosives is prohibited.

Rule - Metal objects and tools carried in the bed of a vehicle transporting explosives must be carried in wood containers or otherwise secured to prevent them from producing sparks.

Rule - Each vehicle used to transport explosives must be equipped with two (2) fire extinguishers each having a rating of at least 3-A:40-B:C.

Rule - A tarpaulin (heavy-duty waterproof cloth) or other waterproof covering must be used to keep IME-22 containers and other components dry during inclement weather.

1.2.2 Pyrotechnics

Many EPCD pyrotechnics are fired from pyrotechnic pistols, which are typically called launchers. Some pyrotechnics are fired from a shotgun, while others have a fuse that is lit. When using pyrotechnic pistols, the pyrotechnic is inserted part way into a receiver at the end of the pistol barrel and fired from the pistol using a blank ignition primer. When the firing hammer strikes the ignition primer, the spark produced from the primer ignites the pyrotechnic, which propels itself out of the pistol's barrel. CAPA cartridges go the furthest distance at up to 1,000 feet.

EPCD pyrotechnics fired from a shotgun, cracker shells, or shell crackers look and function similarly to shotgun ammunition. The pyrotechnic is contained inside a plastic shell, which also contains an ignition primer. When the shotgun's firing pin strikes the primer, the primer creates a spark that ignites the pyrotechnic. Although newer cracker shells are consistent, the barrel needs to be checked after each use to ensure that the wad, which helps project the pyrotechnic in the shell, has cleared the barrel. If the wad is stuck in the barrel, the next pyrotechnic could blow up inside the barrel.

Though rarely used today, some EPCD rockets and other pyrotechnics were activated with fuses. Rockets tended to travel far distances but were somewhat cumbersome. Thus, few are used by WS field personnel. Most rockets are fired from launchers because of ease of use.

WS requirements for overnight storage:

Rule - Never store pyrotechnics or any other explosive material in a residence.

Rule - All pyrotechnics will be stored in accordance with the next Rule to comply with ATF regulations (Federal Explosives Law and Regulations, ATF P 5400.7) and OSHA regulations (29 CFR 1910.109) or in accordance with the temporary overnight vehicle storage variance cited below.

Rule - Magazines approved for overnight storage of pyrotechnics will meet one of the following descriptions:

a. An outdoor magazine meeting ATF Type 1 magazine standards (Federal Explosives Law and Regulations, ATF 5400.7, Subpart K, 55.207) or ATF Type 2 outdoor magazine standards (ATF 5400.7, Subpart K, 55.208(a) (http://www.atf.gov/pub/fireexplo_pub/explo_law_reg.htm) and OSHA standards (29 CFR, Part 1910.109(c)(3)(i)). Type 2 outdoor magazines will be of substantial size and construction to discourage theft, have metal floors, and be securely anchored to a concrete slab or to substantial ground anchors.

b. An indoor magazine that meets ATF Type 2 or ATF Type 4 indoor magazine standards and OSHA standards (29 CFR, Part 1910.109(c)(3)(i)). See ATF 5400.7, Subpart K, 55.208(b) and 55.210 for construction and lock requirements (http://www.atf.gov/pub/fire-explo_pub/explo_law_reg.htm). The IME-22 container (IME SLP No. 22, Part 2, paragraph B and Appendix 3; http://www.ime.org/imestore/default.asp) exceeds these standards and can be used as an indoor storage magazine for Division 1.4 pyrotechnics. Indoor magazines must be locked and kept in a locked building in accordance with ATF 5400.7, Subpart K (http://www.atf.gov/pub/fire-explo_pub/explo_law_reg.htm). Indoor magazines must be painted red

and have in 3" high white lettering "EXPLOSIVES – KEEP FIRE AWAY" on the front, top, and all sides. Each indoor magazine must be provided with substantial wheels or casters (unattached, flat 4-wheel furniture-type dollies are recommended).

Rule - Pyrotechnics will be stored in a magazine containing no other commodities or materials except for gas cartridge fuses and/or boxed small arms ammunition. Pyrotechnics will not be stored in the same magazine with rocket net charges or explosives used for removing beaver dams (detonators, binary explosives, detonating cord, safety fuse, and pull wire igniters). Pyrotechnics will be maintained in the manufacturer's small cardboard boxes when not in use rather than stored loose or in plastic bags.

Rule - The quantity of any explosive materials stored in an indoor magazine must not exceed 50 lbs. per magazine or 50 lbs. per building when explosive materials are stored in more than one indoor magazine in the same building. For example, the average weight of the total pyrotechnic composition in 15mm bird banger and screamer siren cartridges is 4 grams per cartridge. Therefore, the maximum number of 15 mm bird banger or screamer siren cartridges that can be stored in a single indoor magazine or building is 5,600 cartridges if no other explosive materials are present. The average explosives weight for cracker shells is 2 grams per cartridge; therefore, 11,000 cracker shells equal 50 pounds of explosive material. Since CAPA long-range cartridges (18.2mm) contain an average total explosives weight of 5.73 grams, a total of 3,900 CAPA cartridges contain 50 pounds of explosive material. Any combination of pyrotechnic devices containing a total of not more than 50 pounds of explosive material can be stored together in a single magazine, or when multiple magazines are used, in a single building. The storage of up to 300,000 pounds of explosive material is permitted in ATF Type 1 or Type 2 outdoor magazines. The American Table of Distances for Storage of Explosives (ATF 5400.7, Subpart K, 55.218) applies to explosive materials stored in outdoor magazines. This table provides mandatory separation distances between explosives magazines and inhabited buildings, public highways, and railways.

Rule - Smoking, matches, open flame, or spark producing devices are not permitted within 50 feet of explosives magazines. Persons approaching magazines must be warned verbally or by warning signs posted at appropriate locations. Combustible materials and flammable liquids will not be stored within 50 feet of magazines. The land surrounding a magazine will be kept clear of all combustible materials for a distance of at least 25 feet.

Rule - The appropriate Safety Data Sheet(s) (SDS) will be kept with the magazine.

Rule - Each magazine, their contents, and required inventory records will be in the charge of a designated employee who oversees enforcing safety precautions, security, inspections, and inventory records and reporting requirements.

Rule - Access to explosive materials by unauthorized persons will be restricted by keeping magazines locked when not adding or withdrawing explosive materials from them and by providing proper security to magazine keys.

When necessary, EPCD pyrotechnics and their launch components may be stored overnight in a locked vehicle under the following conditions:

Rule - Overnight storage of pyrotechnics in a vehicle is authorized only when they are "in use" on an assigned project, and it is not practical to return them to magazine storage as described above in section A. Overnight Storage. "In use" on an assigned project is defined as the period between the date a field project is initiated until its completion date not to exceed 14 consecutive days and nights. State Directors and NWRC Field Station Leaders are authorized to extend overnight vehicle storage beyond 14 days on a case-by-case basis when necessary to meet program objectives. Permanent overnight storage of pyrotechnics in a vehicle is prohibited.

Rule - No more pyrotechnic cartridges than necessary to complete an assigned project may be stored overnight per vehicle, and in no case will more than 2,000 cartridges per vehicle be stored in the manner prescribed in this section.

Rule - Pyrotechnics temporarily stored in this manner will be locked inside an unmarked (for security reasons) IME-22 or other secure container containing no metal objects, explosive detonators, pesticides, I&E drugs or other chemicals. At a minimum, this container will consist of a metal exterior and an interior surface of non-sparking material. No screw heads or other metal surfaces will be exposed in the interior. The container lid must overlap the sides by at least 1 inch. For overnight vehicle storage, pyrotechnics must be: 1) stored in a locked container as described above under this rule which is placed out of sight inside a locked vehicle, affixed camper shell, or truck box, or 2) in a locked, unmarked IME 22 container securely affixed to the bed of a truck.

WS rules associated with the transportation of EPCD pyrotechnics:

Rule - During transportation over public roadways, pyrotechnics will be locked in a secure container as described above. Transportation of bulk quantities of pyrotechnics in IME-22 containers (e.g., from a central magazine to smaller outlying magazines) is permitted (IME 2007). IME-22 containers will be permanently or temporarily secured to the vehicle during transit to prevent theft or a safety hazard in the event of an accident and be covered by a tarpaulin or other waterproof covering during inclement weather.

Rule - Metal objects, explosive detonators, pesticides, I&E drugs, and other chemicals will not be carried in the same container with pyrotechnics.

Rule - Each vehicle used to transport pyrotechnics or rocket net charges will be equipped with a fire extinguisher having a rating of at least 3-A:40-B:C. Vehicles transporting bulk shipments (5,000 or more cartridges) of pyrotechnics will carry two such fire extinguishers.

1.2.3 Ammunition

Most of the ammunition used by WS in WDM activities is exempt from regulations regarding purchase, storage, and transportation. Smokeless powders designed for use in small arms ammunition, .50 caliber or smaller rifle or handgun ammunition, and most shotgun ammunition, are exempt from regulation under 18 U.S.C. Chapter 40 and the regulations in 27 CFR Part 555, particularly Subpart K – Storage requirements because smokeless powder is considered a propellant rather than an explosive. Ammunition or projectiles with more than ¼ oz. (110 grains) of explosive or incendiary charge would be subject to the National Firearms Act as “missiles,” 26 U.S.C. 5845(f)(1)(D). Standard rifle cartridges and shotgun shells use an eighth of an ounce (55 grains) or less of smokeless powder. In general, shotgun shells use 25 grains of powder, rifle cartridges, which vary widely depending on the caliber of rifle, bullet weight, and powder type and manufacturer, use about 35 grains of powder, and .22 caliber rim-fire 40-grain bullet cartridges use 3 grains of powder. Packaging that readily identifies the smokeless powder as being designed for use in small arms ammunition may help determine whether it is entitled to the exemption.

1.2.4 Rocket and Cannon Nets

Rocket net charges consist of propellant, a black powder charge, and an electric match, which are available pre-packaged by the manufacturer and inserted into the projectile with holes on one end, like a rocket. Rocket nets use M6 howitzer propellant, like smokeless powder in composition (87% nitrocellulose – an explosive, 10% dinitrotoluene – plasticizer, 3% dibutylphthalate – plasticizer, controls burn and flash, <1% dipheylamine - stabilizer, and <1% potassium sulfate – flash reducer), which functions by propelling a rocket assemblage attached to a net (i.e., rocket net), an explosive component regulated by ATF. When using cannon nets, WS would place the

commercially available smokeless powder into a rubber or paper pouch and insert one end of an electric match into the pouch. WS would then use tape to seal the pouch containing the smokeless powder and one end of the electric match. WS would then attach the electric match to the electrical firing line wire. WS would then un-reel the electric firing line to a safe area off to the side of the net. At the appropriate time (i.e., when target animals are present within the capture area of the net), WS personnel attach the electric firing line to an electrical blasting machine that, when connected, sends an electric current through the electric firing line to the electric matches. The electric matches produce an external spark, which ignites the black or smokeless powder. WS use rocket nets and cannon nets to capture a variety of wildlife. WS personnel follow the WS checklist for rocket net and cannon net setup outlined in the Rocket and Cannon Net Safety Manual when using rocket or cannon nets. The risk assessment addressing WS's use of nets further discusses WS's use of rocket nets and cannon nets.

Rocket net charges are classified as Division 1.4 explosives by USDOT. The only rocket net charges approved for use by WS personnel are W115 rocket net charges manufactured by Winn Star. Each W115 rocket net charge consists of 10 grams of black powder and an electric match enclosed in a small plastic bag and 125 grams of M6 howitzer propellant. Those three components are enclosed in a larger plastic bag with shunted leg wires extending out of the bag. Only S200 rockets manufactured by Winn Star are approved for use with the rocket net system.

Cannon net systems consist of various forms of cannons; however, the standard WS cannon net projectile is a heavy metal barrel projectile that is fired from a launch-rod attached to a metal plate. WS personnel may use smokeless gunpowder or black powder ignited by an electric match; however, the WS standard cannon propellant is smokeless powder. Electric matches (used to initiate cannon net charges) may be stored in the same magazine with rocket net charges. Rocket net charges and electric matches must be stored with their leg wires shunted (exposed wire ends twisted together or held together with the manufacturer's shunt device).

WS personnel adhere to all ATF and OSHA regulations, WS policy procedures and directives, state regulations, IME (2015, 2016) safety recommendations, and product manufacturers' instructions pertaining to the handling and use of explosives. The following rules apply to WS use and handling of rocket and cannon net propellants.

Rule - Rocket net charges and electric matches used for cannon nets will not be distributed outside of WS. WS employees are not authorized to use, handle, or dispose of rocket net charges and electric matches used for cannon nets belonging to other agencies. Obtaining rocket net charges or electric matches from any source other than a licensed distributor or manufacturer is prohibited.

Rule - Specific instructions for the safe handling and use of all explosive components as prepared by the manufacturer will be adhered to by all WS personnel certified to use rocket and cannon nets.

Rule - Smoking, open flame producing devices (matches and cigarette lighters), and firearms use are prohibited around explosive materials.

Rule - Only approved rocket or cannon net components will be used.

Rule - During netting operations, the capacitor discharge machine is to always remain in possession of the Net Operator-in-Charge.

Rule - Turn off all cell phones, radios, or any other electronic devices capable of sending a signal while setting-up the system.

Rule - Never work in front of or directly behind armed rockets or cannons.

Rule - Net Operator-in-Charge will not leave loaded rockets or cannons unattended at any time.

Rule - It is the responsibility of the Net Operator-in-Charge to adhere to all state regulations pertaining to the handling and use of explosives.

