**The Norwegian Civilian**
**Marksmanship Association**

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# REPORT

## Environment-Friendly Bullet Traps - The Acquisition of Knowledge

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Oslo 7. December 2021

# Preface

The increasing attention being devoted to lead pollution from shooting ranges has revealed a need to learn more about alternatives to traditional bullet traps made of soil and sand. Lead pollution from bullet traps bonds rapidly with soil and dilutes quickly in rivers and streams. Previous surveys have indicated that lead pollution from shooting ranges generally is minor. Nevertheless, local problems should be limited or avoided, if possible.

The European Chemicals Agency (ECHA) is currently considering a ban on lead in ammunition. An exception from any ban on lead might possibly be granted for sports shooting ranges, since existing types of unleaded ammunition do not offer adequate precision. While there have been strong signals that the exception will only apply to shooting ranges equipped to collect and recycle lead, it is not yet clear exactly which requirements will be adopted.

Traditional bullet traps made of soil and sand are almost the only ones used in Norway today. They are simple and work well with a view to safety. In certain other countries, there is a greater prevalence of mechanical bullet traps made of steel and bullet traps made of granular materials. This is motivated by the desire to recycle the metal from the bullets. The extent to which this actually leads to significantly less environmental pollution is not clear. The issue is highly complex, and it should not be assumed that one particular solution is better than other solutions in other situations.

This report describes the information obtained about different types of bullet traps; it attempts to shed light on the complexity of the issues and makes proposals for the road ahead. The drafting of this report is the first stage of DFS' Environment-Friendly Bullet Trap Project; the next stage will be to test specific solutions, and the final stage will be to compile guidance material regarding the design of bullet traps.

The project was initiated by the Norwegian Civilian Marksmanship Association (DFS) and financed with funding from the Norwegian Ministry of Defence.

The report has been drawn up by Dag Rieber of Rieber Prosjekt AS, with support from DFS. Special thanks to Thomas Getz of the Norwegian Defence Estates Agency (Forsvarsbygg) for generously sharing lessons learned from the Agency's testing of bullet traps.

December 2021

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# Contents

# Summary

This report covers the first stage of a project called “Environment-Friendly Bullet Traps”. The project has been initiated by Det frivillige Skyttervesen (abbreviated DFS, in English: The Norwegian Civilian Marksmanship Association). In this stage, available relevant information has been collected to serve as a basis for the further work to find preferable bullet trap solutions.

The report offers assessments of different types of bullet traps. Although the environment is the focal point of this project, other aspects are also crucial for the assessment of bullet traps. The following aspects have been investigated and described:

- Safety
- Maintenance
- Environment
- Costs

The various types of bullet traps have been divided into sub-categories according to the type of energy-absorbing material used. The main categories of bullet traps are as follows:

- Soil/sand
- Granulated rubber/synthetic material
- Steel

The comparison and assessment of the bullet trap solutions take their point of departure in the distinctive features of the shooting clubs affiliated with DFS. The clubs depend on a great deal of volunteer work, their members have considerable expertise in building and construction, there is a strong focus on safety, and most of them have limited funding opportunities. These distinctive features mean that some types of eco-friendly bullet traps have been ruled out due to complicated operations and maintenance, high investment costs and/or high maintenance costs.

The overall assessments indicate that on the current shooting ranges with existing soil/sand bullet traps, it will be most expedient to consider various environmental improvements of the existing bullet traps, rather than moving the contaminated masses to secure landfills and replacing the bullet traps with new types of bullet traps.

On new shooting ranges, types of bullet traps other than the traditional soil/sand bullet traps may be feasible:

- Sloped granular rubber bullet traps with a bulletproof enclosure/roof seem to be an environment-friendly solution in places requiring zero emissions.
- Bullet traps made of rubber chips from shredded tires are feasible where the bullet trap needs to be ricochet free even in winter.
- Steel boxes with internal steel plates seem suitable for temporary shooting ranges.
- Vertical bullet traps with steel plates may be especially appropriate in places with complex topography.

The report identifies possible areas of improvement for existing bullet traps and suggests steps for the next stage of the project with a view to vertical steel plate bullet traps and front plate materials.

# 1 Introduction

## 1.1 Background

Rifle ranges in Norway are equipped with bullet traps behind the targets. The original purpose of a bullet trap was to catch the bullets so there was no spatter or ricocheting that could be dangerous for markers, and to limit the size of the danger zone. The requirement for bullet traps is laid down in the Safety Provisions for Civilian Shooting, issued as an annex to the Shooting Range Regulations from 1988. The Regulations have now been superseded by Chapter 8 of the Firearms Regulations, but the safety provisions have not yet been revised. The Safety Provisions allow shooting ranges without bullet traps in certain situations. However, these ranges call for such large-scale danger zones that few civilian ranges find them appropriate. The Norwegian Civilian Marksmanship Association (DFS) therefore requires that all shooting ranges affiliated with DFS be equipped with bullet traps.

Rifle bullets generally contain the metals lead, copper, antimony and zinc. In sufficiently high concentrations, all these metals are toxic for organisms, but lead is considered to be the main problem. Consequently, this report focuses on lead pollution. Bullet traps that prevent lead from polluting the environment will also prevent contamination from the other metals from becoming a problem. The simplification inherent in concentrating on lead pollution is therefore considered acceptable. The fact that lead is toxic has been known since ancient times, but in Norway, lead poisoning became the focus of serious attention in the 1930s, after more than 46 cases of lead poisoning were reported during a three-year period at the Navy's main naval yard in Horten (Ongre, 2005). Since then, the toxicity of lead has received increasingly more attention, resulting in a ban on leaded petrol in the 1990s and ban on lead shots (shotgun pellets) in 2002.

In earlier times, the construction of shooting ranges was not conditional on any permits from the authorities. Then in 1983, the Pollution Control Act entered into force, making it necessary to secure a permit for any activities that could lead to pollution, including noise pollution. In 1993, guidelines were introduced to regulate noise pollution from shooting ranges, meaning that only ranges with noise levels above certain critical limits required to have permits. No comparable guidelines were issued with a view to lead pollution. In 1989, amendments to the Planning and Building Act entailed that new shooting ranges could not be built without a zoning plan. Since then, it has been customary to make zoning provisions to govern noise and shooting hours. The processes and documentation requirements for building shooting ranges have increased significantly to date, resulting in a need for a guide on how to plan shooting ranges, which was published by the Norwegian Ministry of Culture in 2019 (Rieber, 2019).

The pollution control authorities would like to be able to regulate lead pollution from shooting ranges. Due to great variations in conditions on shooting ranges, a lack of regulations and limited knowledge about the effects of different initiatives, practices that regulate lead pollution differ greatly. Certain issues regarding lead pollution demonstrate the importance of bullet traps, and it is this aspect that DFS has now begun to address. This report is the first step on the path forward.

In 2021, the European Chemicals Agency (ECHA) embarked on a process that may result in a total or partial ban on leaded ammunition. An exemption from the ban has been proposed for sports shooting since accuracy is not good enough using unleaded alternatives. However, requirements will be laid down for lead recovery from bullet traps, and possibly also for recycling the lead. For the moment, ECHA is focussing on steel bullet traps and the degree of lead recovery. However, the degree of lead recovery says nothing about what happens with the lead that is not collected. The goal of ECHA's work is to limit leaching/runoff of lead contamination into the environment. Based on that, DFS's attitude is not that one particular type of bullet trap should be chosen, but that several alternative bullet trap solutions should be considered.

The starting point for this report is to gather more information about different types of bullet traps, and to examine their known pros and cons from an environmental perspective. Consideration will be given to determining which measures might be able to improve known solutions. The next stage will involve making prototypes to test for the purpose of identifying some preferable solutions that we believe deserve to be called 'environment-friendly bullet traps'. All the assessments in this report take their point of departure in how the marksmanship teams affiliated with DFS operate. Other shooting range users might conceivably arrive at different conclusions.

The terms 'bullet traps', 'bullet catchers' and 'backstop berms' are often used interchangeably. This report uses 'bullet traps' to refer to the entire device behind the targets that is needed to comply with the Safety Provisions' requirements for bullet traps.

## 1.2 Earlier research

Up until a few years ago, safety was the primary reason that bullet traps were used on outdoor rifle ranges. Given the growing attention being devoted to heavy metal pollution, especially lead, the environmental perspective is also important. Many studies on heavy metal pollution have been conducted on and around shooting ranges in recent decades. In Norway, the Norwegian Defence Estates Agency has invested tremendous efforts in cleaning up shooting ranges scheduled for redevelopment. From 2006 to 2009, DFS engaged in a cooperative project with the Norwegian Environment Agency (formerly the Norwegian Pollution Control Authority) and the Norwegian Institute for Water Research (NIVA). The concentration of metals in the runoff from 50 Norwegian shooting ranges (Rognerud & Rustadbakken, 2007) was investigated, and a detailed analysis was made of the amounts of heavy metals leaching from three selected shooting ranges (Rognerud, 2009). Three major challenges involved in the measurement of leaching from bullet traps on existing ranges are: The unknown structure of the bullet traps, different ground conditions and uncertainty about previous use. For example, shooting at field targets without bullet traps and shooting at targets of steel both entail that bullets are shattered, causing fragments to spatter across a large area. Pulverised bullet fragments on the surface of the ground have a large total exposed surface area compared with an intact bullet. They also corrode quickly, and they may account for a considerable percentage of the aggregate runoff from a shooting range.

In connection with this project, we have found numerous reports from all over the world about bullet traps and the environment. The reports' degree of scientificity varies greatly, and it is often difficult to know how well grounded the various conclusions are. Based on the references, even the United States Environmental Protection Agency's (USEPA's) frequently cited report on best practice (Best management practices for lead at outdoor shooting ranges, 2005) may appear to be based more on assumptions than on scientific evidence. Published in 2005, the report recommends regular lead reclamation on shooting ranges.

There is considerable variation in how shooting ranges are used. The number of rounds fired, the spread in the impact zone, and the types of ammunition used are factors with a heavy impact on what kind of solutions are favoured. Climatic conditions also have a major impact on how well different types of bullet traps work. Shooting ranges have different architectures, different uses and quite different climatic conditions in various parts of the world, meaning that much of the investigative research done in other countries has limited relevance in Norway.

In the Nordic countries, we have similar climatic conditions and similar traditions with a view to rifle ranges, hunting and shooting sports. Accordingly, it is natural to start with research and investigations in the Nordic countries and then supplement them with research and studies from other countries. The Finnish report published in 2014 and entitled "Best Available Techniques (BAT) - Management of the Environmental Impact of Shooting Ranges" is especially worthy of note (Kajander & Parri, 2014).