Rule - During netting operations, unattended explosives must be appropriately secured and locked in or on the vehicle (e.g., in locked IME-22, toolbox, or camper shell/topper).

Rule - Before firing a shot, the Net Operator-in-Charge must ensure that the area is clear of people or sensitive nontarget species both downrange and behind the net area.

During the overnight storage of net propellants, WS personnel must follow the following rules.

Rule - Never store rocket or cannon net explosives components or any other explosive material in a residence.

Rule - All rocket net charges and cannon net explosives components will be stored in accordance with Section II (A), Rule 3 to comply with ATF regulations (Federal Explosives Law and Regulations, ATF P 5400.7) and OSHA regulations (29 CFR 1910.109) or in accordance with the temporary overnight vehicle storage variance cited below.

Rule - Magazines approved for overnight storage of rocket net charges/ cannon net explosive components will meet one of the following descriptions:

a. An outdoor magazine meeting ATF Type 1 magazine standards (Federal Explosives Law and Regulations, ATF 5400.7, Subpart K, 55.207) or ATF Type 2 outdoor magazine standards (ATF 5400.7, Subpart K, 55.208(a)) and OSHA standards (29 CFR, Part 1910.109(c)(3)(i)). Type 2 outdoor magazines will be of substantial size and construction to discourage theft, have metal floors, and be securely anchored to a concrete slab or to substantial ground anchors.

b. An indoor magazine that meets ATF Type 2 or ATF Type 4 indoor magazine standards and OSHA standards (29 CFR, Part 1910.109(c)(3)(i)) (see ATF 5400.7, Subpart K, 55.208(b) and 55.210 for construction and lock requirements). Indoor magazines must be locked and kept in a locked building in accordance with ATF 5400.7, Subpart K. Indoor magazines must be painted red and have in 3" high white lettering "EXPLOSIVES – KEEP FIRE AWAY" on the front, top, and all sides. Each indoor magazine must be provided with substantial wheels or casters so that magazines can be easily moved in the event of an emergency. (Unattached, flat 4-wheel furniture-type dollies are recommended).

c. The IME-22 container (IME SLP No. 22, Part 2, paragraph B and Appendix 3) that meets ATF Type 2 indoor magazine standard may be used.

Rule - The quantity of any explosive materials stored in an indoor magazine must not exceed 50 pounds per magazine or 50 pounds per building when explosive materials are stored in more than one indoor magazine in the same building. The storage of up to 300,000 pounds of explosive material is permitted in ATF Type 1 or Type 2 outdoor magazines. The American Table of Distances for Storage of Explosives (ATF 5400.7, Subpart K, 55.218) applies to explosive materials stored in outdoor magazines. This table provides mandatory separation distances between explosives magazines and inhabited buildings, public highways, and railways.

Rule - Smoking, matches, open flame, or spark producing devices are not permitted within 50 feet of explosives magazines. Persons approaching magazines must be warned verbally or by warning signs posted at appropriate locations. Combustible materials and flammable liquids will not be stored within 50 feet of magazines. The land surrounding a magazine will be kept clear of all combustible materials for a distance of at least 25 feet.

Rule - The appropriate Safety Data Sheet(s) will be kept with the magazine.

Rule - Each magazine, their contents, and required inventory records will be designated to an employee who is responsible for maintaining safety precautions, security, inspections, and inventory records and reporting requirements.

Rule - Access to explosive materials by unauthorized persons will be restricted by keeping magazines locked when not adding or removing explosive materials and by providing proper security to magazine keys.

When necessary, WS personnel may store net charges and electric matches, overnight in a locked vehicle pursuant to the following rules.

Rule - Overnight storage of rocket net charges and electric matches in a vehicle is authorized only when they are "in use" on an assigned project, and it is not practical to return them to magazine storage as described for overnight storage. State Directors and NWRC Field Station Leaders are authorized to extend overnight vehicle storage beyond 14 days on a case-by-case basis when necessary to meet program objectives. Permanent overnight storage of rocket net charges, electric matches, and incidental explosives materials in a vehicle is prohibited.

Rule - Only the number of rocket net charges and electric matches needed to complete an assigned project may be temporarily stored overnight per vehicle.

Rule - Rocket net charges and electric matches temporarily stored in a vehicle must be: 1) stored in a locked container, which is placed out of sight inside a locked vehicle, affixed camper shell, or truck box; or 2) in a locked IME-22 container that is securely affixed to the bed of a truck. At a minimum, this container will consist of a metal exterior and an interior surface of non- sparking material. No screw heads or other metal surfaces will be exposed in the interior. The container lid must overlap the sides by at least one inch. The IME-22 or other secure container may not contain detonators.

During transportation of net charges and electric matches WS personnel must adhere to the following rules.

Rule - During transportation over public roadways, rocket net charges and electric matches will be locked in a secure container as described in the rules for temporary overnight vehicle storage.

Rule - Transportation of bulk quantities of rocket net charges and electric matches in IME-22 containers (e.g., from a central magazine to smaller outlying magazines) is permitted. IME-22 containers will be permanently or temporarily secured to the vehicle during transit to prevent theft or a safety hazard in the event of an accident and be covered by a tarpaulin or other waterproof covering during inclement weather.

Rule - Explosive detonators will not be carried in the same container with rocket net charges, electric matches, and incidental explosives materials.

Rule - Each vehicle used to transport rocket net charges and electric matches will be equipped with a fire extinguisher having a rating of at least 3-A:40-B:C.

1.2.5 Incidental Explosive Materials

Examples of incidental explosive materials that WS uses include detonators, detonating cord, nonelectric shock tube, safety fuse, pull-wire fuse lighters, electric matches, fuses for gas cartridges, and primers. Detonators are devices containing an initiating explosive and a base charge used to initiate a detonation in an explosive. WS could use fuse detonators, nonelectric

detonators, and electric detonators during the use of multicomponent explosives. Fuse detonators are detonators that are initiated by a safety fuse. Nonelectric detonators are detonators that do not require the use of electric current or safety fuse to function with initiation occurring by a spark or flash from a shock tube initiation device. A detonation wave transmitted through the shock tube initiates the detonator. The detonation wave travels through the shock tube at a velocity of approximately 6,500 feet per second. Electric detonators are detonators that active by a small electric current. Primers are used for ammunition and pyrotechnic launchers and are responsible for initiating propellant combustion that pushes projectiles out of a gun barrel or pyrotechnic launcher.

From the WS Explosives Safety Manual, WS personnel must follow several rules related to the use, storage, and transportation of detonators and other incidental explosives:

Rule - Detonators must always be stored by themselves packaged as Division 1.4 in a magazine containing no other type of explosive material.

Rule - Detonating cord, safety fuse, pull-wire lighters, and shock tube may be stored together in the same magazine but they must be stored in an approved magazine separate from detonators.

Rule - Detonating cord (gross weight of 99 lbs. or less and with an explosive core load not exceeding 100 grains per foot) must be transported in an IME-22 container not containing any detonators.

Rule - Safety fuse must be transported in an IME-22 container. Safety fuse may be transported with detonating cord and pull-wire lighters in the same IME-22.

Rule - Pull-wire lighters must be transported in an IME-22 container. Pull-wire lighters may be transported with detonating cord and safety fuse in the same IME-22.

Rule - Shock tube must be transported in an IME-22 container. Shock tube may be transported with detonating cord, safety fuse, and pull-wire lighters in the same IME-22.

Rule - Fuse detonators, electric detonators, and nonelectric shock tube detonators received packaged as Division 1.1 explosives must be repacked as Division 1.4 explosives before being transported and stored by WS.

Rule - Detonators must always be stored by themselves in a magazine containing no other type of explosive material.

Rule - Electric detonators, nonelectric shock tube detonators, and fuse detonators must be carried in a locked IME-22 container containing no other explosive materials (i.e., detonating cord, safety fuse, pull-wire lighters, and shock tube (IME 2007)). Detonators may either be transported in their original Division 1.4 container or in an approved wood repack box, which then must be placed in an IME-22 container for transportation.

When using fuse detonators, WS personnel cut a minimum three-foot length of safety fuse and attach a fuse detonator to one end of the safety fuse by gently pushing the safety fuse into the detonator. Using a cap-crimping tool (non-sparking), WS personnel crimp the detonators to the safety fuse. WS personnel then attach pull-wire lighters to the safety fuse before attaching the fuse detonators to the detonating cord trunk line. Personnel tape detonators to the detonating cord trunk line with the detonators pointed toward the direction of detonation. Detonators are attached at least six inches from the end of the trunk line. The safety fuse is secured to an elevated object. WS personnel check and clear the blasting area and yell a loud verbal warning of "***Fire in the Hole***" before igniting the fuses with pull-wire lighters. WS personnel then retreat to a preselected area of safety (minimum distance of 250 feet) and take appropriate cover, preferably

in a preselected area where the blast site can be observed. After the fumes have cleared from the detonation area, WS personnel return, secure the blast area and give a verbal "***All Clear***" signal.

WS personnel follow similar safety procedures when using fuse detonators, nonelectric shock tube detonators and electric detonators. When using explosives, WS personnel are prohibited from conducting blasting activities if thunderstorm activity is occurring in the vicinity. WS safety guidelines not only prohibit the use of electric detonators with thunderstorms, but also do not allow their use around electrical transmission lines, wind turbines, transformers, power stations, radio-frequency transmitters, or where other stray currents could be present, and in dust storms, snowstorms, or other areas where static electricity may be present. When using electric detonators and the associated firing line, the free ends of wiring remain shunted until permitted by the checklist for the use of electric detonators. Shunting is the shorting together of the free ends of electric detonator leg wires, the wire ends of an electric blasting circuit or the name of an electrical shorting device applied to the free end of electric detonators by the manufacturer.

WS safety guidelines impose use restrictions for using fuse detonators by WS explosives specialists. From the WS Explosive Safety Manual, the following use restrictions apply to the use and handling of fuse detonators by WS employees:

Rule - Fuse detonators will only be used when an electric or shock tube initiation system is impractical.

Rule - Use of fuse detonators by WS Explosives Specialists will conform to all applicable laws, regulations, and WS policy procedures. Explosives Specialists must ensure that the use of fuse detonators is legal for use within their State.

Rule - Explosives Specialists will observe the requirements set forth in WS Explosives Safety Bulletins as prescribed by the WS Explosives Safety Subcommittee.

Rule -Every Explosives Specialist must have access to an electric or shock tube initiation system.

Rule - Fuse detonators can only be used at blasting sites located farther than 500 feet from any public road, railroad track, frequently traveled trail or back road, or building or other structure where people are likely to be present.

Rule - Fuse detonators will not be used in areas where low-flying aircraft are likely to be present.

Rule - Two persons must be present during blasting operations involving fuse detonators.

Rule - The use of two fuse detonators ("double-capping") to initiate each shot is mandatory. The use of commercially manufactured fuse detonator assemblies is permitted.

Rule - Use of appropriate warning signals is mandatory for all fuse detonator-initiated shots (i.e., "Fire-in-the-Hole"). Air horn warnings may be required by some State regulations.

Rule - All misfires must be recorded on WS Form 23, Site Blasting Record, and reported to the Explosives Committee Chair.

A shock tube is a small diameter laminated plastic tube coated with a very thin layer of reactive material that ignites at approximately 6,500 feet per second. Detonating cord is a flexible cord containing a center core of high explosive (PETN) used to initiate other explosives. PETN detonates at approximately 23,000 feet per second (4 miles per second). Safety fuse is a flexible cord containing an internal burning medium by which fire or flame is conveyed at a continuous and uniform rate from the point of ignition to the point of use, usually a fuse detonator. Safety fuse

burns at a standard rate of 40 seconds per foot. Because many factors can affect the burn speed of a safety fuse, WS personnel can check the burn rate of the safety cord by timing the burning speed of a one-foot section of the safety fuse roll. When using safety fuse, WS personnel must use a minimum length of three feet of safety fuse.

Pull-wire fuse lighters are safety devices designed for lighting a safety fuse without an open flame. Electric matches are firing devices that burn with an external flash initiation using an electric current and are used for igniting black powder, smokeless powder, or pellet powder when using cannon nets. Gas cartridge fuses are the ignition method for activating gas cartridges. The fuse is inserted into the gas cartridge before placing the gas cartridge into the burrow or den of a target animal. When lit, the fuse slowly burns to the gas cartridge and ignites the contents of the cartridge.

A discussion on the use, storage, and transportation of electric matches by WS personnel can be found in the section discussing net propellants. Gas cartridge fuses can be stored and transported with gas cartridges in containers approved for hazardous chemicals described in WS Directive 2.401. When stored separately from the gas cartridges, fuses must be kept in a locked metal container with a non-sparking lining (e.g., wood, foam rubber, latex paint). During storage and transportation, gas cartridge fuses must remain sealed in a plastic bag. Gas cartridges cannot be stored in an explosives magazine.

1.2.6 Transportation and Storage

WS personnel must follow several rules related to the transportation and storage of explosives material discussed above. The transportation of explosives requires specific placards on vehicles and boxes, which many rules have been included above. The USDOT classifies explosives according to Class, Division, and Compatibility Group. These provide the placard rating for transporting explosives, and the significance of these groups are:

Class: A hazardous material is assigned a class number to indicate that it meets defining criteria relative to its transport hazard. Explosive substances and articles are in Class 1.

Division: Class 1 materials are subdivided into divisions and given a division number to define and describe in greater detail the hazardous characteristics and properties of the substances or article. Class 1 is divided into six divisions based on the primary hazard; 1.1 mass explosion, 1.2 projections, 1.3 fire, 1.4 minor hazard, 1.5 mass explosion but very insensitive and 1.6 very insensitive articles.

Compatibility Group Letter: Further, an explosive is assigned a compatibility group letter to indicate its compatibility with other explosives. Generally, only explosives with the same compatibility group letter can be transported together. Detonators 1.4B or 1.4S and certain detonators 1.1B may be shipped with certain other Division 1.1D materials in accordance with SLP-22 specifications.

Compatible (Compatibility): Class 1 materials are compatible if they can be safely transported together without significantly increasing either the probability of an accident or, for a given quantity, the magnitude of the effect of such an accident.

Storage and transportation of explosives materials were given above for the explosive type. WS vehicles that transport explosives materials, including multicomponent explosives, pyrotechnics, detonating cord, detonators, safety fuses, safety fuse lighters, and nonelectric lead lines, follow placarding requirements of USDOT (49 CFR 172.504) and commercial driver's license requirements (49 CFR 383), but do not have to have placards or a commercial driver's license when the aggregate gross weight of the explosive materials transported is less than 1,001 pounds.

1.2.7 Magazine Inspections

Inspections ensure that stored explosives are safe and secure and that people or animals have not created problems.

Rule - Each magazine site where explosive materials are stored will be inspected at least every 7 days. This weekly inspection need not be an inventory but must be sufficient to determine whether unauthorized entry or theft of explosive materials has occurred.

Rule – Safety inspections of explosives magazine sites will be conducted and documented a minimum of twice annually on APHIS Form 256-5, APHIS Safety Inspection Checklist for explosive materials stored in magazines located at government-owned and leased facilities, and on WS Form 39, WS Self-Inspection Checklist - Residential Storage Sites for Pesticides, Pyrotechnics, Rocket Net Charges, and/or Incidental Explosive Materials, for magazines stored at an employee's place of residence. Upon completion, inspection forms will be forwarded to the State program or NWRC Field Station designated official.

1.2.8 Theft and Security

Theft or loss is a primary concern for WS and the public, as many of these explosives could be used for nefarious purposes. Several rules apply, including laws regarding storage.

Rule – Any WS employee with knowledge of the theft or loss of explosive material will immediately notify their supervisor. As soon as possible, and within 24 hours of discovery, the theft or loss must be reported to ATF. ATF Form 5400.5 will be immediately completed and mailed or faxed to the nearest ATF office along with any invoices and additional information (ATF: Explosives Law and Regulations, ATF P 5400.7, Subpart C, 55.30).

Rule – Any suspicious or unusual activity, theft or attempted theft of explosive materials as well as break-ins or attempted break-ins to buildings where explosive materials are stored will be reported in a timely manner to State and local law enforcement and the appropriate WS authorities.

1.3 Use Pattern

Pyrotechnics and ammunition for firearms are the most widely used "*explosives*" that WS employs, being used in all states and three territories[4]. The primary use is at airports and airbases where WS personnel haze wildlife from runways and the air operating area. Additional uses are to protect agriculture, property, and natural resources from wildlife and protect human safety in other areas outside of airports. From FY16-FY20, WS used an annual average of 356,824 pyrotechnics of all types, including rockets and 360 firearm blanks, to disperse 34 species of mammals, 329 species of birds, and 3 species of reptiles totaling 22,115,160 wildlife hazed from areas (Table 2). This equates to an average of 62 animals hazed per pyrotechnic used. Similarly, from FY11 to FY15, WS used an annual average of 457,981 pyrotechnics of all types, including rockets and 104 firearm blanks, to haze 15,634,354 wildlife (348 species), including 31 mammalian species, 311 avian species, and 6 reptilian species (Appendix 2). This equates to an average of 34 animals hazed per pyrotechnic used; it should be noted that several species of flocking birds, such as blackbirds, can number in thousands during hazing.

[4] MIS - Computer-based Management Information System used for nationally tracking APHIS-WS WDM devices used and activities. Not all devices or activities are tracked such as ammunition or primers used, thus some usage will need to be estimated as a result.

Table 2. The annual average number of target animals hazed with all pyrotechnics and blanks by WS in WDM activities from FY16 to FY20 throughout the United States and its territories. Nontarget animals incidentally hazed included an annual average of 600 mallards. During the 5 years, one target American white pelican was accidentally killed with a pyrotechnic at an aquaculture facility.

ANNUAL AVERAGE SPECIES HAZED WITH PYROTECHNICS AND BLANKS FY16-FY20					
Species[1]	**Disperse**	**Species[1]**	**Disperse**	**Species[1]**	**Disperse**
Mammals		Eastern Meadowlark	7,153	Bufflehead	10,741
Northwestern Gray Wolf T&E	1	Western Meadowlark	4,524	Common Goldeneye	3,001
Steller Sea Lion T&E	3,827	Other Grass Passer. (20	2,484	Barrow's Goldeneye	1,373
California Sea Lion	1,184	American Robin	14,921	Hooded Merganser	2,926
Other Predator (14 sp.+1	308	House Finch	1,072	Common Merganser	3,752
Caribou	1,685	Pine Siskin	1,626	Red-breasted Merganser	37,863
Other Hoofed Mammals (8	381	Other Forest Passerine (22	1,570	Ruddy Duck	7,420
Other Mammal (8 sp.)	45	Common Myna	7,093	- Mixed Ducks	1,526
Total Mammal (34 sp.)	**7,431**	Scaly-breasted Mannikin	5,240	Other Waterfowl (20 sp.)	4,314
Birds Associated with Land		House Sparrow	2,360	Newell's Shearwater T&E	2
European Starling*	13,631,10	Other Invasive Passer. (7	547	Western & Clark's Grebe	27,894
Yellow-headed Blackbird	1,779	**Land Bird Total (155 sp.)**	**15,769,871**	American White Pelican	17,118
Tricolored Blackbird	3,728	**Birds Associated with Water**		Brown Pelican	2,068
Red-winged Blackbird	860,605	Red-legged Kittiwake	4,512	Pelagic Cormorant	2,365
Brown-headed Cowbird	61,030	Bonaparte's Gull	4,955	Double-crested Cormorant	173,502
Brewer's Blackbird	8,838	Laughing Gull	264,393	Other Open Waterb. (18	1,165
Rusty Blackbird	60	Franklin's Gull	109,448	Wood Stork Some T&E	427
Common Grackle	19,965	Short-billed (Mew) Gull	2,554	American White Ibis	17,525
Boat-tailed Grackle	2,307	Ring-billed Gull	2,919,563	Glossy Ibis	1,113
Great-tailed Grackle	3,495	California Gull	254,918	White-faced Ibis	1,502
- Mixed Blackbirds	66,862	Great Black-backed Gull	66,506	Western Cattle Egret^	38,672
Rock Pigeon*	15,011	Glaucous-winged Gull	72,697	Great Blue Heron	4,683
Eurasian Collared-Dove	1,890	Western Gull	1,854	Great Egret	9,830
Mourning Dove^	48,759	American Herring Gull	1,151,025	Snowy Egret	2,484
White-winged Dove	34,773	Caspian Tern	17,952	American Coot	10,456
Other Dove (7 sp.)	1,207	Roseate Tern T&E	10	Sandhill Crane	73,643
American Crow	660,521	Common Tern	1,492	Whooping Crane T&E	7
Fish Crow	8,711	Least Tern	12,258	Other Wading Birds (11	1,538
Common Raven	34,889	Black Tern	1,312	Black-necked Stilt	461
Other Corvid (4 sp.)	183	Other Larid (18 sp.)	2,887	- Hawaiian Stilt T&E	254
Turkey Vulture	59,686	Greater White-fronted	19,043	Pacific Golden-Plover	24,027
Black Vulture	30,437	Snow Goose	242,887	Gray (*Black-bellied*)	7,148
Western Osprey	1,916	Brant	2,292	Semipalmated Plover	4,725
Bald Eagle	36,967	Cackling Goose	309,836	Killdeer	8,759
Hawaiian Hawk T&E	1	Canada Goose	182,913	Whimbrel	1,652
Red-tailed Hawk	4,189	Hawaiian Goose T&E	860	Long-billed Curlew	7,065
American Kestrel	1,672	Gadwall	8,016	Willet	3,113
Other Raptor (29 sp.)	3,699	American Wigeon	8,528	Black Turnstone	1,172
Gallinaceous Birds (12 sp.)	982	Mallard (incl. 44 feral*, 600	44,558	Sanderling	3,642
Bank Swallow	13,483	Hawaiian Duck T&E	243	Dunlin	9,775
Tree Swallow	30,139	Blue-winged Teal	5,903	Red Knot T&E	5
Barn Swallow	32,168	Northern Shoveler	18,149	Least Sandpiper	2,789
American Cliff Swallow	13,507	Northern Pintail	8,820	Western Sandpiper	4,898
Cave Swallow	1,364	Green-winged Teal	5,062	Long-billed Dowitcher	1,310
Other Aerialists (6 sp.)	1,910	Canvasback	2,100	Other Shorebirds (29 sp.)	6,565
Nonpasserine Forest Birds (7	310	Redhead	4,750	**Water Bird Total (172**	**6,337,790**
Horned Lark	14,398	Ring-necked Duck	4,420	**Unidentified Bird**	**64**
American Pipit	4,800	Greater Scaup	7,347	**Total Bird (327 sp.)**	**22,107,72**
Snow Bunting	1,731	Lesser Scaup	27,407	**Reptile (2 sp + Unid**	**4**
Savannah Sparrow	2,205	Spectacled Eider T&E	50	**GRAND TOTAL (363**	**22,115,16**

***** Introduced Species ^ Some populations introduced

[1] Accounts of species are given only for those mammals and reptiles that had an annual average of 100 or more hazed, birds with 1,000 or more hazed, and all sensitive species with one or more; "Other" species are listed in Appendix 1.

The European starling (62%)[5], ring-billed gull (13%), American herring gull (5%), red-winged blackbird (4%), and American crow (3%) were the most frequently hazed species; the groups of species that accounted for the most use of pyrotechnics included 10 species of starlings and blackbirds (66%), 34 species of larids (22%), 47 species of waterfowl (4%), and 7 species of corvids (3%) (Table 2). The most common pyrotechnics used are from launchers, including the use of reports, screamers, and CAPA cartridges and cracker shells, with an annual average of 355,887 used from FY16 to FY120, hazing 22,115,160 animals. Rockets, an annual average of 937 used from FY16 to FY20, hazed 31,430 animals. Firearm ammunition blanks were used 360 times to haze 40,642 animals. Additionally, 1,084 blanks were used to fire Coda Enterprises, Inc 271 nets that captured 247 and hazed 134 animals (Table 3).

Some pyrotechnics, rockets, and colored flares are fired from the ground or platform. These have different risks associated with them because they must be lit with a flame and may travel further distances. Due to the recording of data in the MIS, a code "Pyrotechnics (All)" could be used that does not differentiate among the different types; thus, it is unknown just how many rockets are used, but a minimum of 937 annually from FY16 to FY20 (Table 3).

Table 3. The annual average number of beaver dams removed and multicomponent explosives used, pyrotechnics and blanks used and animals dispersed, gas cartridge fuses used, and target and nontarget animals captured or taken with nets and firearms by WS in WDM activities from FY16 to FY20 throughout the United States.

ANNUAL AVERAGE SPECIES TAKEN WITH METHODS INVOLVING EXPLOSIVE PER ATF FOR FY16-FY20					
ACTIVITY (# SPECIES INVOLVED) # STATES USED	**TARGET**			**# USED**	
MULTICOMPONENT EXPLOSIVE USAGE	**Dams Removed**			**Binary Explosives**	
Beaver Dams Removed (1 T sp.) 20 States	1,379			3,084 lb. (2.2 lbs./dam)	
PYROTECHNIC & BLANK USAGE[1]	**Target Dispersed**			**# Pyrotechnics Used**	
15 mm Report/Screamer Cartr. (318 T sp.) 16 States,1	15,733,372			166,674	
Pyrotechnic Rockets (25 T sp.) 7 States	31,431			937	
Cracker shells – 12 Ga. Shotgun (226 sp.) 14 States	990,831			26,339	
CAPA Cartridges (66 T sp.) 11 States	45,613			370	
Pyrotechnics (All) (268 T sp, 2 NT) 0.2 Killed 41 States, 2	5,273,271			162,504	
Blank Usage (82 T sp.) 10 States	40,642			~360	
Pyrotechnic/Blank Take (369T, 2 NT – 369 sp.) 50 States,	**22,115,160**			**357,184**	
GAS CARTRIDGE FUSES USED[2]	**Est. Rodents/Predators Taken**			**Fuses Used**	
Gas Cartridge Fuses (16T, 1 NT sp.) 33 States, DC	10,458			15,042	
TAKE WITH NETGUN, ROCKET AND CANNON NETS[3]	**Killed**	**Release**	**Disperse**	**Shots**	**Charges**
Rocket/Cannon Net Take (16T, 1NT – 16 sp.) 18 States	862	418	28	38	142
Coda Netguns and Cannon Nets (15T) 14 States	87	160	134	271	1084
Total Netgun Take (24T, 1NT - 24 sp.) 27 States	949	578	162	309	1,226
FIREARM USAGE[4]	**Killed**	**Disperse**	**NT**	**Shots**	**Lbs. GP**
Shotgun (346 T, 6 NT - 348 sp.)	293,295	2,911,25	2	844,343	3,015
Small Caliber Rifle/Pistol (.22) (104T, 37NT - 109 sp.)	82,007	460	990	121,953	53
Large Caliber Rifle/Pistol (35T, 7NT - 36 sp.)	74,070	891	235	113,177	566
Total Firearm Take (438T, 54NT - 442 sp.) 50 States, 3	**449,372**	**2,912,61**	**1,227**	**1,079,473**	**3,634**

T – Target **NT** – Nontarget (# T and NT species in group, # sp. is all species in group including T and NT)

[1] See Table 2 for the breakdown of species

[2] See "*The Use of Carbon Monoxide from Gas Cartridges and Forced Gas Fumigation Systems in Wildlife Damage Management*" for further information and species taken

[3] See "*The Use of Nets in Wildlife Damage Management*" for further information and species taken – does not include use of Coda net launchers (271 uses-1,084 blanks (.308 cart))

[4] See "*The Use of Firearms in Wildlife Damage Management*" for further information and species taken including the estimated number of target and nontarget animals captured with other WDM methods such as foothold traps and euthanized with a shot to the brain

[5] This actually could be higher as starlings are included in the MIS code "Mixed Blackbirds" and 67,000 were hazed in this category.