## 1.3 Safety requirements for bullet traps

Chapter 8 of the Firearms Regulations deals with technical requirements for shooting ranges, among other things. § 8.2 reads:

***§ 8-2. Technical requirements for shooting ranges and inspection***

*Shooting ranges must satisfy the requirements for safety laid down by the National Police Directorate, as well as other official requirements.*

*The police shall carry out inspections of civilian shooting ranges, and they can ban the use of shooting ranges that do not satisfy the technical requirements pursuant to the first subsection, or when shooting range instructions are violated.*

The safety requirements are found in "Safety Provisions for Civilian Shooting" which superseded the earlier Shooting Range Regulations from 1988. The requirements for bullet traps do not apply to all shooting ranges, only to ranges with high natural background close to the range. In actual practice, the vast majority of shooting ranges will be subject to this requirement, so it is often interpreted as meaning that bullet traps are required on all civilian shooting ranges in Norway. The requirements for bullet traps are found in point 2.7 of the Safety Provisions:

***2.7. Bullet traps.***

*Bullet traps are necessary at ranges with natural background and built-up backstops.*

*2.7.1. Bullet traps used with natural background for rifle ranges. A bullet trap shall be built in accordance with the following guidelines:*

- *it shall be at least 1.5 m. higher than the targets in the upper position as seen from every shooting position.*
- *the uppermost 50 cm may consist of a shield with 30 cm of reinforced concrete.*
- *where a shield is used, it can be attached to the retaining wall.*
- *there shall be at least 2 m. on either side of the flank targets, as seen from the right (left) side of the firing point.*
- *the top shall be of the requisite height and have* a *minimum thickness of 1 m.*
- *the bullet trap shall have an angle of at least 30°.*
- *it shall be covered by a 50 cm layer of mass with a particle size of less than 10 mm., e.g., clean soil, turf, sand or bark.*
- *the bullet trap shall be kept free of rocks.*

In 1988, it was taken for granted that bullet traps would be made of soil or the like, and up to the present, almost all bullet traps on civilian shooting ranges in Norway have been built this way. The figures below illustrate the requirements:

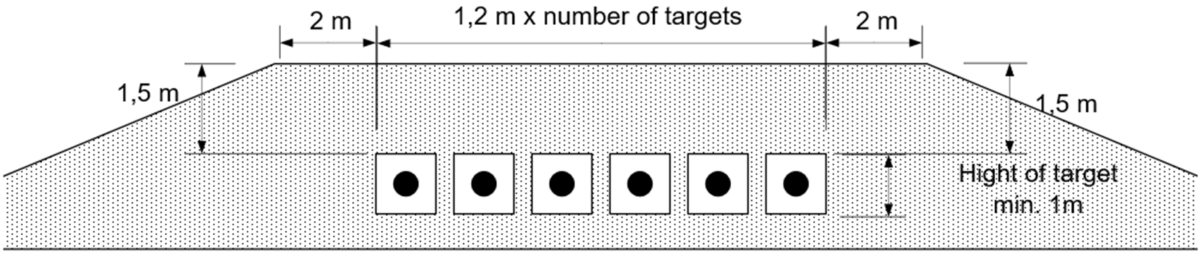



*Figure 1 Requirements for a bullet trap's dimensions, seen from every shooting position*

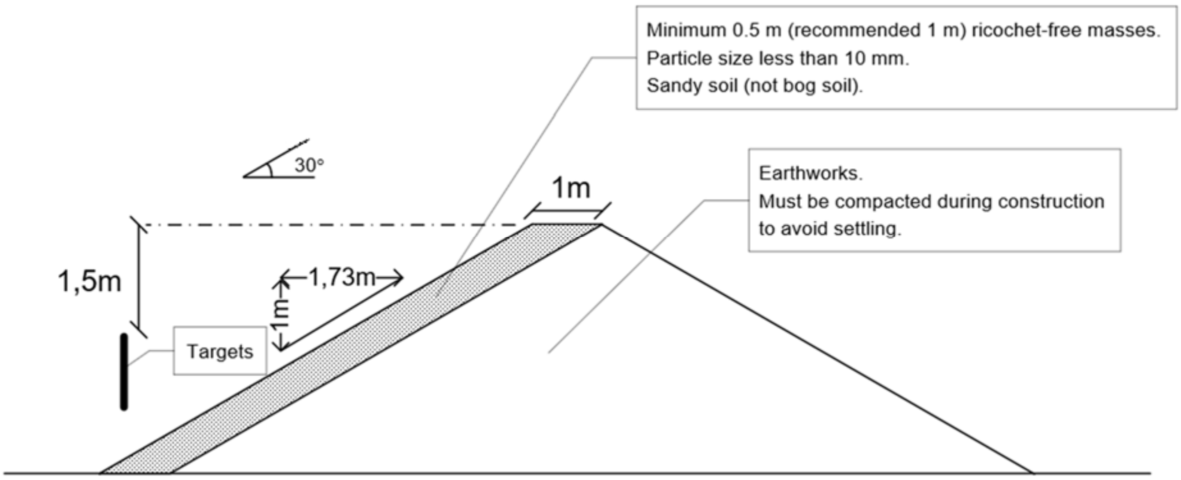



*Figure 2 Requirements for a bullet trap's construction (cross-section of a bullet trap)*

The purpose of bullet traps as described in the Safety Provisions of 1988 is to capture bullets and avoid deflection, spatter and ricochets. Safety is their sole justification. Bullets have tremendous kinetic energy, so bullet traps have to absorb or cushion this energy, while ensuring that bullets do not escape from the bullet trap. Kinetic energy is generally converted to heat when a bullet trap stops bullets. Accordingly, it is definitely an obvious advantage to use non-combustible materials in bullet traps. Soil and sand work well. Bark, sawdust, etc. also work well, although in very dry summer months, there have been incidents of spontaneous combustion in dry bullet traps.
The use of tracer ammunition adds to the risk of fire considerably, and most reported bullet trap fires are assumed to be caused by tracers.

Even though the Safety Provisions for Civilian Shooting are highly specific when it comes to the design of bullet traps, it must be accepted that bullet traps can be designed differently. In any event, there must be satisfactory coverage above as well as on the sides, and a bullet trap must capture bullets and contain them to prevent blow back, spatter and ricochets.

## 1.4 Bullet traps and the environment

This report is intended to shed light on the environmental aspects of different bullet trap solutions. To limit the scope of the issue, the main focus of the report is on the quantity of bullets that can be recovered, and on what happens to the lead that is not captured or recovered from the bullet traps.

Today, bullet traps on civilian shooting ranges are made almost exclusively of soil, sand and fine gravel. When exposed to water and oxygen, the lead in the bullets will corrode and may leach when diluted by water. This can lead to local pollution, especially in marshy areas or if there is open water near the range. Further out in streams and rivers, the concentration will invariably be diluted before eventually becoming negligible. Nevertheless, pollution can be a problem at the local level, e.g., for grazing animals, fish and other organisms. Polluted drinking water can also be harmful to humans.

To reduce the chances that lead will leach into the environment, existing bullet traps can be improved, or entirely different types of bullet traps can be built, but such improvements or the use of other types of bullet traps might conceivably involve other challenges. This report will try to shed light on how different solutions work in the light of how they are actually used, and the degree to which the different types of bullet traps prevent the spread of heavy metals in nature.

The further transport of metals in the environment is outside the scope of this report. Numerous studies have been made in many countries on corrosion, leaching and the transport of metals in various situations and with different ground conditions. The chemistry of the earth and water in and around shooting ranges varies considerably; such factors have a significant impact on both the corrosion rate and the leaching of metals (Bolstad, 2015). In this context, suffice it to note the following:

- Rain and surface water can carry corroded metal away from shooting ranges.
- Leachate can carry corroded metal. Copper, zinc and antimony have greater mobility than lead and can be washed out to a greater extent. Leaching and transport vary a great deal, depending on the soil chemistry.
- The transport of lead mainly takes place when metal bonds to particles in surface water.
- Water can carry lead pollution through sand. (Strømseng & Ljønes, 2000)
- Water transports little lead through soil, meaning that lead contamination from shooting ranges is rarely found in groundwater.

The question to be explored in this report is:

***Is it possible to find some clearly preferable bullet trap designs for outdoor rifle shooting that satisfy safety requirements and represent an environmental improvement compared with the bullet traps currently in common use?***

## 1.5 Goal and project stages

The goal of the project is to compile a list of different bullet trap solutions to identify bullet traps that satisfy safety and environmental requirements while remaining within reasonable cost parameters for establishment and maintenance.

The Environment-Friendly Bullet Trap Project has been divided into three stages.

This report is the result of Stage 1, which consists of the following:

- The acquisition of knowledge through searches of the literature and contact with organisations and manufacturers
- Assessment of known solutions with a view to suitability for use, safety, the need for maintenance, environmental aspects, and costs
- Assessment of potentially favourable bullet trap solutions

In Stage 2 of the project, new solutions and improvements will be rendered more concrete. The project will start with an evaluation of the input from the consultative hearing related to the report from Stage 1 of the project. Further, Stage 2 will consist of:

- Planning some specific solutions
- Making prototypes
- Testing the prototypes in actual practice in the short term and over at least one year of operations based on intensive use.
- Reporting

Stage 3 of the project will focus on making a guide for environment-friendly bullet trap designs based on investigations and lessons learned from the project's first two stages.

# 2 Method

## 2.1 The acquisition of knowledge

DFS has had its own construction department for several decades. For the past 15 years, Rieber Prosjekt has been commissioned by DFS to serve as a technical consultant for the construction department. This report is based on knowledge and experience acquired throughout this period. In addition, new knowledge has been acquired through the following activities:

1. Searches of the literature/studies. Searches of the literature show that a great deal has been written about shooting ranges, bullet traps and the environment, but that an exceedingly small part of the literature is based on scientific methods, a requirement for being characterised as research. However, some research has been performed on specific topics that might help corroborate the assessments made in this report. Only the most relevant ones are referenced.

2. The ECHA process. The EU Chemicals Agency is carrying out a process that will probably lead to a ban on lead ammunition except for sports shooting with bullet traps that offer a high rate of recovery and possibly a recycling option.