WS used multicomponent explosives to remove beaver dams in 20 states. Beaver dams cause damage, such as the flooding of roads, crops, and property, including residential homes. An annual average of 1,379 dams were removed from FY16 to FY20 using an average of 3,084 pounds of explosives, which equates to 2.2 pounds per beaver dam (Table 3). All WS users are certified and follow all applicable regulations.

WS uses cannon and rocket nets, and new models that launch nets with.308 cartridge blanks or compressed air, which are being used more due to their ease and added safety, were included in Table 3. Take from rocket and cannon nets and nets propelled by.308 cartridges are given in *The Use of Nets in Wildlife Damage Management* risk assessment, but explosive use was reserved for this risk assessment. Even so, WS personnel captured animals in an annual average of 309 activations (no animals were captured in some activations that were either demonstrations or the target animal was missed. Thus, about 309 activations were conducted per year, capturing 1,527 target birds (Table 3). Additionally, though not the intended use of cannon nets, 162 birds were dispersed from the use site (Table 3), which is a typical reaction from those not captured, usually not within the area covered by the net. If we assume that 4 cannons/rockets (3 are often used, so likely an overestimate) were used per net firing, and all uses with no captures fired a cannons/rocket net (WS personnel may put down the use of a rocket and cannon net even if they do not fire the rocket and cannon net), then an average of 1,236 individual cannons/rockets would have been fired.

WS fired an estimated annual average of 1,079,473 rounds of ammunition for FY16-FY20 based on *The Use of Lead in Wildlife Damage Management Risk Assessment*[6], 844,343 shotgun shells (2.75" shell with 25 grains powder), 113,177 rifle cartridges (130 grain bullet with 35 grains powder), and 121,953 .22 cartridges (40 grain bullet with 3 grains powder) (Table 3). This would equate to the use of about 3,604 pounds of powder used annually (this is likely overestimated to be conservative). Similarly, in FY11-FY15, WS fired an estimated annual average 1,076,933 ammunition loads, 876,751 shotgun shells (2.75" shell with 25 grains powder), 73,938 rifle cartridges (130 grain bullet with 35 grains powder), and 126,244 .22 cartridges (40 grain bullet with 3 grains powder) (Table 3). This would equate to the use of about 3,555 pounds of powder used annually (this is likely overestimated to be conservative).

The use of incidental explosive materials is not tracked but can be estimated from the use of the other equipment in WDM. WS used an estimated annual average of 1,379 detonation cords (an average of 50-100 ft. of leads per dam or 137,900 ft. annually by WS) and associated devices (e.g., safety fuse) for beaver dams and 142 electric matches for rocket and cannon nets (4 cannons/rockets per net). Primers are fired in ammunition and pyrotechnics to initiate an explosion. WS fired an annual estimated average of 356,247 pyrotechnics, which excludes known pyrotechnic rockets, and 1,079,473 rounds of ammunition from FY16 to FY20 that used primers, or 1,079,473 primers used. Finally, WS used 15,042 gas cartridges[7] annually from FY16 to FY20. Thus, 15,042 fuses were also used to actuate these, and 937 fuses were used for pyrotechnic rockets. Fuses are usually about 6 inches long, though pyrotechnic fuses can sometimes be a little longer or shorter. However, estimating 6 inches for safety fuses would amount to 7,990 feet used annually. The incidental explosives are important for the proper function of WDM devices but add another risk.

[6] The Use of Lead in Wildlife Damage Management provided assumptions on how we estimated ammunition use, overestimating to be conservative, and was used to estimate ammunition use.

[7] The Use of Carbon Monoxide from Gas Cartridges and Forced Gas Fumigation Systems in Wildlife Damage Management considered the carbon monoxide and take associated with gas cartridges.

2 HAZARDS

Many industries, from road departments and mining to movie production and law enforcement agencies, use explosives. WS uses several explosives in WDM. Explosive devices inherently can be hazardous to people and the environment and, as a result, require safe and reasonable use. The use of explosives has two components of risks, the physical hazards such as injuries and burns and the chemical hazards from the gas emissions from explosives and solids produced. Since the primary hazards are physical, this risk assessment is formatted more like a mechanical risk assessment than a chemical risk assessment. Standard hazards associated with the physical aspects will be discussed, followed by the chemical aspects for human health and environmental health.

Because multicomponent explosives, net propellants, pyrotechnics, and incidental explosive materials are all explosive materials, WS adheres to all OSHA regulations and WS policy procedures. Policies outlined in WS safety manuals, state regulations, IME safety recommendations, and product manufacturer's instructions pertaining to the handling and use of explosive materials reduce risks to human safety. WS employees must complete training and a certification process established by WS before handling and using explosives for official WS WDM activities. WS employees must complete a 24-hour basic explosive training course administered by WS before using multicomponent explosives. To use net propellants for rocket and cannon nets, WS personnel must complete a 16-hour basic training course administered by WS. The WS Explosives Safety Subcommittee will determine training requirements, conduct training, and recommend candidates eligible for certification. Recertification training is required every three years for WS employees to retain certification in the use of multicomponent explosives and net propellants. Recertification requires a minimum of eight hours of approved refresher training. WS explosive specialists are authorized to use only those explosive materials and components listed in the WS Explosive Safety Manual and the WS Rocket and Cannon Net Safety Manual. Obtaining explosive materials from any source other than licensed distributors or manufacturers is prohibited. Additional trainings and certifications are required for other methods, such as Firearms and pyrotechnics; this was discussed in *The Use of Firearms in Wildlife Damage Management*" risk assessment.

Explosive magazines, their contents, and required inventory records will be designated to an employee responsible for maintaining safety precautions, security, inspections, and inventory records and reporting requirements. The responsible employee must inspect their facility and magazines at least every seven days and must document the inspection (ATF: Explosives Law and Regulations, ATF P 5400.7, Subpart K, 555.204). The inspection by the responsible employee must be sufficient to determine whether there has been unauthorized entry, attempted entry, or unauthorized removal of the contents of the magazines. The inspections should also identify magazine and building maintenance needs. WS must conduct and document detailed safety inspections of all explosive storage work sites at least biannually.

Any WS employee who knows of the theft or loss of any explosive materials must report the theft or loss to ATF by telephoning 1-888-283-2662 as soon as possible and within 24 hours of discovery. In addition, the employee must immediately complete ATF Form 5400.5. The employee must then mail or fax ATF Form 5400.5 along with any invoices and additional information to the nearest ATF office (ATF: Explosives Law and Regulations, ATF P 5400.7, Subpart C, 555.30). The employee must report the theft or loss of any explosive materials to the Regional Director and local authorities through appropriate channels in a timely manner. In addition, WS employees must report to state and local law enforcement authorities and the Committee Chair of the WS

Explosives Safety Subcommittee any suspicious or unusual activity or attempted theft of explosive materials as well as break-ins or attempted break-ins to buildings where explosives are stored.

WS State Directors are responsible for ensuring that explosives magazine inspection, record keeping, and inventory requirements are met in accordance with WS safety manuals, guidelines, and directives, which include the biannual magazine site safety inspections and physical inventories of all explosives on hand and recorded on WS Form 22. The physical inventory records are reviewed and signed by the State Director or their designee to certify accuracy. All WS use, storage, and transportation of explosive materials would comply with applicable federal, state, and local laws and regulations (unless exempted), procedures outlined in the WS safety manuals, and requirements set forth in the OSHA standard for explosives found in the Code of Federal Regulations, Title 29, part 1910.109, Explosives and Blasting Agents.

WS State Directors are the authorizing officials for designating nominees for explosives training and for approving the purchase, handling, and use of explosives by specialists on projects approved by the State Director. WS Explosives Specialists must notify local emergency response agencies and officials (fire department / Fire Marshall) of explosives storage location(s). The WS explosives certification process requires that State Directors nominate qualified candidates under their supervision for explosives training. Those candidates must complete the basic training required by WS, including explosives handling procedures, security, and legal compliance. Candidates must demonstrate safe and proficient use of explosive components and procedures approved for WS field operations and must successfully complete all WS explosives certification requirements. Candidates who satisfy all WS explosives training requirements will undergo a review by the WS Explosives Safety Subcommittee to determine their eligibility for certification. The Explosives Safety Subcommittee Chair will review the Committee's recommendations and, as the certifying official, will certify eligible candidates and deny certification to those that are deemed ineligible.

2.1 Human Health and Safety Hazards

Occasional accidents that result in burns and other injuries and deaths can occur from the use of pyrotechnics, multicomponent explosives, ammunition, gas cartridge fuses, or cannon and rocket nets. Hearing damage could occur from the noise associated with blasts. Burns could occur when igniting or mishandling fuses or accidentally igniting gunpowder when reloading ammunition. Safety training and certification is required by most agencies and organizations, including WS. Explosives can be a hazard to people if not appropriately used and rarely due to manufacturing defects. While working in the field, WS personnel could also be injured from falls or slips due to the typical terrain around areas where they are setting explosive charges, such as beaver dams. Finally, gases and byproducts of explosions are considered due to their potential to be harmful to humans and the environment (Section 2.1.5 and 2.2.5).

2.1.1 Multicomponent Explosives

Multicomponent explosives are not classified as explosives until the components are mixed; the mixture becomes a mass explosion hazard once mixed. WS only uses multicomponent explosives to breach beaver dams. Therefore, injuries would primarily be associated with a mass explosion event if accidental detonation occurred. If people were too close to the blast area, human health and safety hazards would primarily be associated with the explosion's concussive blast. If the explosives were already placed inside the beaver dam, the flying debris caused as the explosion pushes mud, sticks, rocks, and other debris away from the beaver dam would also cause a hazard. Therefore, injuries to WS personnel or the public from the concussive blast and debris

could include internal injuries, loss of limbs, extremities, and eyesight, broken bones, bruises, scratches, puncture wounds, and death.

Injuries could also occur as WS personnel place explosives in beaver dams or set rocket/cannon nets, such as scrapes, bruises, strains, and broken bones. Beaver dams and the aquatic habitat associated with beaver dams require WS personnel to traverse uneven ground, through mud or water, or across tree logs, tree branches, rocks, and other debris that beavers use to build dams. Accidental drowning is also a risk. As described in Section 1.5, WS personnel will place explosives inside a beaver dam by creating channels inside the mud and debris of the dam using a pole made with non-sparking material. Creating a channel by pushing the pole into the mud and other debris of a beaver dam could also cause scrapes, bruises, blisters, and muscle strains.

Additionally, some concern arises from the potential for disruption to public utilities (e.g., electric, water, gas), if the public could be endangered by an explosion that damaged those utilities or structures, or if traffic patterns had to change where roads or bridges were damaged in a blast. These concerns are mitigated by following WS procedures and rules for beaver dam removal projects involving explosives.

2.1.2 Pyrotechnics

Human health and safety hazards from the use of pyrotechnics include hearing damage from sustained noise exposure without proper hearing protection, eye damage from fired pyrotechnic debris, and burns if the pyrotechnic malfunctions or misfires. An explosion from a defective pyrotechnic or improper use of a pyrotechnic in a firearm (cracker shells) or firearm-like device could cause lacerations, punctures, loss of extremities, eye damage, and possibly death due to shrapnel. When using a firearm, shrapnel and similar injuries could also occur if a barrel ruptured due to an obstruction, such as a previously fired pyrotechnic lodging in the barrel or a barrel being plugged with mud or other debris from personnel falling or setting the barrel down improperly. Similar shrapnel and injuries could also occur if personnel improperly clean a launcher or firearm or use inappropriate cleaning materials, which could cause a buildup of fouling material or flammable material in the firearm or firearm-like device. Misfiring pyrotechnics, contact with a lit cartridge, or accidentally starting a field fire with pyrotechnics could cause burn injuries.

Most pyrotechnics use primers, which are discussed under incidental explosive materials. Many pyrotechnic rockets use fuses that could result in burns. Gases are produced by pyrotechnics and are discussed below.

2.1.3 Net Propellants and Burning Gunpowder in Ammunition

Cannon and rocket net charges propel projectiles attached to a net for capturing wildlife. Smokeless (cannon) or black powder and M6 propellant (rocket) are used as the primary propellants. Hazards to human health and safety associated with the use of rocket net charges is like those discussed for multicomponent explosives. If rocket net charges unintentionally detonate, injuries to WS personnel or the public could include internal injuries, loss of limbs, loss of extremities, broken bones, loss of eyesight, bruises, scratches, puncture wounds, and death. In addition, similar injuries could occur if the projectiles accidentally struck people. If the rocket or cannon came unhooked from the net, it could be a projectile that could injure someone further away. Hearing loss could also occur from the noise produced when firing rocket nets. An additional concern would be that the firing of net propellants could ignite grass or other flammable material.

Hazards associated with the use of firearms and ammunition were reviewed in the "*The Use of Firearms in Wildlife Damage Management*" risk assessment. However, this document considers the burning of gunpowder used in firearms. The ammunition used by WS burns gunpowder, almost exclusively smokeless powder. Smokeless gunpowder, especially for hand-loaders with a canister of powder, could cause burns and other accidents like the above for cannon and rocket nets, primarily if ammunition is loaded too hot (more powder than necessary). Hearing loss could occur, especially with repeated use of ammunition while not wearing hearing protection. Gases are also produced from burning gunpowder and are discussed below.

2.1.4 Incidental Explosive Materials

Given the explosion hazard of incidental explosive materials and because the risks associated with the use of these materials would be accidental ignition or detonation, hazards to the user would be like other explosive materials. Those hazards to the user and non-users would be burns, lacerations, punctures, loss of extremities, eye damage, and possibly death. Of greatest concern are detonators and detonating cord. Similar to other explosive materials, those materials that burn or produce a spark would produce gaseous materials.

2.1.5 Gases and Solids Produced from Explosives Problem Formulation

Gases, vapors, and solids are produced when using various explosives, including the firing of multicomponent explosives, burning gunpowder and fuses, or when a primer is fired. Still, these are minor risks compared to the physical harm of risks associated with explosives due to the low volume of gas and solids produced. Smoke is particulate matter consisting of very fine solid particles and condensed vapor, which constitutes most of the visible part of the products of combustion observed at a fire. Gas is a product of combustion that remains a gas even when cooled to normal building temperatures, and vapor is a product of combustion that is gas when produced but reverts to solid or liquid at normal temperatures (Sumi and Tsuchiya 1971). The quantities of toxic gases and vapors produced by combustion depend on the material involved, and the environmental condition but are equal to the explosive's weight (e.g., the number of grains). Some are already known, while others can often be predicted from knowledge of the organic compounds' chemical composition and molecular structure. A basis for prediction is important for research work identifying combustion products and designers.

The gases produced by detonation of multicomponent explosives and gunpowder are mostly nontoxic carbon dioxide (CO_2), nitrogen (N_2), steam (H_2O), and hydrogen (H), and small amounts of toxic carbon monoxide (CO_1[8]) and nitrogen oxides (NO_x), which WS personnel or the public could inhale. Black powder also makes small amounts of hydrogen sulfide (H_2S) and methane (CH_4). Solids produced, primarily from black powder, include potassium carbonate (K_2CO_3), potassium sulfate (K_2SO_4), potassium sulfide (K_2S), S, KNO_3, potassium thiocyanate (KSCN), C, and ammonium carbonate ($(NH_4)_2CO_3$). Primers emit small quantities of $C_6HN_3O_8Pb$ and $Pb(N_3)_2$. Gases dissipate into the air rapidly and would have little opportunity to affect WS personnel and the public because they are not allowed near the explosives, and reentry takes enough time for the gases to disperse. Additionally, some of the gases produced are also produced by the human body. The body and the environment produce H_2S and CO_1 in small quantities and can effectively absorb and detoxify this amount of these gases. CH_4 is nontoxic but highly flammable and can be an asphyxiant if oxygen levels fall below 16% (Kumar and Gupta 2021). It should be noted that with the advent of smokeless gunpowder, sulfur, for the most part, was removed as sulfur was highly corrosive and an irritant.

[8] CO_1 is used for carbon monoxide, where necessary, to differentiate from the abbreviation for Colorado.

Nitrogen Oxides

There are three common oxides of nitrogen: nitrous oxide (N_2O), nitric oxide (NO), and the two forms of nitrogen dioxide (NO_2 and N_2O_4). Very toxic nitrogen dioxide can be produced from the combustion of cellulose nitrate. Nitric oxide does not exist in atmospheric air because it is converted into dioxide in the presence of oxygen. These compounds are strong irritants, particularly to mucous membranes, and thus when inhaled, will damage tissues in the respiratory tract by reacting with moisture to produce nitrous and nitric acids.

Nitrogen dioxide can be dangerous and even fatal to humans and is the most toxic nitrogen oxide. The physiological responses of people to various nitrogen dioxide concentrations are given in Table 4.

Table 4. Human physiological response to various concentrations of nitrogen dioxide

Physiological Response	NO_2 in Air
Threshold Limit	5 ppm
Least Amount Causing Immediate Throat Irritation	62 ppm
Dangerous for Short Exposure	117-154 ppm
Rapidly Fatal for Short Exposure.	240-775 ppm

Carbon Monoxide

CO_1 is produced by incomplete combustion of materials containing carbon and is present in large quantities at most fires. CO_1 causes asphyxiation if inhaled, but relatively little is produced in explosions considered in the risk assessment. CO_1 is produced in large quantities with other WDM methods and was considered at much higher levels in "*The Use of Carbon Monoxide from Gas Cartridges and Forced Gas Fumigation Systems in Wildlife Damage Management."* This risk assessment considered the effects of CO_1 on humans at much higher levels and found minimal concern. Thus, we will not consider CO_1 further except to note when, where, and how much is produced by the different explosives considered in this document.

Lead Styphnate

Lead styphnate ($C_6HN_3O_8Pb$) is used as a primer in detonators and ammunition. After combustion, lead styphnate is released as airborne lead particles. Lead styphnate or lead particles may be inhaled. Hazards of lead exposure were considered in "*Use of Lead in Wildlife Damage Management Risk Assessment.*" This risk assessment considered the effects of lead on humans related to lead shot, bullets, or pellets, and fishing sinkers. Although the route of exposure is different (e.g., inhalation vs. ingestion), the toxic effects due to lead are similar and will not be covered in this document except to note when, where, and how much is produced by the different explosives considered in this document.

2.2 Ecological Hazards

The use of multicomponent explosives, pyrotechnics, ammunition, gas cartridge fuses, or cannon and rocket nets have the potential to have ecological effects. Explosives can be a hazard to the environment if not used properly, but WS personnel are extensively trained in procedures to minimize these effects.

2.2.1 Multicomponent Explosives

Multicomponent explosives are used to remove beaver dams by WS. The detonation of mixed multicomponent explosive components produces large explosions that have the potential to alter waterways. A spill of chemical components has the potential to contaminate soils and waters.

Beaver dams can have varying effects on the environment. Beaver dam removal is generally conducted to maintain existing stream channels and drainage patterns and reduce flood waters that have affected agriculture (ranching and farming activities), roads, bridges, and residential and commercial property or drainage structures such as culverts. Beaver dams are made from natural debris such as logs, sticks, vegetation, and mud that beavers take from the immediate area. This portion is dislodged during a beaver dam removal operation with multicomponent explosives. The removal of dams is most often associated with recent beaver activity. It has not been in place long enough to take on the qualities of a true wetland (i.e., hydric soils, hydrophytic vegetation, and preexisting function). Unwanted beaver dams can be removed by hand with a rake, power tools (e.g., a winch), heavy equipment, or explosives. Beaver dam removal does not affect the substrate or the stream's natural course and returns the area to its preexisting condition with similar flows and circulations. Because beaver dams involve waters of the United States, removal is regulated under Section 404 of the Clean Water Act. WS projects involving beaver dam removal are discussed with the U.S. Army Corps of Engineers or are specifically exempted under Section 404.

Multicomponent explosives are mixed at the site and placed within the beaver dam to create a vortex of energy to cause the dam material to go up and out (the path of least resistance). When the charges detonate, the dam’s material is lifted up to 100 feet in the air. The energy associated with the explosion is directed away from the water to maximize the impact. The intent of removal or breaching with explosives is to loosen the dam material at the center portion of the dam and allow the force of impounded water to wash away the remaining debris closest to the stream banks.

The primary adverse effect of using explosives to remove dams is the quick release of water above the dam. Rapid water runoff from breached beaver dams could impact some wildlife, primarily fish and invertebrates. Sometimes fish, especially small ones, can be stranded in small, isolated pools or on land when the water is released from removing a dam. WS personnel pick up these fish and return them to the flowing stream or ditch. The release of debris and mud can affect some species downstream, like high water events from spring runoff and heavy rains. On the other hand, extensive beaver activity often eliminates essential habitats such as gravel or sandy bottoms for many species of mollusks and fish, especially where beaver activity has increased past historical norms. WS removes dams to restore streams to their original state, allowing natural water flow and alleviating flooding. Without taking the proper precautions, removing beaver dams by any method has the potential to result in flood damage to roadways, public or private property, or downstream ecosystems.

2.2.2 Pyrotechnics

When fired, pyrotechnics produce a loud whistle or blast intended to frighten target animals from an area. The adverse noise produced by pyrotechnics is also likely to frighten nontarget animals from the area. Pyrotechnics use black powder as a propellant and produce a frightening noise (e.g., whistle, blast). As discussed for net propellants, firing pyrotechnics would also produce small amounts of solid and gaseous components. Those solid and gaseous components produced and the environmental hazards associated with those components as the pyrotechnic

burns, would be like the components and environmental hazards discussed for net propellants. In addition, firing pyrotechnics could ignite grass or other flammable material.

WS accidentally hazed an annual average of 120 mallards from FY16 to FY20 and killed an annual average of 0.2 wildlife (one American white pelican over the five years); no other wildlife was injured. Very rarely is wildlife killed or injured accidentally during hazing activities. WS pyrotechnic use resulted in an average of 0.2 fires from FY16 to FY20. Historically, fires were more common due to quality control, with cracker shells being less stringent; many would go out 75 yards or so and not explode midair as designed. The "duds" would land on the ground 75-100 yards away, and the smoldering pyrotechnic, basically an M-80 firecracker, would start a ground fire; this was a rare occurrence. All fires resulting from pyrotechnic use were extinguished quickly, resulting in no property damage or injury to humans or wildlife.

2.2.3 Net Propellants and Ammunition

Ecological hazards for rocket and cannon nets and ammunition are discussed in other Risk Assessments as has been discussed. Gunpowder could start fires, but not as likely as pyrotechnics. Thus, fires will be discussed in that section. Gases and solids produced from these are discussed under gases and solids produced below.

2.2.4 Incidental Explosive Materials

Given the explosion hazard of incidental explosive materials and because the risks associated with using these materials would be accidental ignition or detonation, hazards to the environment would be like using other explosive materials. Those environmental hazards would primarily be related to fires accidentally ignited by their use. The gases and solids produced using incidental explosives will be discussed in Section 2.2.5.

2.2.5 Gases and Solids Produced from Explosives Problem Formulation

The gases produced by detonating multicomponent explosives and gunpowder are mostly nontoxic CO_2, N_2, H_2O, and H, and smaller amounts of toxic CO_1 and NO_x, which wildlife could inhale. Black powder also makes small amounts of H_2S and CH_4. Solids produced, primarily from black powder, include potassium carbonate K_2CO_3, K_2SO_4, K_2S, S, KNO_3, KSCN, C, and $(NH_4)_2CO_3$. Primers emit small quantities of $C_6HN_3O_8Pb$ and $Pb(N_3)_2$. Gases dissipate into the air rapidly and would have little opportunity to affect the environment. Additionally, the biggest portion of the gases produced is in the environment. The environment produces H_2S and CO_1 in small quantities and can effectively absorb and detoxify small quantities. CH_4, is basically nontoxic, but extremely flammable and can be an asphyxiant if oxygen levels fall below 16% (Kumar and Gupta 2021). It should be noted that with the advent of smokeless gunpowder, sulfur, for the most part, was removed as sulfur was highly corrosive and an irritant. USEPA (1995) provided emissions from standard explosives at the time and Table 5 provides emissions for NOx, CO1, and lead from the use of firearms and pyrotechnics used by WS. When considered that gunpowder for pyrotechnics and firearms are used throughout the year, outdoors, and in all 50 states and 3 territories, emissions are minimal. Shotgun usage creates the highest amounts of emissions but would not be minimal when spread across the landscape. Further discussion for each is given.

<u>Nitrogen Oxides</u>

Nitrogen oxides are produced from multicomponent explosives, but only limited data are available on these emissions (United States Environmental Protection Agency (USEPA) 1995). Nitrogen

oxides produced from ammunition and pyrotechnic use are listed in Table 5. Quantities of nitrogen oxides produced from ammunition and pyrotechnic use are low (USEPA 1995).

Table 5. Carbon monoxide, nitrogen oxides, and lead emissions produced from WS average annual use of explosives during FY16-FY20 calculated from USEPA (1995) Compilation of air pollutant emission factors.

Explosive	Number used	Lbs. produced		
		CO_1	NOx	Pb
Pyrotechnic (Cracker Shell)	26,339	39.5	1.1	0.5
Pyrotechnic (15 mm report/ screamer)	166,674	46.7	3.3	0.2
Pyrotechnic (Blank)	360	0.1	0.007	0.0003
Shotgun	844,343	1266.5	35.5	16.9
Small Caliber Rifle/Pistol (.22)	121,953	8.8	0.4	0.2
Large Caliber Rifle/Pistol	113,177	339.5	1.5	2.0

Carbon Monoxide

Charges of multicomponent explosives detonate at 2,000° F, consuming the binary components, resulting in no release of known toxic residues into the water. Although CO_1 is a common by-product of fuel combustion, it is highly unlikely that gas will enter the water, except in minute quantities, due to its volatile nature, resulting in very little concern about reduced water quality. CO_1 produced from ammunition and pyrotechnic use is listed in Table 5. These quantities represent the annual average emission for all ammunition and pyrotechnic use. Because these are for outdoor use, no emission controls are needed for use (USEPA 1995).