3. Contact with
   - DFS and its Nordic sister organisations
   - The Norwegian Defence Estates Agency
   - The Norwegian Shooting Association
   - The Norwegian Association of Hunters and Anglers
   - OBSIMA Technology AS (supplier of material)

4. Inspections of shooting ranges to examine solutions and relevant issues

## 2.2 The categorisation of bullet traps

Bullet traps can be designed in many ways. In this report, bullet traps have been divided into three main categories based on the material that absorbs the bullets' energy, thereby stopping and capturing the bullets. The three categories are:

- Soil/sand
- Granulated rubber/synthetic material
- Steel

Bullet traps can also use combinations of these materials to stop bullets, and there are an infinite number of variations. However, the point of dividing the traps into main categories is intended to shed light on the pros and cons of the various materials as the basis for further developing good solutions.

## *2.3 Assessment points for different solutions*

This report is about environment-friendly bullet traps. Although the report focuses on the environment, there is little point in identifying environmentally optimal bullet traps unless it is also possible to ensure safety, while avoiding an unrealistic amount of maintenance and extremely high costs. Accordingly, other factors have also been considered, beyond those exclusively related to the environment. The following assessment points are described:

Safety:

- Ricochet safety
- The risk of spatter and blow back
- The possibility of shooting through the bullet trap
- Suitability for different types of shooting activities and ammunition

Maintenance:

- The need for maintenance/durability in connection with the use of different weapons/ammunition (sharpshooter ammunition, .22 LR calibre, hunting ammunition and steel core ammunition)
- Consequences of a lack of maintenance
- Maintenance intervals and scope

Environment:

- Possibility for leaching from the bullet trap
- Degree of recovery
- Degree of recycling
- What happens with the lead that is not possible to collect?
- Runoff filtration method

Costs (rough estimates):

- Establishment
- Operation/maintenance

The assessments of the points above are based on information from a variety of sources. These sources differ greatly, making it challenging to balance the assessments in a way that facilitates comparison. The point of departure is bullet traps that are relevant for typical Norwegian rifle ranges for 'DFS shooting' with sharpshooter calibre and fine calibre rifles, hunting training with rifles, and where the Armed Forces/Norwegian Home Guard shoot using military non-leaded ammunition.

This report concentrates on the mechanical functions of a bullet trap and what happens to bullets once they strike a bullet trap. The ultimate fate of the lead not caught in the bullet trap is not discussed. The chemistry of corrosion processes, leaching, bonding of metal with soil, etc. are therefore beyond the scope of this report.

# 3 Characteristics of different types of bullet traps

## 3.1 Soil/sand bullet traps

### 3.1.1 Concept

One traditional type of bullet trap consists of steep earthworks located behind the targets. The requirement in the Safety Provisions stipulates a slope of at least 30°. With such a steep slope, ricochets of ordinary leaded ammunition in the bullet trap are prevented from escaping the bullet trap. A slope of 30° degrees is steep. It is possible to shape soil and sand more steeply than this, but in the face of precipitation, even the most stable types of soil or sand will have trouble maintaining a slope as steep as 35°. In other words, bullet traps with a 30° slope border on what is feasible in practice using soil/sand.

Soil, sand or a mixture of soil and sand are highly effective for decelerating bullets, and the bullets are normally stopped after less than 50 cm penetration in compacted or settled soil/sand.

Ordinary types of mass in the top layer of soil/sand bullet traps

- Local growing soil is the most common material in bullet traps. Such soil is often relatively stable, and vegetation starts to grow quickly, allowing the bullet trap to retain its shape.
- For many years, it has been recommended not to use bog soil since it is acidic and can accelerate corrosion and leaching from heavy metals. Notwithstanding, bog soil is used in many places where shooting ranges are built on bogs, quite simply because this soil is often without rocks and easily accessible.
- Sand alone is not particularly stable, so it is not prudent to use sand alone to build bullet traps. It is, however, common to mix sand and soil or to use sandy soil in bullet traps. As long as the proportion of sand is not excessively high, sandy soil can work well.
- Fine gravel is relatively common as a top layer on bullet traps. Fine gravel is more stable than sand, but fine gravel alone also presents challenges due to its limited stability. Fine gravel is easier to access than fine grained soil, and gravel is easy to work with. Consequently, fine gravel is often used, especially for the maintenance of bullet traps.
- Bark is a non-ricocheting mass and is sometimes used as a top layer on bullet traps. Bark is relatively stable, but will rot over time, so it has to be topped up regularly. Bark can also be a fire hazard when it is extremely dry. (Finney, Maynard, McAllister, & Grob, 2013).
- Sawdust has some of the same properties as bark, but it is less stable, rots more quickly and gets compacted more quickly.
- Old tyres are often used as a 'retainer' material to get bullet traps to maintain a sufficiently steep slope. However, old tyres are defined as waste, so they are not generally allowed to be used like this in bullet traps.

Below, please see illustrations of some bullet traps that are fairly typical on Norwegian rifle ranges.

*Figure 3  Bullet trap as a free-standing berm, in this case for Stang and field rapid shooting targets*


*Figure 4   Bullet trap on a 200 m range as part of the background terrain*

*Figure 5 Example of old tyres used in bullet traps in an effort to stabilise mass*

*Figure 6 Example of crevice formation in a part of the bullet trap with fine gravel (foreground) and a lesser degree of crevice formation in a part of the bullet trap with soil (further away)*

On some shooting ranges, the terrain makes it difficult or impossible to make earthworks high enough to serve as a bullet trap immediately behind the targets. This may be because the terrain slopes steeply, there is not sufficient space available, the ground cannot take the weight of a large enough berm, etc. The pictures below show one example of such a situation, where a strong box was built of impregnated poles and beams, then filled with soil/fine gravel/sand. The shooting compacts and breaks down the mass. In this type of bullet trap, where there is no excess thickness of the mass, rapid wear and tear causes the bullet trap to no longer meet the safety requirements. The pictures show that attempts have been made to stabilise the mass using old tyres, and that bark has been used for fill because it is easier to handle than soil.


*Figure 7 Bullet trap built up with a box of wooden poles and wooden beams*


*Figure 8 Close-up of a bullet trap with a box built of wooden poles and wooden beams to keep the soil/sand in the bullet trap*

### 3.1.2 Safety

The function of a soil/sand bullet trap is easy to understand. Accordingly, this type of bullet trap does not call for any special expertise to ensure safety. This, in itself, is a safety measure.

For leaded ammunition used for civilian rifle shooting, there is an estimated ricochet angle of up to 22°, (Sikkerhetsbestemmelser for sivil skyting, 1988) point 1.6. There may be ricochets with angles greater than this, but then a great deal of the kinetic energy will be converted to heat when the bullets are deformed. In such cases, the ricochets will have little residual kinetic energy, meaning they will not go far. The Armed Forces' unleaded ammunition has steel cores, meaning that the bullets are less subject to deformation when they strike hard objects. This implies that far more of the kinetic energy can be preserved when the bullets ricochet. The Armed Forces therefore operate with a ricochet angle of 45°, (Forsvarsbygg, Håndbok for skyte- og øvingsfelt 2020 - 2022, 2020) point 7.3.5. This ammunition may also have greater ricochet angles than specified, but then with limited residual kinetic energy.

Civilian ammunition has a ricochet angle that is less than the slope to the bullet trap. Accordingly, any ricochets that might occur in the bullet trap will not escape the bullet trap. Steel core military ammunition has a ricochet angle greater than the bullet trap's slope, so ricochets that occur in the bullet trap can avoid this. When military ammunition is used on civilian shooting ranges, it is therefore particularly important for bullet traps to be well maintained to avoid ricochets to occur in the bullet trap. There is also reason to assume that massive copper bullets may have a wider ricochet angle than bullets containing lead. The use of massive copper bullets is on the rise, and this may translate into the need for even more maintenance of bullet traps made of soil/sand in future.

Occasionally bullets or bullet fragments can blow back from bullet traps made of soil/sand. When firing at distances of 100 m or 200 m, bullets blown back all the way to the firing point is exceedingly rare. In the Armed Forces, there have nonetheless been incidents where steel core bullets have been blown back to the firing point, especially when firing at a distance of 50 metres or less, and especially in winter when there is frost in the bullet trap.

When firing leaded civilian ammunition at bullet traps made of soil/sand, safety is generally good, provided there has been at least a minimum of maintenance. Challenges arise more quickly when other kinds of ammunition are used. Stones rising towards the surface of the bullet trap, crevice formation in the bullet impact area, tyres, buckling and frost in the bullet trap are factors that can pose safety challenges with all kinds of ammunition, but the most pronounced problems are with hard core ammunition.

### 3.1.3 The need for maintenance

A bullet trap of soil/sand should be inspected at least in the spring and once again during the shooting season, and maintenance should be performed as needed. Inspections should be more frequent on shooting ranges where unleaded ammunition is used.

The need for maintenance usually arises in response to the following conditions:

- Bullet traps buckle when the soil gets compacted from firing. Poor compacting of mass when the bullet trap was built, or bullet traps being built on soft ground, may reinforce this effect. New bullet traps should always have a certain amount of excess height as a safety margin. Making a sound foundation and compacting the mass well enough when making the bullet trap are crucial for avoiding any need for extensive maintenance later.

- Crevice formation in the ricochet-free top layer in the bullet strike zone.
- If there is insufficient cover over rocks when a bullet trap is built, the rocks can migrate upwards and show up in the ricochet-free mass.

The consequences of poor maintenance are primarily a greater danger of ricochet, but poor maintenance can also increase the possibility that lead will leach out of the bullet trap.

The most common type of maintenance involves keeping the ricochet-free mass in front of the bullet trap topped up, especially by filling in the crevices. Fine gravel is often used for maintenance since it is possible to handle using manual labour and has greater stability than sand. In some cases, mass must also be placed behind and on top of the bullet trap to maintain the requisite elevation. Such maintenance is usually simple to perform and reasonably priced, but more extensive maintenance work requires access to earthmoving equipment.

In Norway, we have no tradition of lead reclamation from bullet traps, but this is done in a number of other countries. More about this in the next point.

### 3.1.4 Environmental factors

Inadequate bullet traps and bullet traps with an insufficient slope will cause ricochets and thereby spread of bullets into the surrounding terrain. This spreads pollution across a large area (Bolstad, 2015). Where satisfactory soil/sand bullet traps are used, the bullets will be concentrated in a small area. Thus, a bullet trap that serves its purpose with a view to safety will also be an important step for safeguarding the environment.

When there is humidity, metal can corrode and leach into the surrounding environment. The extent to which this happens depends on factors related to the design and operation of the shooting range.