Lead Styphnate

Lead styphnate is a component of primers for ammunition, pyrotechnics, and detonators. A conservative estimate of lead styphnate per ammunition round is 30% of a 45 mg primer. Using the annual average ammunition used by WS, approximately 32 pounds of lead may be released into the environment annually. However, firearms are used by WS in all 50 states and 3 territories and used periodically throughout the year. Thus, there is no concentration of lead exposure in a single location or area due to firearms use. The amount of lead styphnate in electric matches and detonators is minimal. WS use of cannon/rocket nets and detonators for explosives is spread across multiple states such that the minimal use would not cause a hazard of lead contamination. Additional estimates of lead emissions are provided in Table 5.

3 RISKS

3.1 Human Health and Safety Risks

The combustion of explosive materials is likely to produce small amounts of solid and gaseous components. WS use of explosive materials would occur outdoors in open-air situations and would not occur in confined spaces. Those gaseous components produced would quickly dissipate into the air and any solid components would settle onto the ground. The primary risks would occur to WS employees that use explosive materials. When using multicomponent explosives, WS personnel would retreat to a safe area at least 250 feet from the beaver dam and would allow the smoke and fumes to clear before returning to the blast site. A similar scenario would occur during the use of rocket and cannon nets. When using pyrotechnics and incidental explosive materials, WS personnel may be exposed to gaseous and solid components immediately upon firing or igniting those materials. However, those materials would immediately move away from the employee upon firing. For example, when fired, a pyrotechnic exits the launcher and travels downrange; therefore, primary exposure would occur as the pyrotechnic

exits the launchers. Although explosive materials could produce noxious fumes, WS does not anticipate exposure to occur at a level that would result in adverse effects to human safety.

WS operational field personnel averaged 0.6 injuries/burns from explosives accidents per year from FY16-FY20. These injuries were directly related to pyrotechnic misfires/misloads, firearm misfires, or lighting of gas cartridge fuses. In addition, there were 2 incidents per year from FY16-FY20 that did not result in injury. For example, a cracker shell with an improper load caused damage to a shot gun barrel. In reference to binary explosives, OWCP had no claims or reports of injuries or other maladies related to detonating explosives for beaver dam removal from FY16 to FY20.

Four personnel (0.8 annually) were injured between FY11 through FY15 in all WDM firearm activities, including aerial shooting. One injury was to the leg from a .22 caliber pistol, one to a foot from an air rifle, and two to hands and face from defective ammunition. Six additional personnel were injured in accidents from FY04 to FY10. Two additional injuries were to the leg (one a pellet from an air rifle and one from a high-powered rifle), three injuries were to hands, face, and eardrums from rounds going off in the barrel, and one, an accident involving a pyrotechnic launcher, was an injury that resulted in the loss of the pinky finger and part of the ring finger of a WS employee[9].

WS requires stringent training of employees for firearm and explosive use, which has likely resulted in fewer accidents (data is unavailable for comparison). However, considering the number of firearms used by WS and the number of rounds fired (in the hundreds of thousands annually), few accidents and incidents occurred and the risk of injury is low. In summary for FY16 to FY20, WS personnel had an annual average of 2.6 accidents (of these 0.6 resulted in injury). However, some accidents and most incidents involving mechanical failure of the firearm or ammunition would not likely be avoided. It should be noted that many potential accidents are avoided by inspecting the ammunition and firearm prior to use (when something abnormal is found, it is marked as an incident).

Exposure to the gases and solids produced by detonating multicomponent explosives and gunpowder is minimal due to the activities being spread out over time (e.g., few explosives, firearms discharged at a time) and space (e.g., throughout the U.S. and its territories and among ~1,900 WS employees). Gases produced due to explosives dissipate into the air rapidly and would have little opportunity to affect WS personnel and the public because they are not allowed near the explosives. In addition, reentry into the area takes enough time for the gases to disperse. One of the most significant exposure risks to humans is indoor firing ranges. Studies have shown that law enforcement personnel are exposed to mean air lead levels above 2,000 ug/m^3, more than 40 times the OSHA standard of 50 ug/$m^{3,}$ when training at indoor ranges (Valway et al. 1989). WS personnel conduct all firearm and explosive operations outdoors and at various locations, where exposure to gases and solids is minimal.

3.2 Ecological Risks

WS would reduce environmental risks by adhering to all OSHA regulations, WS policy procedures, the WS Explosive Safety Manual, state regulations, IME safety recommendations, and product manufacturers' instructions on handling and using explosive materials. The primary environmental risk from using explosive materials would be fires caused when using pyrotechnics, net propellants, and incidental explosive materials. As indicated in WS safety manuals, each

[9] A firearm accident is defined by policy as an event that results in an injury or property damage whereas in an incident neither occurs.

vehicle used to transport explosive materials must be equipped with one to two fire extinguishers depending on the explosive material being transported. In addition, WS personnel would fire pyrotechnics away from buildings, vehicles, and dry vegetation.

Although using explosive materials could produce gaseous and solid components, the quantities produced are minor and would not occur in such a limited area to cause adverse effects. The gaseous and solid components produced would occur in a localized area. The gaseous components would dissipate into the air. The solid components would likely settle onto the ground but would be in extremely limited quantities.

Nontarget animals are usually not affected by the noise produced by pyrotechnics or explosions, except for the occasional startling due to those methods. In those cases, animals may temporarily leave the immediate vicinity but would most likely settle in a new area like the space they left or return after the conclusion of the action.

The likelihood of cannon or rocket assemblies striking a target or nontarget animal is extremely low. For nontarget animals, the risk is likely extremely low because a nontarget animal would have to be present when WS personnel activated the net, and the nontarget animal would have to be in a position where the assemblies strike the animal. WS personnel position nets so the net envelops target animals upon deployment, which would minimize the risk of assemblies striking both target and nontarget animals. When using nets, WS personnel often use bait to attract target species and to concentrate target species in a specific area to ensure the net completely envelopes target animals. Therefore, WS personnel refrain from firing the net at a time when target or nontarget animals are in areas where strikes could occur.

4 UNCERTAINTIES AND CUMULATIVE IMPACTS

Uncertainties about the use of explosives are negligible as WS has many years of experience using explosives in WDM. The knowledge gained from this experience has helped reduce risks associated with explosives, especially regarding human health and safety with all forms of explosives and to captured animals from the standpoint of injuries to nontargets.

The *Introduction to WS Methods Risk Assessments*, Chapter 1, gives all species taken by WS from FY11 to FY15 and shows no significant cumulative impacts from a population standpoint due to all methods used in WDM, and explosive use was considered in those. Additionally, cumulative impacts are addressed in National Environmental Policy Act documents and found not to be significant to any native species population. From a human health perspective, the use of explosives in WDM does not have any known cumulative impacts or involve unknown risks. Certification and training in the use of explosives reduce the risk of injury and nontarget hazards.

5 SUMMARY

WS uses explosives to manage wildlife, causing damage to agriculture, natural resources, or property or threatening public safety. WS explosive methods include multicomponent explosives for removing beaver dams to reduce flooding and pyrotechnics used to haze wildlife from airports to avoid aircraft strikes and keep them away from other resources. Other uses include ammunition, cannon and rocket net charges, and gas cartridges for fumigation, which have been discussed in other risk assessments, except for the use of smokeless powder for ammunition, propellants for nets, and fuses for gas cartridges. Finally, other incidental explosive materials are used to initiate some types of explosives, including detonation cord for multicomponent explosives, fuses for all types of explosives, electric matches for rocket and cannon nets, and

primers for pyrotechnics and ammunition rounds. Environmental risks to nontarget animals are insignificant as animals are usually not affected by the noise produced by pyrotechnics or explosions, except for the occasional startling due to those methods. WS personnel are at risk of being injured or killed by explosives; however, WS trains personnel properly to handle explosive materials to minimize this risk. The annual average accidents in the last ten years were three or fewer, with less than one accident resulting in human injury annually. WS and public exposure to potentially toxic gases and solids produced from explosives are negligible due to the minimal use by individual employees and in multiple areas. Thus, exposure is limited, and gases disperse quickly.

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7 PREPARERS

7.1 APHIS-WS Methods Risk Assessment Committee

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7.2 Internal Reviewers

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7.3 Peer Review

The Office of Management and Budget requires agencies to have peer review guidelines for scientific documents. The APHIS guidelines were followed to have "Use of Exclusion in Wildlife Damage Management" peer reviewed. WS worked with the Association of Fish and Wildlife Agencies to have experts review the documents.

7.3.1 Peer Reviewers Selected by the Association of Fish and Wildlife Agencies

South Dakota Game, Fish and Parks

Missouri Department of Conservation

7.3.2 Comments

Comments not requiring a response

1. After a thorough review of the document on Explosives, I have no comments except to say that the document looks good. Thank you for the opportunity to review this document.

2. Staff with experience in using explosives for rocket netting waterfowl, deer, and turkey do not have any comments or concerns.

Appendix 1. "Other Species" Included in Table 2.

Other predator = Virginia opossum, feral cat*, lynx (AK), coyote^, feral dog*, red fox^, arctic fox^, common gray fox, black bear, brown bear, northern sea otter, river otter, mink, raccoon, and striped skunk

Other hoofed mammal = feral swine*, collared peccary, moose, elk, white-tailed deer, mule deer, axis deer*, and American pronghorn

Other mammal = Hoary marmot, woodchuck, round-tailed ground squirrel, common muskrat, American beaver, eastern cottontail^, white-tailed jackrabbit, and nine-banded armadillo

Other dove = island collared-dove*, spotted dove*, zebra (barred ground) dove*, common ground-dove, zenaida dove, scaly-naped pigeon, and white-crowned pigeon

Other corvid = Canada (gray) jay, blue jay, black-billed magpie, and yellow-billed magpie

Other raptor = white-tailed kite, swallow-tailed kite, sharp-shinned hawk, Cooper's hawk, northern goshawk, northern harrier, Mississippi kite, Harris's hawk, red-shouldered hawk, broad-winged hawk, Swainson's hawk, rough-legged hawk, white-tailed hawk, ferruginous hawk, golden eagle, barn owl, snowy owl, great-horned owl, barred owl, great gray owl, northern hawk owl, northern pygmy-owl, burrowing owl, short-eared owl, crested caracara, merlin, gyrfalcon, prairie falcon, and peregrine falcon

Gallinaceous bird = Gambel's quail, California quail^, northern bobwhite, wild turkey, sharp-tailed grouse, willow ptarmigan, rock ptarmigan, gray partridge*, black francolin*, gray francolin*, ring-necked pheasant*, and common peafowl*

Other aerialist = Common nighthawk, Chuck-Will's-widow, chimney swift, violet-green swallow, northern rough-winged swallow, and purple martin

Nonpasserine forest bird = greater roadrunner, mangrove cuckoo, smooth-billed ani, belted kingfisher, red-breasted sapsucker, northern flicker, and monk parakeet*

Other grassland passerine = black phoebe, Say's phoebe, western kingbird, scissor-tailed flycatcher, eastern kingbird, gray kingbird, loggerhead shrike, great gray (northern) shrike, Lapland longspur, chipping sparrow, field sparrow, lark sparrow, lark bunting, American tree sparrow, fox sparrow, song sparrow, white-crowned sparrow, dark-eyed junco, dickcissel, and bobolink

Other forest passerine =Black-capped chickadee, Bohemian waxwing, cedar waxwing, gray catbird, northern mockingbird, pearly-eyed thrasher, eastern bluebird, mountain bluebird, Swainson's thrush, hermit thrush, varied thrush, common redpoll, red crossbill, white-winged crossbill, American goldfinch, lesser goldfinch, Wilson's warbler, American yellow warbler, orange-crowned warbler, Townsend's warbler, pine warbler, and yellow-rumped warbler

Other invasive passerine = Eurasian skylark*, red-vented bulbul*, black drongo*, saffron finch*, red-crested cardinal*, chestnut munia*, and northern red bishop*

Other larid = black skimmer, black-legged kittiwake, Sabine's gull, Heermann's gull, glaucous gull, Iceland gull, lesser black-backed gull, gull-billed tern, sandwich tern, royal tern, elegant tern, arctic tern, Forster's tern, bridled tern, whiskered tern, pomarine jaeger, parasitic jaeger, and long-tailed jaeger

Other waterfowl = black-bellied whistling duck, domestic goose*, Egyptian goose*, Ross's goose, mute swan*, trumpeter swan, tundra swan, wood duck, mottled duck, American black duck, cinnamon teal, Eurasian wigeon, white-cheeked pintail, king eider, common eider, harlequin duck, white-winged scoter, surf scoter, black scoter, and long-tailed duck

Other open-waterbird = red-throated loon, Pacific loon, common loon, Laysan albatross, pied-billed grebe, red-necked grebe, horned grebe, eared grebe, magnificent frigatebird, great frigatebird, northern gannet, brown booby, Brandt's cormorant, anhinga, common murre, marbled murrelet (AK), tufted puffin, and parakeet auklet

Other wading bird= American flamingo, roseate spoonbill, American bittern, yellow bittern, black-crowned night-heron, yellow-crowned night-heron, green heron, little blue heron, reddish egret, tricolored heron, and common gallinule

Other shorebird = black oystercatcher, American oystercatcher, American avocet, American golden-plover, Wilson's plover, mountain plover, Western snowy plover$^{T\&E}$ (0.2), upland sandpiper, bristle-thighed curlew, Hudsonian godwit, marbled godwit, ruddy turnstone, surfbird, stilt sandpiper, white-rumped sandpiper, buff-breasted sandpiper, semipalmated sandpiper, pectoral sandpiper, sharp-tailed sandpiper, short-billed dowitcher, American woodcock, Wilson's snipe, Wilson's phalarope, red-necked phalarope, spotted sandpiper, solitary sandpiper, wood sandpiper, lesser yellowlegs, and greater yellowlegs,

Reptile = American alligator, green iguana*, and 3.2 unidentified FL snake (46 sp.)