#### 3.1.4.1 Building bullet traps of soil/sand

The Norwegian Environment Agency (formerly, the Norwegian Pollution Control Authority), DFS and NIVA have conducted surveys to map the leaching of heavy metals from shooting ranges in Norway. The results have been collected in two NIVA reports (Rognerud & Rustadbakken, 2007) (Rognerud, 2009). The first report lists important factors for limiting the leaching of heavy metals from shooting ranges. The following are the three most important and relevant points in this context:

<u>1. The target area should be made of mass that does not fragment bullets to any appreciable extent</u>

The bullets should not be fragmented because fragmentation increases the exposed surface area of the lead, speeding up corrosion. According to the Safety Provisions, shooters should fire at bullet traps made with finely graded mass that captures the bullets. Bullet traps are constructed with a slope in the direction of the firing line of at least 30 degrees. These requirements ensure that bullets strike the bullet traps, and that all leaded material penetrates deep into the bullet trap. Regular maintenance ensures that bullet traps do not erode.

2. Bullet traps should not be built with soil that has a low pH and/or a high content of organic matter
Acidic soil (low pH) and a high content of total organic carbon (TOC) will increase the corrosion rate and leaching of heavy metals. Bog soil is usually acidic and contains a lot of TOC in the form of humus, so it should not be used in bullet traps.

3. The flow of water through bullet traps should be limited
Limiting the flow of water through bullet traps reduces the corrosion rate and significantly limits the chances of leaching. A properly constructed and maintained bullet trap will only be vulnerable to the infiltration of water in the form of precipitation. Most precipitation will run off the bullet trap or evaporate, so that relatively little of this water will reach the bullets. Thus, there is little water available to wash out corroded lead. Corroded lead bonds with the soil in the bullet trap quickly.

The two reports concluded that with properly constructed bullet traps of soil/sand that do not contain bog soil, shooting ranges will not represent any pollution problems of significance. Any amount of lead that leaches out will be diluted rapidly.

#### 3.1.4.2 Reclamation of lead from bullet traps

Reclamation of bullets from bullet traps is often mentioned as a relevant measure for limiting environmental pollution. Such reclamation will reduce the total volume of metals in the soil of the bullet trap considerably. In 2005, USEPA published a guide for dealing with lead on outdoor shooting ranges (Best management practices for lead at outdoor shooting ranges, 2005). This guide recommends removing and recycling of bullets from soil/sand bullet traps on a regular basis. This type of sorting will remove large bullet fragments, although small fragments and lead dust may be left in the soil. Due to their large surface areas, small fragments and dust will corrode far more rapidly than bullets that are intact. Accordingly, it is doubtful whether the type of bullet recovery recommended by USEPA actually leads to any significant reduction in the leaching of lead. The transfer value of this to conditions in Norway is also uncertain. There has been no reply to our query to USEPA, asking whether there is any experiential data to indicate that reclamation has an environmental impact.

The Swedish Shooting Sport Federation has taken annual readings of heavy metals from a groundwater well with an inflow of water from a soil/sand bullet trap on a shooting range in Kronobergshed, northwest of Växjö, Sweden. With the exception of two years, the annual readings have shown results for lead, copper and zinc that are within the parameters specified in the Drinking Water Regulations. During the two years when overruns were recorded, there had just been excavation work done in the bullet traps. In Norway, the Norwegian Defence Estates Agency has also registered that the leaching of heavy metals can escalate markedly in connection with excavations of soil polluted with rifle bullets (Bolstad, 2015).

Due to the increased risk of leaching from bullet traps when earth is moved, it is hard to tell whether or not regular reclamation of bullets from bullet traps has a positive impact on pollution of the surroundings. There is reason to believe that increased leaching for a period of time after reclamation may lead to more overall leaching than if the bullet trap had been left alone and maintenance done by refilling mass on an *ad hoc* basis. To draw clear conclusions about this, we need to conduct comprehensive tests with verifiable parameters that are relevant for conditions in Norway. Until there is clear evidence that reclamation of bullets from bullet traps yields a significant environmental dividend, it is hardly right to recommend initiating comprehensive cleaning of the soil in bullet traps on shooting ranges that are in active use.

#### 3.1.4.3 Potential environmental improvements

To prevent corrosion and leaching, it is prudent to limit the amount of water that infiltrates a bullet trap. Possible measures are:

- A roof that prevents rainwater from infiltrating the bullet trap. This could also dry out the mass and possibly lead to more dust, which is not desirable. Any roof should therefore be designed to allow some torrential rain to seep into the bullet trap.
- Having a cover over the bullet trap may help prevent rain from getting into it. Bullets will perforate the cover where they strike it. If there are crevices formed behind the cover, the cover may dip somewhat where the perforations are, allowing water to run into the bullet trap through the bullet holes if maintenance is not satisfactory.
- Digging trenches and draining the runoff towards the bullet trap is undoubtedly a good idea in locations where a bullet trap is located immediately in front of a rising terrain.

On range 13B at Sessvollmoen, the Norwegian Defence Estates Agency has a bullet trap built with a wooden frame filled with sand, then covered with a 6 mm rubber sheet cover. The cover gets a great many holes from shooting in the winter, probably because the material is somewhat stiffer when it is cold. The first cover that was tested got brittle from exposure to the sun, even though it was supposed to be UV-resistant. As long as the cover is in good condition, it will prevent water from flowing through the bullet trap. Any water that manages to infiltrate the bullet trap will seep into a drainage trench and be diverted to a tank for sampling and possible cleaning. The cover is relatively heavy, meaning it is not easy to lift it up to check the status of the bullet trap underneath it.


*Figure 9 Range 13B at Sessvollmoen is a sand trap with a rubber sheet cover.*

### 3.1.5 Costs

Building soil/sand bullet traps is fairly simple and reasonably priced in many places. In its simplest form, such a bullet trap consists of a mound of mixed masses, where the outermost half meter facing the targets is made of fine graded soil and sand. If one has free access to such masses, the costs are limited to earthmoving equipment and labour. Building a typical bullet trap for a small shooting range can be done with an excavator in a couple of days, and the cost may add up to as little as roughly NOK 50 000, including VAT. Where it is necessary to purchase fine grained soil, costs may be substantially higher, since large volumes of mass are required, and transport costs may also be substantial. To avoid transport costs, it may be possible to sift soil on the spot, but that also requires some heavy equipment and operators. Bog soil is sometimes used because it may be easily accessible, but using it is not recommended for environmental reasons.

On shooting ranges with steeply sloping terrain across the range, the construction of soil/sand bullet traps may potentially require extremely large volumes of mass. Earthworks are not stable on a slope that is steeper than 30-35°, and in steeply sloping terrain, the toe of the mound may end up far from the crest of the bullet trap. Such factors may drive costs up significantly.

The need for special measures to prevent water from infiltrating a bullet trap may also lead to substantially higher costs. This may include using membranes behind the bullet trap, drainage trenches and drainage pipes, a cover over the bullet trap, etc.

Ordinary maintenance on soil/sand bullet traps will typically consist of having a load of gravel delivered to the range and then having members pitch in to spread it across the bullet trap as needed. Such maintenance may cost less than NOK 10 000, including VAT, per year.

## *3.2 Granular/synthetic bullet trap*

### 3.2.1 Concept

Granular/synthetic bullet traps are found in many forms, but they are all similar in the fact that the energy of the bullets is absorbed by a type of granulated rubber or a synthetic material. Granulated rubber is used as designation when the granular layer is made of old tyres, even though the actual content of natural rubber might be modest. Several variations of such bullet traps are presented below.

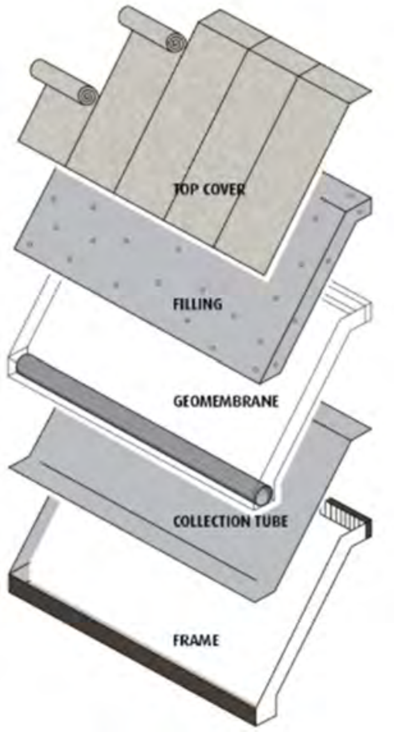
<u>Sloped granular bullet traps with covers on them</u>

At Sessvollmoen, the Armed Forces has a test bullet trap of granulated rubber covered by a rubber liner. The granular material is relatively finely grained and similar to that used on artificial grass pitches. The cover is 2 mm thick and does not appear to have been seriously perforated by the shots. The granular material settles slightly from use. As time passes, it must be refilled occasionally. Bullets are not often crushed if a bullet trap is maintained frequently, but if it is not well maintained, bullets can lump together and cause ricochets. This is especially challenging with unleaded ammunition like that used by the Armed Forces, since these bullets are not much heavier than the granulate, meaning they are less likely to migrate down through the granulate.
The test bullet trap has a drainage pipe under it, which leads to a tank where it is possible to take readings from runoff water.


*Figure 10 Granular bullet trap on range 13A at Sessvollmoen*

The Stapp bullet trap is a patented system consisting of a frame, collection tube, geomembrane, granular filling and a top cover. The manufacturer states that the rubber membranes need repairs after every 3-4 years of normal use and that the bullet trap can tolerate up to 30 000 rounds per target before it needs maintenance. This bullet trap should tolerate both high temperatures and many degrees below freezing.

*Figure 11 Images from the manufacturer's website.*
*https://www.stapp.se/products/outdoor-bullet-traps/*




In Germany, bullet traps have been built using the plastic material RUTEC R5000 as the energy-absorbing material. There is a cover on this one, in addition to a roof that limits most infiltration by rain. This plastic material supposedly does not generate dust, and it is purported to be easy to separate from the bullets because the material has a low specific gravity, allowing the bullets drop to the bottom of the bullet trap.