Appendix 2. Tables A-1 and A-2 for FY11-FY15 for Comparison

Table A-1: The annual average number of target and nontarget (28) animals hazed with all pyrotechnics and blanks by WS in WDM activities from FY11 to FY15 throughout the United States.

ANNUAL AVERAGE SPECIES HAZED WITH PYROTECHNICS AND FIREARM BLANKS FY11-FY15					
Species[1]	**Hazed**	**Species[1]**	**Hazed**	**Species[1]**	**Hazed**
Mammals		Lapland Longspur	1,232	Surf Scoter	1,045
Grizzly Bear (0.2 T&E)	3	Snow Bunting (**20NT**)	1,097	Long-tailed Duck	1,374
Steller Sea Lion[T&E]	1,171	Savannah Sparrow	2,633	Bufflehead	11,346
California Sea Lion	812	Eastern Meadowlark	3,508	Common Goldeneye	2,995
Other Predator (13 sp.)	188	Western Meadowlark	8,046	Barrow's Goldeneye	1,290
Axis Deer*	330	Other Grassl Passerine (17 sp.)	1490	Hooded Merganser	1,728
White-tailed Deer	145	Cedar Waxwing	1,486	Common Merganser	2,157
Caribou	550	American Robin	10,595	Red-breasted Merganser	82,338
Other Hoofed Mammals (5 sp.)	63	American Goldfinch	1,430	Other Waterfowl (19T sp.)	3,973
Other Mammal (7 sp.)	16	Other Forest Passerine (15 sp.)	1,962	Hawaiian Petrel[T&E]	0.4
Total Mammal (31 sp.)	**3,278**	Common Myna	4,822	Western & Clark's Grebe	7,708
Birds Associated with Land		Chestnut Mannikin	1,091	American White Pelican	5,715
European Starling*	6,185,995	Nutmeg Mannikin	1,390	Brown Pelican	1,567
Yellow-headed Blackbird	911	House Sparrow	2,127	Pelagic Cormorant	1,332
Tricolored Blackbird	2,469	Other Invasive Passerine (6 sp.)	207	Double-crested Cormorant	88,193
Red-winged Blackbird	486,846	**Land Bird Total (138 sp.)**	**9,705,249**	Other Waterbirds (16 sp.)	1,543
Brown-headed Cowbird	59,595	**Birds Associated with Water**		Wood Stork[T&E]	103
Brewer's Blackbird	17,379	Red-legged Kittiwake	10,204	American White Ibis	26,471
Common Grackle	40,192	Bonaparte's Gull	6,146	White-faced Ibis	2,774
Boat-tailed Grackle	64,119	Laughing Gull	678,337	Western Cattle Egret^	60,105
Great-tailed Grackle	18,328	Franklin's Gull	10,591	Great Blue Heron	5,446
- Mixed Blackbirds	1,427,774	Mew Gull	3,547	Great Egret	6,779
Rock Pigeon*	13,698	Ring-billed Gull	2,347,574	Little Blue Heron	1,323
Spotted Dove*	1,018	California Gull	165,248	Snowy Egret	3,056
Zebra (*Barred Ground-*) Dove*	1,276	Great Black-backed Gull	84,192	Hawaiian Coot[T&E]	0.2
Mourning Dove^	64,661	Glaucous-winged Gull	105,157	American Coot	11,162
White-winged Dove	40,435	Western Gull	1,390	Sandhill Crane	139,519
Other Dove (4 sp.)	581	American Herring Gull	1,298,802	Whooping Crane[T&E]	0.6
American Crow	862,864	Caspian Tern	13,426	Other Wading Birds (12 sp.)	1,756
Northwestern Crow	14,711	Royal Tern	1,541	Black-necked Stilt	1,327
Fish Crow	3,745	Least Tern	9,169	- Hawaiian Black-necked Stilt[T&E]	276
Common Raven	25,835	- California Least Tern[T&E]	14	American Avocet	7,894
Other Corvid (3T sp.)	115	Other Larid (17 sp.)	2,743	Pacific Golden-Plover	82,213
Turkey Vulture	61,885	Greater White-fronted Goose	32,642	Gray (*Black-bellied*) Plover	2,825
Black Vulture	32,196	Snow Goose	109,152	Semipalmated Plover	6,661
Western Osprey	1,041	Cackling Goose	83,863	Wilson's Plover	2,560
Bald Eagle	34,285	Canada Goose	178,751	Killdeer	7,802
Hawaiian Hawk[T&E]	10	Hawaiian Goose[T&E]	499	Short-billed Dowitcher	1,036
Red-tailed Hawk	2,912	Gadwall	1,489	Marbled Godwit	1,619
Golden Eagle	28	American Wigeon	6,913	Whimbrel	2,405
American Kestrel	1,407	American Black Duck	1,892	Long-billed Curlew	8,432
Other Raptor (28 sp.)	2,608	Mallard (incl. 112 feral mallard*)	46,253	Willet	1,119
Gallinaceous Birds (10 sp.)	874	Hawaiian Duck[T&E]	284	Ruddy Turnstone	4,237
Bank Swallow	16,913	Blue-winged Teal	3,337	Sanderling	4,232
Tree Swallow	20,103	Northern Shoveler	23,795	Semipalmated Sandpiper	2,206
Violet-green Swallow	1,006	Northern Pintail	13,680	Western Sandpiper	8,890
Purple Martin	4,496	Green-winged Teal	7,307	Least Sandpiper	2,342
Barn Swallow	74,660	Canvasback	1,428	Dunlin	3,899
American Cliff Swallow	57,045	Redhead	4,798	Other Shorebirds (30 sp.)	3,634
Other Aerialists (5 T sp.)	1,445	Ring-necked Duck	1,367	**Water Bird Total (173 sp.)**	**5,918,439**
Nonpasserine Forest Bird (4 sp.)	349	Greater Scaup	9,045	**Unidentified Bird**	**8,883**
Horned Lark (**8NT**.)	11,459	Lesser Scaup	25,426	**Reptile (6T sp.)**	**3**
American Pipit	4,864	Spectacled Eider[T&E]	29	**GRAND TOTAL HAZED (348 sp.)**	**15,635,852**
		Blanks		**GRAND TOTAL Blanks (31 sp.)**	**1,557**

***** Introduced Species **T** – Target **NT** – Nontarget (the # NT species in ( ) and included in T take)

[1] Accounts of species are given only for those mammals and reptiles that had an annual average of 100 or more hazed, birds with 1,000 or more hazed, and sensitive species.

"Other Species" (FY11-15). "Other Species" Included in Appendix 2. Table A-1.

Other predator = Virginia opossum^, feral cat*, bobcat, coyote^, feral dog*, red fox^, arctic fox^, common gray fox, black bear, river otter, mink, raccoon, and striped skunk

Other hoofed mammal = feral swine*, collared peccary, moose, mule deer, and muskox

Other mammal = American beaver, woodchuck, eastern fox squirrel, North American porcupine, eastern cottontail^, black-tailed jackrabbit, and nine-banded armadillo

Other dove = island collared-dove*, Eurasian collared-dove, common ground-dove, and white-crowned pigeon

Other corvid = Canada (gray) jay, black-billed magpie, and yellow-billed magpie

Other raptor = white-tailed kite, swallow-tailed kite, sharp-shinned hawk, Cooper's hawk, northern goshawk, northern harrier, Mississippi kite, common black hawk, Harris's hawk, red-shouldered hawk, broad-winged hawk, Swainson's hawk, zone-tailed hawk, rough-legged hawk, ferruginous hawk, barn owl, snowy owl, great-horned owl, barred owl, great gray owl, northern hawk owl, burrowing owl, short-eared owl, crested caracara, merlin, gyrfalcon, prairie falcon, and peregrine falcon (not counted in species is escaped hybrid falcon*)

Gallinaceous bird = Gambel's quail, northern bobwhite, wild turkey, sharp-tailed grouse, willow ptarmigan, black francolin*, gray francolin*, Erckel's francolin*, ring-necked pheasant*, and common peafowl*

Other aerialist = common nighthawk, chimney swift, white-throated swift, northern rough-winged swallow, and cave swallow

Nonpasserine forest bird = belted kingfisher, northern flicker, monk parakeet, and rose-ringed parakeet

Other grassland passerine = black phoebe, Say's phoebe, western kingbird, scissor-tailed flycatcher, eastern kingbird, gray kingbird, loggerhead shrike, great gray (northern) shrike, chipping sparrow, field sparrow, lark sparrow, fox sparrow, song sparrow, Lincoln's sparrow, white-crowned sparrow, dark-eyed junco, and bobolink

Other forest passerine =Bohemian waxwing, northern mockingbird, eastern bluebird, western bluebird, mountain bluebird, Swainson's thrush, house finch, common redpoll, lesser goldfinch, pine siskin, American yellow warbler, pine warbler, yellow-rumped warbler, northern cardinal, and indigo bunting

Other invasive passerine = Eurasian skylark*, red-vented bulbul*, common waxbill*, red avadavat*, warbling silverbill*, and red-crested cardinal*

Other larid = white tern, black skimmer, black-legged kittiwake, Heermann's gull, glaucous gull, Iceland (Thayer's) gull, lesser black-backed gull, gull-billed tern, sandwich tern, arctic tern, common tern, Forster's tern, whiskered tern, black tern, pomarine jaeger, parasitic jaeger, and long-tailed jaeger

Other waterfowl = black-bellied whistling duck, domestic goose, Ross's goose, brant, mute swan, trumpeter swan, tundra swan, domestic Muscovy duck, wood duck, mottled duck, cinnamon teal, Eurasian wigeon, Eurasian teal, king eider, common eider, harlequin duck, white-winged scoter, black scoter, and ruddy duck

Other waterbird = red-throated loon, Pacific loon, common loon, Laysan albatross, wedge-tailed shearwater, pied-billed grebe, red-necked grebe, horned grebe, eared grebe, magnificent frigatebird, great frigatebird, Brandt's cormorant, anhinga, common murre, pigeon guillemot, and marbled murrelet (AK)

Other wading bird= American flamingo, glossy ibis, roseate spoonbill, American bittern, least bittern, yellow bittern*, black-crowned night-heron, yellow-crowned night-heron, green heron, reddish egret, tricolored heron, and common gallinule

Other shorebird = black oystercatcher, American oystercatcher, American golden-plover, lesser sand plover, snowy plover, mountain plover, American woodcock, Wilson's snipe, long-billed dowitcher, Hudsonian godwit, bar-tailed godwit, bristle-thighed curlew, upland sandpiper, greater yellowlegs, lesser yellowlegs, solitary sandpiper, wandering tattler, common sandpiper, spotted sandpiper, black turnstone, surfbird, white-rumped sandpiper, Baird's sandpiper, pectoral sandpiper, rock sandpiper, stilt sandpiper, buff-breasted sandpiper, Wilson's phalarope, red-necked phalarope, and red phalarope

Reptile = American alligator, spectacled caiman*, African rainbow lizard*, green iguana*, coachwhip, and one unidentified FL snake (43 sp.)

Table A-2. The annual average number of beaver dams removed and multicomponent explosives used, pyrotechnics and blanks used and animals dispersed, gas cartridge fuses used, and target and nontarget animals captured or taken with nets and firearms by WS in WDM activities from FY11 to FY15 throughout the United States.