*Figure 12 Granulated plastic bullet trap with a cover. Excerpted from https://www.obsima.no/produkter/skyte-og-ovingsanlegg/rikosjettsikring/sgp-rutec-r5000-granulat*

The Ringerike Gun Range at Buttentjern has a bullet trap of granulated rubber with a cover, which also has a concrete roof over it. In its day, the bullet trap was built at the expense of the Armed Forces. This bullet trap has been used for years and the need for maintenance has been limited. The rubber cover has been patched multiple times, but it is not known whether the bullets were ever removed from the bullet trap. With a thick enough layer of granulated rubber, bullets can accumulate in such bullet traps for many years. The roof structure eliminates runoff. The bullet trap shows signs of the granulate starting to settle, but only after many years of use.
With this bullet trap, bullets that miss the targets will be shattered, causing spatter outside the bullet trap. With improved solutions, this can also be eliminated.


*Figure 13 Sloped granular bullet trap with a cover and roof over it, at the Ringerike Gun Range*

<u>Bullet traps of tyre chips</u>
Tyre chips consist of old tyres that have been shredded and cut up. There are several fractions of tyre chips available on the market. Relatively coarse tyre chips are considered to be most appropriate because the chips stay in place even with frequent use. The tyre chips can be placed at a significantly steeper slope than soil/sand or ordinary granulated rubber. This is good with a view to avoiding the danger of ricochets. The pictures below show the rifle range with a bullet trap made of tyre chips at the Police National Emergency Response Center in Norway. The shooting range features drainage of the bullet trap that leads the water to a filtration system that captures a high percentage of the metal that corrodes from the bullets. Tyre chips last for a long time in bullet traps. Depending on the frequency of use, it may be years before they need to be replaced or topped up. Over time, there may be a build-up of microplastics that could contaminate the runoff and the environment.

The use of tracers has led to fires in roofed bullet traps made of tyre chips. Surveys indicate that it is the textile component in the tyres that catches fire. The combination of textiles and fine particulate matter can generate enough heat to cause an entire bullet trap to combust. Fires in this kind of bullet traps are almost impossible to extinguish, so the solution is simply to let them burn out, while keeping them from spreading. In a bullet trap made of tyre chips without a roof over it, the fine particulate matter is washed out and the risk of fire is deemed almost non-existent, even when tracers are used (Østeraas, 2014).

*Figure 14 Target mound and bullet trap made of tyre chips, seen from the firing point*

*Figure 15 Target mound and bullet trap made of tyre chips, seen from the side*

Granulated rubber in a box with a vertical front

Bullet traps consisting of a box structure filled with granulated rubber are used on some indoor shooting ranges. They can also be used outdoors as long as water is prevented from getting into the box. Variations of such bullet traps are often used on ranges for .22 calibre rifles. This solution is also used in some places where large calibre rifles are used. The greatest challenge may possibly be that the front of the bullet trap must be relatively rigid to prevent pressure from the granulate from causing the front to bulge. Accordingly, 50-80 mm plates of high-density polyethylene (HDPE) are used on the front of bullet traps for large calibre shooting. HDPE plates are virtually self-sealing, but after being in use for some time, the perforations will also make these bulge. It remains to be seen whether it is possible to find a front plate material that lends itself to all types of weapons that might be used on DFS ranges.

The maintenance for this kind of granular bullet traps involves replacing the front, emptying bullets from the box, and topping up the granulated rubber.

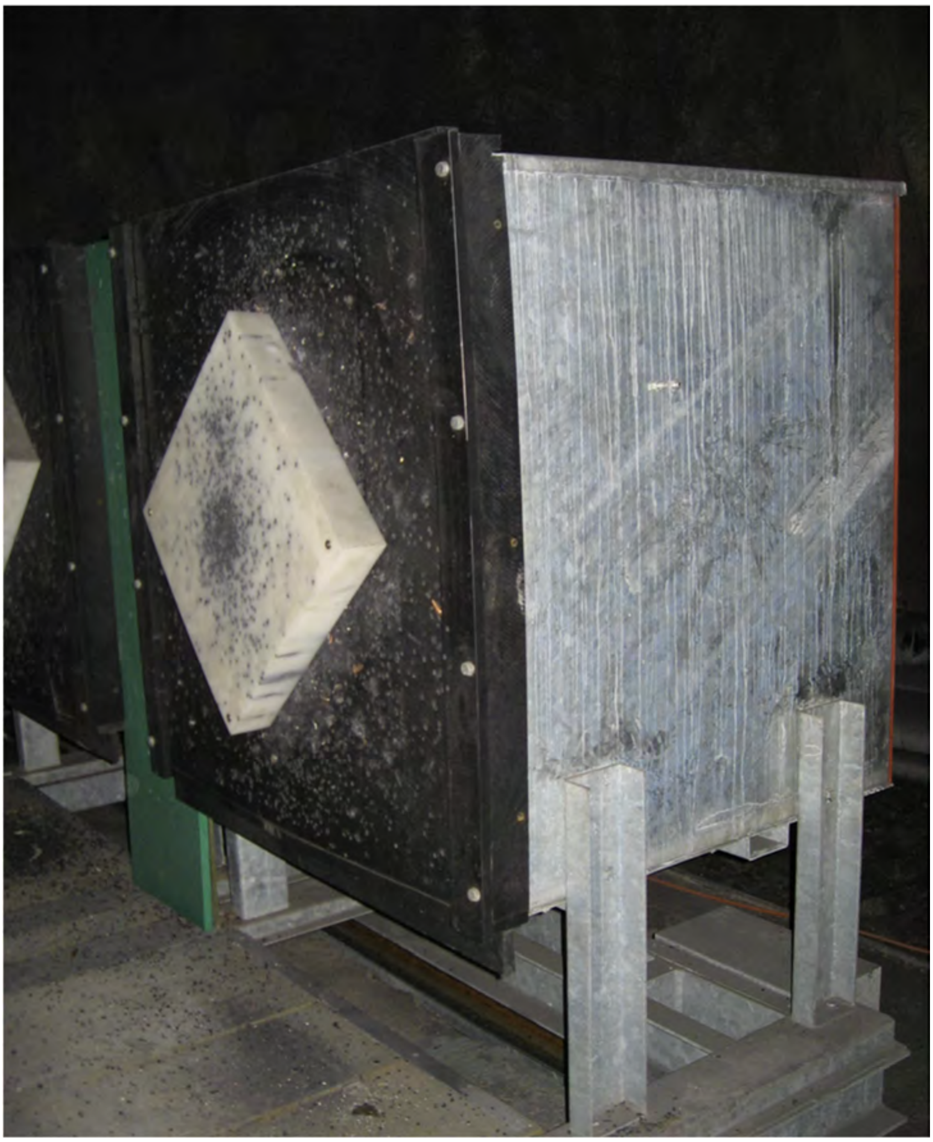


*Figure 16 Steel box with granulated rubber and HDPE front plate. Brünig Indoor in Switzerland*

Vertical lamellas

Bullet traps with multiple layers of vertical lamellas have been tested several places. The lamellas may, for example, be made of discarded conveyor belts cut to appropriate size. The number of lamellas must be adapted to the type of lamellas and the type of weapon with the highest impact energy used on the range. The bullet trap works by reducing a bullet's energy each time it passes through a lamella. Ultimately, the bullet will fall to the bottom of the bullet trap. The greatest challenge with lamellar bullet traps is that they wear out quickly, especially on ranges where there are many repetitive hits in the same place. Additionally, the wear and tear lead to a great deal of waste from the lamellas that gets mixed in with the bullets. The picture below comes from an indoor handgun range at Brünig Indoor in Switzerland. As can be seen, wear and tear are greatest immediately behind the bull's eye, and unless it is inspected on a very regular basis, there is a risk of shooting directly into the back plate of the bullet trap owing to the heavy wear. If the steel in the box is not hard enough, there is a risk that someone could shoot straight through the bullet trap.

*Figure 17 Steel box with vertical lamellas made of conveyor belts. Brünig Indoor in Switzerland*

Cylindrical bullet trap

The SGP RUTEC R9000 cylindrical bullet trap is a granular bullet trap consisting of two rows of vertically hanging cylinders backed by a steel plate. The cylinders have an outer tube filled with PUR granulate. These can be rotated and replaced so that all sides of the cylinders can be used before they have to be repaired or eventually replaced. A bullet trap like this is compact, a mere 650 mm deep. This is primarily an advantage indoors, where space is limited. One advantage of this solution is that the bullet trap works well from .22 calibre and up to more powerful, sharpshooter and hunting rifles.

*Figure 18 Cylindrical bullet trap, excerpted from* https://www.obsima.no/produkter/skyte-og-ovingsanlegg/kulefangere/sgp-r9000-sylinderkulefanger

### 3.2.2 Safety

In general, the safety of bullet traps made of granular or synthetic material is good as long as they are well maintained. When planning, it is important to note that the larger the calibre to be used, the thicker the layers of energy-absorbing material must be used.

Bullet traps made of granulate/synthetic material like those shown here all have some type of cover that limits the amount of water that gets in, thus reducing the risk of ricochets due to frost considerably. Bullet traps made of tyre chips are the exception, as they do not need covers since they have such an open structure that ricochets due to frost are highly unlikely.

The danger that lumps of bullets will build up in the bullet traps, increasing the risk of ricochets, varies considerably from one type of shooting range to the next. The properties of the granulate will make a big difference in this context. The probability of ricochets due to bullet lumps is highest in sloped granular bullet traps. The risk is especially high when firing

steel core ammunition since it is light, meaning it does not sink into the granulate easily, and because ricochets are more common owing to the larger ricochet angle with steel core ammunition. The manufacturer of Stapp bullet traps claims that the risk of ricochets is minimal with their bullet traps. If so, that may be due to the ability of their granulate to allow the bullets to sink down through the granulate. This effect has been proven in bullet traps made of the plastic material Rutec R5000, probably because the material is lighter than ordinary granulated rubber.
A granular bullet trap with a roof and walls of concrete will mean that any ricochets will be captured by the enclosure. A well-designed enclosure in the front of the bullet trap virtually eliminates the risk of ricochets.

Bullet traps made of steel boxes filled with granulate can satisfy good safety standards, but they work differently, depending on the types of weapons used. A hard front plate may work well with sharpshooter ammunition, but it may be difficult for bullets made entirely of lead to pierce the plate. This applies to .22 calibre bullets in particular. If the bullets are left in the plastic and build up, they may lead to ricochets and spatter from new bullets that are shattered and fail to penetrate the front plate. Lead-tipped hunting ammunition expands easily and can destroy the front plate. The possibility of blow back is also present when shooting with ammunition that has low kinetic energy.

Granulate/synthetic material is generally flammable. This means that such bullet traps could be fire hazards. The vast majority of granulates will form fine particulate matter (dust) from being used, and the fine particulate matter can burn fiercely if ignited. In principle, the risk of fire can be limited by preventing access to oxygen or ensuring that water washes out much of the fine particulate matter. According to the manufacturer, the Stapp bullet trap should be so firmly closed that there is not enough access to oxygen for it to burn, even with tracer rounds. Many other types of bullet traps will burn fiercely if they first catch fire, so tracers should never be allowed to be used to shoot at bullet traps based on synthetics as energy-absorbing materials. A bullet trap made of tyre chips is highly porous, and any build-up of fine particulate matter can be a fire hazard if the bullet trap is extremely dry. Access to rainwater will wash out the fine particulate matter and prevent the tyre chips from catching fire, probably even when tracers are used. For that reason, bullet traps made of tyre chips should not have roofs.

### 3.2.3 Maintenance requirements

The need for maintenance varies considerably from one type of bullet trap to the next, based on the granulate/synthetic material used.

Sloped bullet traps with covers on them depend on the covers not being perforated too much. Rainwater will run down a cover, but if there are holes in it, much of the rainwater could run into the bullet trap. That eliminates some of the environmental benefits of these bullet traps, so it may be necessary to install a floor drain that leads infiltrated water to a filtration tank. Therefore, such bullet traps must be repaired before there are too many holes in the cover. The size of the holes in the cover varies from cover to cover and must be tested. The repair of covers often depends on having dry weather so the glue used to patch them will hold. This means that it is an advantage if the patching of the cover is simple enough to be handled by local labour. In actual practice, patching covers can be challenging since it requires both skill and dry weather.
Sloped granular bullet traps with a roof are less sensitive to holes in the cover, and they are also easier to repair because the bullet traps are always dry.

A bullet trap made of tyre chips is durable, and it is only necessary to add new tyre chips in the crevices that form in the impact zones. Crevice formation takes time, so little maintenance is needed. The need for maintenance is usually apparent after 40-50 000 rounds are fired at a target (Forsvarsbygg, Veileder - Utforming av HMS- og Miljøriktige basisbaner, u.å.).

Granulate in boxes is often used for firing indoors with .22 calibre rifles, and it works well in this context. Shooting with larger calibre ammunition requires a stronger front plate, which has to be replaced after a few thousand rounds. At the same time, it will be necessary to separate the rubber from the bullets and refill the granulate using supplementary granulate. If this is done often enough, the bullets will remain relatively intact, and easy to handle. Putting maintenance off for too long and not sorting out bullets means that new bullets will hit the old ones in the bullet trap and shatter them. That leads to dust and complicates the process of purging the bullet trap. Separating bullets from granulate can be difficult, and it may also mean that those who carry out this work will be exposed to significant amounts of lead. Accordingly, it is important to use the right type of PPEs (personal protective equipment), along with purpose-built machines. In practice, the purging of bullets that have to be separated from granulate involves work that should be performed by professionals.

### 3.2.4 Environmental factors

For lead to corrode and leach out, water has to infiltrate the bullet trap.

Sloped granular bullet traps are covered, so rainwater runs off and does not infiltrate them. However, every bullet that hits such a bullet trap will make a hole in the cover upon impact. The size of the holes can vary considerably. The Armed Forces have experienced that light unleaded bullets roll (somersault) easily. For example, a little snow on a bullet trap could be enough to cause this to happen. A bullet that rolls can hit the bullet trap crosswise and leave a gaping hole in the cover. This could be seen clearly when the bullet trap was tested at Sessvollmoen. Regular sharpshooter ammunition has pointed bullets with a full metal jacket of copper, which also have great directional stability. These bullets normally make the fewest holes in the covers over the bullet traps. It is clear that bullets from many hunting weapons make big holes in the rubber cloths on electronic targets, and there is reason to believe that this will also apply to the covers over the bullet traps. .22 calibre rifles may also make bigger holes in the covers than sharpshooter ammunition does, since .22 calibre bullets are not pointed. There are major differences in the quality of the materials used for the covers, as reflected in the size of the holes made by bullets. An outdoor bullet trap is exposed to considerable ultra-violet (UV) radiation, which can be hard on a cover made of rubber/synthetic material. The ideal cover must tolerate small holes made by the bullets, and it has to be highly UV resistant.

Bullet traps made of granulated rubber develop crevices where the bulk of the bullets hit. In addition, bullets can accumulate so that bullets are shattered when new ones strike in the same place. Other types of light synthetic material can mean that the bullets have more of a tendency to sink downwards into the granulate, reducing the danger of congestion in the strike zones. If maintenance is neglected, there is a risk that rainwater will run into the crevices through big holes in the cover where there are large volumes of shattered bullets immediately inside. Under such circumstances, the cover will not prevent corrosion and leaching. This is why good maintenance of granular bullet traps is profoundly important. An initiative that compensates for the infiltration of water might be to have an impervious ground cover on the floor of the bullet trap and to set up a drain that runs to a sedimentation basin or a tank with a heavy metal filter and the possibility for sampling, similar to the solution in the Stapp bullet trap and the Armed Forces' test bullet trap at Sessvollmoen. Filters also call for maintenance, meaning that good routines are crucial.

Building a roof over the bullet trap to prevent water from getting in will eliminate the risk of metals leaching.

Of the described variations of sloped bullet traps, only bullet traps made with tyre chips are not protected by covers. The Norwegian Defence Research Establishment has assessed the environmental risk related to bullet traps made of tyre chips, and found that the environmental risk of leaching from metals, PAH and phthalates is considered to be modest (Aanyeby & Johnsen, 2019). The amount of microplastics expected to come out of such bullet traps was found to be uncertain. Bearing in mind the wear and tear on tyres from road traffic, it is assumed that the amount of microplastics from such bullet traps would be negligible by comparison. There are not many crevices formed in bullet traps made of tyre chips. Bullets rarely accumulate. Even though some of the bullets remain stuck in the tyre chips, the bulk of them will migrate down through the bullet trap. The probability of the bullets being shattered is therefore small. The fact that bullet traps made of tyre chips are not equipped with anything to prevent the infiltration of rainwater means that the bullets are not protected against corrosion. Notwithstanding, the fact that the bullets do not usually shatter helps ensure that corrosion is slow. With expedient drainage and a sedimentation basin, both microplastics and runoff containing heavy metals can be captured. The Police National Emergency Response Center, Norway, has used this type of solution. According to their own environmental follow-up programme, samples will be taken regularly. This may provide useful data in the long-term, but the centre has only been in operation for a little more than a year, meaning it is still too early to draw any clear conclusions about their system.

In bullet traps that use granulate/synthetic materials to catch the bullets inside a more or less closed container, there is generally little danger of metal corroding and leaching out. It is a prerequisite that the bullet traps are designed so that water cannot infiltrate them. The purpose of such bullet traps is to make it possible to purge the bullets and send them to recycling. In that context, it is important that heavy metals are not spread during the separation process. If possible, the most expedient method can often be to transport the bullet traps to an indoor location where bullets and granulate can be separated in a controlled manner without any danger of spreading heavy metals into the surrounding environment. Alternatively, the separation can be handled by professionals with special equipment.

Closed containers have to have some kind of a cover or plate in the front to prevent granulate and bullets from getting out of the container. A soft cover has the advantage that all types of bullets can penetrate it easily, but a soft cover will not manage to resist the pressure from the granulate in the box. In a cylindrical bullet trap, the pressure will be facilitated by the stretchiness of the cover. As long there is not too much perforation, it will keep the granulate in place. A box with granulated rubber must have a more rigid front. HDPE plates are often used for this. Where pointed full metal jacket rifle ammunition is used exclusively, this will work well, but lead bullets like those from .22 calibre rifles may be shattered or produce fine lead dust that can pollute the environment.

In general, a well-designed and well-maintained granular/synthetic bullet trap will be a good environment-friendly choice. Even if microplastics and chemical components can leach from the anti-ricochet material, there is reason to assume that such bullet traps are at least as environment friendly as bullet traps of soil/sand. The challenge with granular/synthetic bullet traps is that such bullet traps are more sophisticated and call for more expertise in connection with use and maintenance. A lack of maintenance, improper use etc. may, in the worst case, cause more leaching.

### 3.2.5 Costs

It is assumed that different varieties of sloped bullet traps are appropriate on the outdoor rifle ranges of rifle clubs in Norway. The vast majority of bullet traps based on granulate/synthetic material as the energy-absorbing material require some preparation of the ground before they can be installed. In simple terms, one can assume that the cost of preparation of the ground for building granular/synthetic bullet traps will be roughly the same as what it would cost to build a bullet trap of soil/sand. This means that the cost of building sloped granular bullet traps will be incurred in addition to what it costs to build a bullet trap of soil/sand.

The professional Stapp bullet trap may be a good starting point in this context. For a typical Norwegian rifle range with 10 targets at 100 m and 10 targets at 200 m, installation costs can add up to roughly NOK 2 million, incl. VAT. Maintenance and purging are carried out by the supplier and may average about NOK 100 000, incl. VAT, per year.

Bullet traps with granulated rubber, a floor covering and a top cover, as well as simple drainage to a tank can be built by the rifle club itself. Such bullet traps built through joint volunteer efforts can probably be set up with 10+10 targets at a cost of approximately NOK 300 000, incl. VAT. Maintenance can be done by volunteers, and the costs incurred will be for new covers, supplemental granulate and any costs for delivering extracted bullets to a recycling centre. The main challenge inherent in a solution like this is ensuring that it is built and maintained in a way that guarantees that it will work as intended. That calls for considerable interest and a significant amount of expertise in building and maintaining such a bullet trap. Accordingly, this solution may be overly complex for most rifle clubs.

Granular bullet traps with roofs may offer a good solution. With an enclosed structure like the one at the Ringerike Shooting Centre, there is no danger of runoff. As long as the chamber containing granulate is big enough, the bullet trap can be used for many years before it needs to be purged. Then it will require simple ongoing maintenance with inspections, topping up the granulate and patching the cover. Building costs for a bullet trap like this for 10+10 targets can be assumed to be on the order of MNOK 2.5, incl. VAT. Annual maintenance can cost approximately NOK 20 000, incl. VAT. In addition, bullets will have to be separated and the granulate refilled in the bullet trap about every 15 years, and each time will cost an estimated NOK 300 000, incl. VAT.