ANNUAL AVERAGE SPECIES TAKEN WITH METHODS INVOLVING EXPLOSIVE PER ATF FOR FY11-FY15					
ACTIVITY (# SPECIES INVOLVED) # STATES USED	**TARGET**			**# USED**	
MULTICOMPONENT EXPLOSIVE USAGE	**Dams Removed**			**Binary Explosives**	
Beaver Dams Removed (1T - 1 sp.) 20 States	1,314			5,008 lb. (3.8 lbs./dam)	
PYROTECHNIC & BLANK USAGE[1]	**Target Dispersed**			**# Pyrotechnics Used**	
Launcher Cartr./Crackershells (347T, 2NT – 347 sp.) 49 States, 3	15,634,324 (28 NT)			452,103	
Pyrotechnic Rockets (44T – 44 sp.) 7 States	77,223			5,878	
Blank Usage (35 T – 35 sp.) 3 States	1,557			104	
Pyrotechnic/Blank Take (348T, 2 NT – 348 sp.) 49 States, 3	**15,713,104**			**458,085**	
GAS CARTRIDGE FUSES USED[2]	**Est. Rodents/Predators Taken**			**Fuses Used**	
Gas Cartridge Fuses (15T – 15 sp.) 34 States, DC	11,211			6,080	
TAKE WITH ROCKET AND CANNON NETS[3]	**Killed**	**Released**	**Dispersed**	**Killed**	**Released**
Rocket/Cannon Net Take (22T, 2NT – 22 sp.) 30 States – 177 uses	3,167	234	8,592	0.2	2
FIREARM USAGE[4]	**Killed**	**Nests**	**Dispersed**	**NT Killed**	**Shots**
Shotgun (310 T, 6 NT - 310 sp.)	359,050	50	4,33,8,717	3	876,751
Small Caliber Rifle/Pistol (0.22) (140T, 77NT - 187 sp.)	89,344	-	8329	1,186	126,244
Large Caliber Rifle/Pistol (39T, 12NT - 41 sp.)	44,275	-	1,490	127	73,938
Total Firearm Take (401T, 101NT - 429 sp.) 49 States, 4	**492,669**	**50**	**4,348,536**	**1,316**	**1,076,933**

T – Target **NT** – Nontarget (# T and NT species in group, # sp. is all species in group including T and NT)

[1] See Table 2 for breakdown of species

[2] See "*The Use of Carbon Monoxide from Gas Cartridges and Forced Gas Fumigation Systems in Wildlife Damage Management*" for further information and species taken

[3] See "*The Use of Nets in Wildlife Damage Management*" for further information and species taken

[4] See "*The Use of Firearms in Wildlife Damage Management*" for further information and species taken including the estimated number of target and nontarget animals captured with other WDM methods such as foothold traps and euthanized with a shot to the brain

Appendix 3. Pyrotechnic Chemical Guide [*Accessed 6/16/2022* @: https://cannonfuse.com/pyrocomp-chapter-9-glossary.html]

Pyrotechnics may use a wide variety of additional ingredients that create different affects. Generally, these chemicals are very minor in the product and would cause minimal human health and ecological risks because they are used in minor quantities.

Acetone (2-Propanone) [C_3H_6O] Flammable liquid used as a solvent in pyrotechnics (i.e., in mixtures that can't contain water). Nitrocellulose can be dissolved in it to create nitrocellulose lacquer, which can be used as an adhesive or a waterproof coating. Acetone is hard to work with because it evaporates so quickly, thus making the composition cold and causing water to condense.

Aluminum [Al] Most widely used fuel in modern pyrotechnics; produces a brilliant, bright flame. The particles come in several of different shapes, such as flakes and grains.

Ammonium Chloride [NH_3 HCl] Used in white smoke compositions. When burned, it decomposes into HCl and NH_3, then quickly re-combines in the air to form a fine smoke of ammonium chloride particles.

Ammonium Nitrate [NH_4NO3] Oxidizer used in high explosives (such as ANFO), but not commonly used in fireworks due to its hygroscopicity.

Ammonium Perchlorate [NH_4ClO_4] Slow burning, widely used oxidizer. Though many rich colors can be made with it, the burn rate is too slow for use in star compositions. However, it is ideal for use in lances and torches, where slow burning is an advantage. Since all the decomposition products are gases, it is also used in rocket propellants (such as the Solid Rocket Boosters on the Space Shuttle).

Antimony Trisulfide (Antimony Sulfide, realgar) [Sb_2S_3] A fuel sometimes used in glitter and fountain compositions to create the color white. At one point it was used in flash compositions, but it was poisonous and extremely sensitive to shock and static electricity. Comes in two forms - "Chinese Needle" and "Dark Pyro." The former is used in glitter compositions and white comets/stars. The latter is used to sharpen the report of salutes and increase the sensitivity of flash powder.

Barium Carbonate [$BaCO_3$] Functions as a **green** color agent when burned with chlorine present (from the formation of BaCl+), burns white by itself (with oxygen, creating BaO). Can also be used to reduce acidity in chlorate-based color compositions.

Barium Chlorate [$BaClO_3$] Used as an oxidizer in **green** color compositions.

Barium Nitrate [$Ba(NO_3)_2$] Can be used as both a **green** color agent and an oxidizer. Functions as a green color agent when burned with chlorine present (from the formation of BaCl+), burns white by itself (with oxygen, creating BaO).

Barium Sulfate [$BaSO_4$] Used as a high-temperature oxidizer in metal-based **green** color compositions.

Benzoic Acid [C_6H_5COOH] Used to make metallic benzoates.

Bismuth Trioxide [Bi_2O_3] Used as a non-toxic alternative to lead tetraoxide to make crackling stars.

Bismuth Subcarbonate [$(BiO)_2CO_3$] Also used as a non-toxic alternative to lead tetraoxide to make crackling stars.

Boric Acid [H_3BO_3] Weak acid in a powder form which is added to compositions containing aluminum or magnesium and a nitrate. Metals react with nitrates to form amides, which can further react with the metal powder to create a highly exothermic reaction which could spontaneously ignite the compound. Even a few percent boric acid added to the mixture will neutralize any amides that form.

Cab-O-Sil (fumed silica, colloidal silica) [SiO_2] Used as an anti-caking agent and to prevent hygroscopic chemicals from absorbing water from the air. Sometimes used in flash powders.

Calcium Carbonate (chalk) [$CaCO_3$] [$CaCO_3$] [$CaCO_3$] Used as a color agent in **orange** star compositions, or as an acid-absorber.

Calcium Sulfate [$CaSO_4\ xH_2O$, where x = 0, 2, 3, 5] Calcium sulfate anhydrate (where x = 0) can be used as a high temperature oxidizer in **orange** color compositions or in strobe compositions.

Charcoal (Carbon) [C] Charcoal is used very widely in pyrotechnics. Charcoal is the by-product of the burning of organic substances. It contains impurities which make is more reactive, and therefore is used more often than pure carbon in fireworks. It can be made from many types of wood. Charcoal from soft woods, such as grape vine or willow, is good for fast-burning compositions like black powder, whereas charcoal from hard woods like pine are used to create long-lasting spark effects. Very fine charcoal is known as ***air float***. Another type of fine charcoal called ***lampblack.***

Clay (bentonite, sodium aluminum silicate) Powder used for plugs and nozzles in fountains, drivers, rockets, and other devices. Can also be made into a paste if mixed with water.

Confectioners' Sugar (sucrose, table sugar) [$C_{12}H_{22}O_{11}$] Can be used with an oxidizer such as potassium nitrate to create smoke devices or rocket fuel.

Copper Acetoarsenite (Paris green) [$Cu_3As_2O_3Cu(C_2H_3O_2)_2$] The best **blue** color agent. It is extremely poisonous, however, and is hardly ever used in modern pyrotechnics.

Copper Benzoate [$Cu(C_6H_5COO)_2$] Can be used as a fuel in **blue** color compositions. Not often used because it is expensive.

Copper(II) Carbonate [$CuCO_3$] Light green powder used as a **blue** color agent.

Copper Chlorate (Hexahydrate) [$Cu(ClO_3)_2\ 6H_2O$] Used as an oxidizer is **blue** color compositions.

Copper(II) Chloride (campfire blue) [$CuCl_2$] Brownish-yellow compound used as a **blue** color agent.

Copper Chromite [$CuCr_2O_4$] Can be used as a catalyst in rocket propellants. It is added in small quantities (1-5%) to rocket fuels and whistle compositions to increase the burn rate.

Copper (II) Oxide [CuO] Black powder used as a **blue** color agent.

Copper Oxychloride [$3CuO\ CuCl_2\ 3.5H_2O$] Green powder used as a **blue** color agent.

Copper (II) Sulfate (Pentahydrate) [$CuSO_4\ 5H_2O$] Anhydrous form is used as a **blue** color agent.

Copper Benzoate [$Cu(C_6H_5COO)_2$] Used as a fuel and as a **blue** color agent.

Cryolite (sodium fluoaluminate) [Na_3AlF_6] White powder used as a **yellow** color agent.

Dechlorane [$C_{10}Cl_{12}$] Used as a chlorine donor.

Dextrin [$C_6H_{10}O_5$] Commonly used, water-activated pyrotechnic binder used to hold compositions together or as a paste.

Ethanol (Ethyl Alcohol) [CH_3CH_2OH] Commonly used as a solvent for compositions containing organic fuels/binders such as shellac and red gum.

Ferrotitanium [60/40 ratio of Fe and Ti] Alloy of iron (ferrum) and titanium, used to create yellow-white sparks in fountains and star compositions.

Gallic Acid [$C_7H_6O_5$ H_2O] White powder used to create whistles.

Gum Arabic Vegetable gum used as a water-soluble binder.

Hexachlorethane (carbon hexachloride) [C_2Cl_6] White powder used as a chlorine donor and in smoke compositions.

Hexamine (hexamethylenetetramine, methenamine) [$C_6H_{12}N_4$] Used as an low reactivity fuel in blue star compositions.

Iron [Fe] Gray metallic powder used to create yellow branching sparks, mainly in sparklers and fountains. Iron alloys rich in carbon work best.

Iron(II) Oxide (ferrous oxide) [FeO Fe_2O_3 or Fe_3O_4] Black powder used as a high-temperature oxidizer in thermite compositions.

Iron(III) Oxide (ferric oxide) [FeO Fe_2O_3 or Fe_3O_4] Red powder used as a catalyst in rocket compositions, as a high-temperate oxidizer in thermite compositions or ignition compositions.

Lactose (milk sugar) [$C_{12}H_{22}O_{11}$ $2H_2O$] Which powder used in smoke compositions and as a low reactivity fuel in blue color compositions.

Lampblack (carbon black) [C] Extremely fine form of charcoal obtained from the burning of crude oils. It is used to produce long lasting, finely dispersed orange sparks.

Lead Dioxide (lead (IV) oxide) [PbO_2] Used as an oxidizer in friction-sensitive ignitor compositions, such as matches.

Lead Tetraoxide [Pb_3O_4] Red powder most commonly used to make crackling stars, sometimes in high-temperature primes.

Manganese Dioxide [MnO_2] Used as a catalyst in composite and whistling rocket propellant formulations.

Magnalium (magnesium-aluminum) [Mg/Al] Alloy of magnesium and aluminum, with properties of both metals. Not quite as reactive as magnesium, and not as hard to ignite as aluminum. Used primarily in glitter, strobes, colored stars, and crackling stars.

Magnesium [Mg] Highly reactive and flammable metal used to brighten flames without decreasing color quality. Coarser grades are used to produce white sparks, whereas fine magnesium is used in flare and star compositions. The by-products of the burning of magnesium are more easily vaporized than those of aluminum, making magnesium a better fuel.

Methanol [CH_3OH] Used as a solvent (similar to ethanol) to dissolve red gum and shellac. Is often mixed with water when used in compositions in order to reduce the surface tension of the water (thus making it more "wet").

Nitrocellulose Lacquer [$C_6H_7N_3O_{11}$] Flammable liquid used primarily as a binder in fireworks compositions, and as a water-resistant coating for fuses.

Parlon [$(C_4H_6Cl_2)_n$] A polymer used as both a chlorine donor and binder.

Potassium Benzoate [C_6H_5COOK ($C_6H_5KO_2$)] Used with potassium perchlorate to make whistle compositions.

Potassium Chlorate [$KClO_3$] Common oxidizer used for mainly for colored star, smoke, and priming compositions.

Potassium Dichromate [$K_2Cr_2O_7$] Carcinogenic orange crystalline powder used to treat magnesium powder in order to make it less susceptible to undesired spontaneous reactions with other chemicals.

Potassium Nitrate (saltpeter) [KNO_3] Most commonly used oxidizer in pyrotechnics that is used for many applications, the most important being black power (a 75:15:10 ratio of potassium nitrate, charcoal, and sulfur).

Potassium Perchlorate [$KClO_4$] Another common oxidizer that is much more stable than potassium chlorate. It decomposes at a higher temperature but gives off more oxygen when it does.

Red Gum (accaroid resin) [mixture of different compounds] A common organic fuel and binder that comes from the hardened red Kino from a certain tree native to Australia.

Saran [chlorinated polymer] Used as a chlorine donor much like PVC and parlon. Can also be used as a binder when mixed with acetone.

Shellac [$C_{16}H_{26}O_4$] A common fuel and binder that has been used for centuries; sometimes thought to be the best fuel for making colored flames. Comes from the excretions of an insect native to India.

Sodium Benzoate [$NaC_7O_2H_5$] Sometimes used as a fuel, most often used to make "whistle mix" to burst shells or create whistles.

Sodium Chlorate [$NaClO_3$] Not often used because of its hygroscopicity, but sometimes used in rocket propellants.

Sodium Nitrate (Chile saltpeter) [$NaNO_3$] Also very hygroscopic, but sometimes used in flares and stars because of the bright **yellow** light it emits.

Sodium Oxalate [$Na_2C_2O_4$] Used as a **yellow** color agent.

Strontium Carbonate [$SrCO_3$] Used as a **red** color agent

Strontium Nitrate [$Sr(NO_3)_2$] Oxidizer sometimes used in red color compositions.

Strontium Sulfate [$SrSO_4$] Sometimes used as a high-temperature Oxidizer sometimes used in red color compositions.

Sulfur [S] Serves as a fuel, and to reduce the ignition temperature/increase the burning rate of some mixtures.

Titanium [Ti] Metal used to produce bright white sparks, the intensity and duration of which is affected by particle size.

Wood Meal (wood flour, sawdust) [mixture of compounds including cellulose, $C_6H_{10}O_5$] Fine sawdust used as a fuel, mainly in lance compositions.

Zinc [Zn] Used in rocket propellants and to create white sparks.

Zinc Oxide [ZnO] Used to produce white smoke.