Tyre chips are a very reasonably priced material. Using volunteer labour, the chips for a bullet trap can be bought and spread out for roughly NOK 100 000, incl. VAT for 10 + 10 targets. Even though the material is reasonably priced, transport costs can be high if the shooting range located far from where the tyres are processed. The costs of a drainage system, a sedimentation basin and any cleaning filters can quickly add up to approximately NOK 500 000. The choice of solutions is heavily site-specific, and there can be huge variations in recommended solutions and costs alike. In this situation, there may also be a need for assistance from environmental consultants with expertise in such solutions. Ongoing maintenance involves topping up the tyre chips when crevices are formed. After about 10 years, it may be advisable to remove all the tyre chips, sift out the bullets and rebuild the bullet trap. The cost of this may be roughly NOK 300 000, incl. VAT.

A box filled with granulate or lamellas and cylindrical bullet traps will all call for some additional structural work around the bullet traps in order to work. The solutions will necessarily vary, and it is difficult to estimate costs with any real degree of accuracy. Advanced solutions can be assumed to cost about the same as the establishment and maintenance of a Stapp bullet trap, while simpler solutions can probably be built for as little as about half that amount. In some cases, increased operating/maintenance costs must be expected if solutions are selected that significantly reduce establishment costs.

## *3.3 Steel bullet traps*

### 3.3.1 Concept

Steel bullet traps work by the bullets striking a steel plate and then being captured in a chamber. That way, the metal in the bullets can be delivered to recycling. There are a number of different principles in play here. The angle at which a bullet strikes the steel plate largely determines how much the bullet is deformed or shattered. The total surface area of a bullet is greater when the bullet is shattered than when it remains intact. The finer the particles, the larger the overall surface area and, of course, the more lead that can corrode. Accordingly, it will generally be an advantage to minimise the shattering of bullets. The challenges of shattered bullets can be compensated by the shattering taking place into a closed chamber that ensures that shattered residual bullet fragments and lead dust do not end up out in nature. The next section is a presentation of some relevant types of steel bullet traps.

<u>Helical (snail house) bullet traps</u>

The goal of helical bullet traps is to avoid shattering bullets. The steel plates have such a narrow angle compared with the trajectory of the bullet that the bullets change direction without getting shattered. After that, the bullets are guided into a deceleration chamber where they rotate until they lose velocity and drop down into a collection gutter, preferably with a conveying screw in the bottom. This type of bullet trap is most common indoors, but they are also used outdoors in some places in countries that rarely experience frost.
There are many different types of helical bullet traps. Many of them need some sort of lubrication with water or oil to prevent excessive wear and tear. Both lubrication and the large opening at the front of the bullet trap make it difficult to adopt such solutions, given the climate conditions in Norway. In the event, it would require a large superstructure.

One variation on a high-quality helical bullet trap is available from Action Target. See the drawing below.

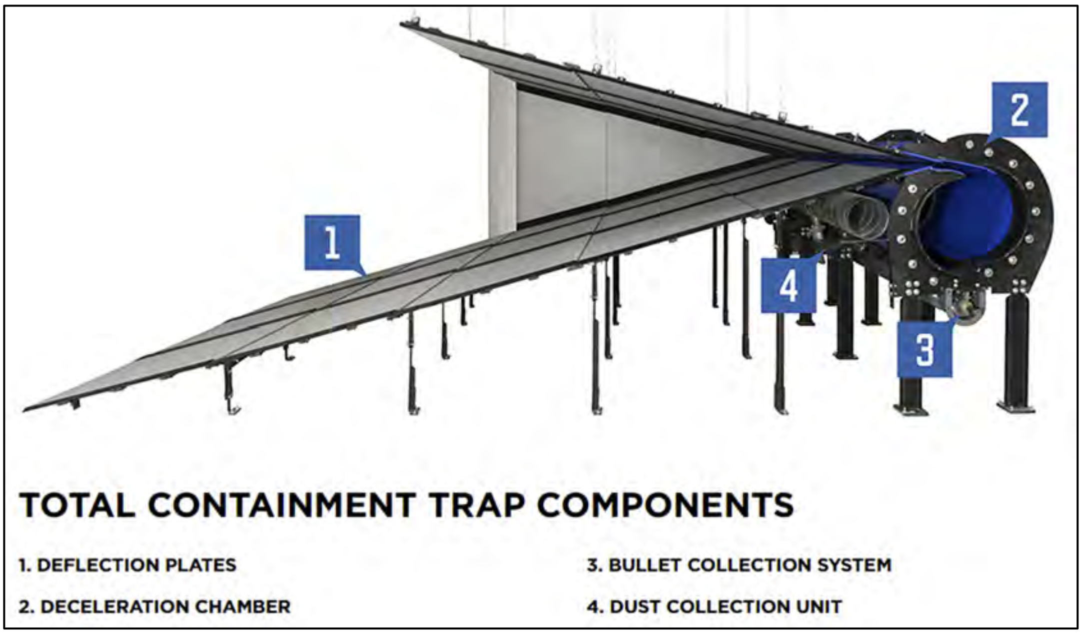



*Figure 19 Helical bullet trap from Action Target. https://actiontarget.com/products/tct/*

Helical bullet traps can be delivered with automatic bullet feeds and filtered ventilation to prevent lead dust from escaping the bullet trap. A bullet trap like this will have an exceptionally high degree of collection and minimal risk for leaching lead.

<u>Lamella bullet traps</u>

A lamella bullet trap works by having angled steel plates built up like overlapping lamellas. These lamellas are usually angled downwards so that the shattered bullets drop into a gutter or a drawer under the bullet trap. One advantage of this bullet trap is that it is not very deep. Some lamella bullet traps are equipped with a conveying screw at the bottom that feeds the bullet fragments into a container on one side. The container can be loaded directly onto a vehicle and driven to recycling. Lamella bullet traps are also sometimes built with a drawer in the bottom of the bullet trap. The drawer has to be emptied frequently. This is because the lead is very hot when it shatters, meaning it can partially melt together into a hard lump in the collection drawer. By angling the lamellas upwards, the bullet fragments have time to cool off before dropping to the bottom of the bullet trap, making the bullet fragments easier to remove. The disadvantage is that there may be significantly more spreading of dust because the dust is forced upwards. In addition, bullet fragments will end up in front of the lamellas when they fall down. Consequently, this calls for a bigger collection tank and it poses stricter requirements for impermeability in the front of the bullet trap.

The front of the bullet trap has to have a cover or plates that one shoots through. The more robust this material is, the closer to the lamellas it can be without risking that bullet fragments fly out again. HDPE plates work well as front material when firing with full metal jacket sharpshooter ammunition. The bullet will pierce the plate and the hole in the plate will close again almost completely. The Armed Forces' unleaded ammunition also pierces it easily. Hunting ammunition often has a lead point and is made to deform when it hits. Accordingly, such ammunition can damage HDPE plates. .22 calibre firearms may have problems piercing the relatively thin HDPE plates. Similar issues can arise when using Regupol plates as front material. Regupol plates are made of a particular type of granulated rubber and are used often for ricochet prevention. All types of bullets will penetrate rubber mats, but the mats offer little resistance against bullet fragments flying out again.

Lamella bullet traps are typically made so that the lamellas cover a width comparable to one or two targets. The installation points for the lamellas must always be outside the target zone to ensure that as many bullets as possible hit the lamellas and not the frame that supports them. The lamellas can be mounted in a track without fasteners and be rotated to avoid the lamellas located right behind the middle of the target from wearing out too quickly.

To comply with the safety requirement stating that the bullet trap must be at least 1.5 metres higher than the top of the targets, the enclosure around the bullet trap facing the targets can be bulletproof. It can be built of concrete or steel covered with anti-ricochet material. The few bullets that miss the targets will then be captured and not cause spatter or ricochets.

Lamella bullet traps are commonly used on indoor shooting ranges, but they may also lend themselves to outdoor use. The example shown in the images below is located at Camp Trondenes. A superstructure has been erected over the targets and the bullet trap here. This may be necessary outdoors to avoid problems with water, snow and ice.


*Figure 20 Lamella bullet trap, Camp Trondenes, with a conveying screw in the bottom to remove bullet fragments. (Forsvarsbygg, Håndbok for skyte- og øvingsfelt 2020 - 2022, 2020)*

*Figure 21 Steel lamellas in a bullet trap. The lamellas and the back plate are both made of Hardox steel plates*

Bullet trap cassettes

While lamella bullet traps have angled plates relative to the vertical plane, bullet traps can also be built with vertical steel plates angled in the horizontal plane relative to the trajectory of the bullet. Such bullet traps will be natural to build as separate bullet trap cassettes for each target since the plates have to be angled in opposite directions. One example of such a solution is shown in the figures below. These were made by Leu + Helfenstein AG in Switzerland.

*Figure 22 Bullet trap cassettes lined with steel plates. Leu + Helfenstein AG (Switzerland)*

*Figure 23 Back of the bullet trap cassettes lined with steel plates. Leu + Helfenstein AG (Switzerland)*

*Figure 24 Interior of a bullet trap cassette lined with steel plates. Leu + Helfenstein AG (Switzerland)*

The bullet traps from Leu + Helfenstein AG have a very simple structure, where the bullets strike angled Hardox plates, shatter and drop down into a drawer in the bottom. Since lead is heavy, the drawers have to be emptied frequently so the weight of the drawer remains manageable. The drawers need to be emptied in a way that ensures there is no spillage of lead residue. In particular, the fine particulate matter can easily be spread around and end up as runoff, since that is what corrodes most quickly.

The simple structure of the bullet trap cassettes means that the rifle clubs can perform maintenance themselves. Maintenance consists mainly of replacing the front plate when it becomes worn, and rotating or replacing the steel plates when they are worn. Both the handling of the lead and maintenance are simple, although the work itself can be heavy-going.

Since the front plate is close to the steel plates, the front plate must be so robust that it will not allow spatter from shattered bullets to get out again. In the middle zone, where most of the bullets strike, the bullet traps have a thick HDPE plate. Here, the same issue will apply as what was described in relation to the front of a lamella bullet trap, where hunting ammunition may be a problem, and any .22 calibre bullets probably won’t go through. Consequently, this solution generally lends itself to ranges where it only is to be shoot with full metal jacket ammunition and the Armed Forces' unleaded ammunition.

<u>Bullet traps with a vertical steel plate</u>

Traditionally, steel bullet traps are built with angled steel plates. With hard grades of steel, it is, however also possible to make bullet traps using steel plates that are perpendicular to the trajectory of the bullets. In Norway, we are aware of two outdoor bullet traps where one shoots into a vertically positioned steel plate. One was built at the Indre Breim Rifle Club's shooting range at Byrkjelo because it was not physically possible to build a traditional bullet trap of soil/sand. The second bullet trap was built at Sessvollmoen and is used by the Armed Forces. Both the bullet traps are relatively new and subject to constant improvements. So far, experience indicates that the bullet traps work well.

The bullet trap in Byrkjelo was made by erecting a 300 mm thick concrete wall immediately behind the targets. The concrete wall is large enough to satisfy the requirements for bullet traps laid down in the safety regulations. Right behind the targets, where almost all the bullets strike, there are 20 mm thick plates of Hardox 500. The system is suspended so that the plates can be replaced if they get too worn or start to bulge, but after one season they show no signs of wear and tear, so it looks like they will have a long useful economic life. In front of the steel plates there are Regupol plates mounted at some centimetres distance. When shots are fired at the bullet trap, the bullets are shattered on the steel plate and fall down into a gutter to the bottom of the bullet trap. Bullet fragments are emptied from this gutter regularly. The Regupol plates show some wear from shooting, especially when hunting ammunition is used. The plates can be dismantled. By switching places, the wear can be distributed across the plates. This allows a great deal more shooting before the plates have to be replaced. The plates are robust enough to keep spatter from getting out of the bullet trap, but .22 calibre bullets may get stuck in the plates.

Steel plates are located only immediately behind the targets. The rest of the bullet trap consists of a concrete wall covered by wood to prevent ricochets or spatter if the concrete wall is hit. If there are many hits in exactly the same spot on the concrete wall, eventually, it will show some wear and tear. Accordingly, on busy ranges, a bullet trap like this should have steel plates also some distance abowe from the targets.

*Figure 25 Bullet trap wall with interior vertical steel plate and a collection gutter for bullet fragments (the targets are covered by a green tarpaulin in the picture)*

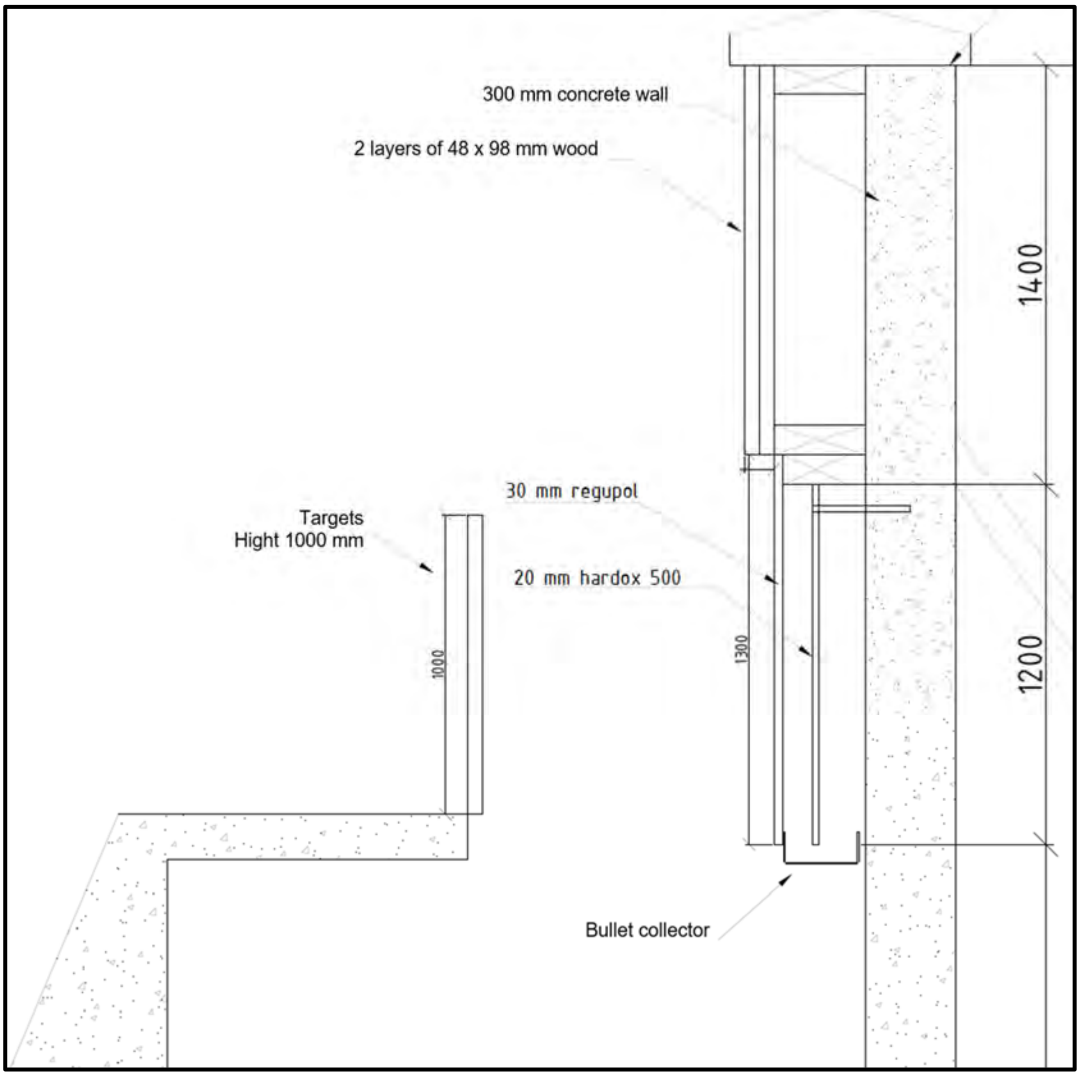



*Figure 26 Schematic diagram of a bullet trap with vertical steel plate. The Indre Breim Rifle Club*

Range 10 at Sessvollmoen features a large bullet trap with a vertical steel plate. The bullet trap has been constructed with 4-metre-high L elements of concrete with a berm behind it, holding the elements in place. Outside the elements, 25 mm thick Hardox 500 plates have been mounted, and 40 mm Regupol plates are mounted in front of the steel plates with an air gap of about 50 mm.

*Figure 27   The bullet trap with a vertical steel plate on Range 10 at Sessvollmoen*

Many different weapons are used on Range 10, but mostly rifles and carbines with steel core 5.56 calibre ammunition. The bullet trap works well with all the types of ammunition being used here. The bullets from 9 mm handguns do not always pass completely through the Regupol plates in the front but are eventually pushed through by subsequent bullets.

*Figure 28 The bullet trap on range 10 at Sessvollmoen, seen from the side*

The Regupol plates are mounted at studs made of composite materials. Experiments using wooden studs showed extensive wear and tear, as the wooden studs splintered from the spatter from shattered bullets. The composite studs are mounted in U-steel elements attached to the Hardox plates.

Bullets that strike right in the composite stanchions or U-shaped steel elements deform these, but they are not torn by spatter. It is important that the targets are placed so that the impact area is between the studs, so that as few bullets as possible hit the studs directly.

*Figure 29 Picture showing the inside of the bullet trap on Range 10 at Sessvollmoen*

Since many different weapons are fired at targets placed in different spots, the bullet trap on Range 10 at Sessvollmoen features a large impact area. The entire area covered by the red Regupol plates is backed by steel plates. The rest of the bullet trap features impregnated wood cladding for spatter and ricochet safety in front of the concrete elements.

The Regupol plates expand when the sun shines on them. An impact zone as big as this one, means that the plates can bulge if they are too close together. Meanwhile, the spaces between them need to be small to prevent spatter and lead dust from bullets from getting out again.

The Hardox plates in the bullet trap at Sessvollmoen have many small crevices. The Armed Forces shoots with steel core ammunition, which leads to more wear and tear than lead ammunition. Notwithstanding, inspection shows that after a very great deal of firing, there is still no sign that wear is a problem. Especially when firing the Armed Forces' ammunition, it will be an advantage not to hit exactly the same place with an exceptional number of rounds.

Even though the shooting range is in daily use, the steel plates are expected to last for many years. After more than a year of daily use, the Regupol plates show no indication that there is any need to replace them. When the first signs of wear are detected in the strike zones, the plates can be moved to a new place, allowing all the plates to be used before they have to be replaced at some point.

<u>Other types of steel bullet traps</u>

Steel plate and sand pit: Indoor handgun ranges, often use bullet traps made of steel plates that are angled relative to the vertical plane, with a sand pit under them. Similar solutions may, in principle, also be used on outdoor rifle ranges, but the solution is hardly cost-effective, at the same time as the danger of shatter and deflection of bullets would be significantly higher than with the other steel bullet traps described here. In addition, the bullets must be separated from the sand before they can be sent to recycling.

Some helical bullet traps do not have deceleration chambers but are instead equipped with several angled steel plates where the bullets shatter before dropping down into a container. The disadvantage is the relatively high cost and no significant advantages relative to the less expensive steel bullet traps.

### 3.3.2 Safety

Steel bullet traps are generally designed so that the bullets that hit them are captured. Some unfortunate structural designs can lead to the blow back of splinters. This refers in particular to bullet traps that bounce the fragments upwards and bullet traps that are relatively open in front. With well-designed helical bullet traps, lamella bullet traps, bullet trap cassettes and bullet traps with vertical steel plates, blowback is not a significant problem. The greatest danger of bullets being blown back against the firing point take place with fine calibre shooting at relatively hard front plates.

Bullet traps that cover only the area immediately behind the target have the disadvantage that bullets that graze the bullet trap can ricochet. That means that an additional enclosure or earthworks must be built right behind the bullet trap to satisfy the requirements in the safety regulations. Examples of lamella bullet traps and bullet traps with vertical steel plates have to be equipped with enclosures that are large enough to meet the requirement for the size of the bullet trap. This eliminates the danger of ricochets almost entirely. If the enclosure is made even larger and combined with extra safety berms or screens on the sides of the shooting range, it is possible to comply with the requirement for a so-called artificial background so the shooting range can be used year-round even though the range lacks a natural background.

Appropriately sized steel bullet traps are generally very safe solutions. The challenge lies in finding solutions that are conducive to safe firing with all relevant calibres without causing either dangerous blow back of fine calibre bullets, or shatter and blow back of larger calibre or steel core ammunition. In this context, it is necessary to perform detailed testing.

### 3.3.3 Maintenance requirements

Generally speaking, correctly dimensioned steel bullet traps are very durable. The amount of wear and tear on the steel plates depends on the type of steel, thickness, angle, type of ammunition used, etc. Precision shooting involves many bullets striking an extremely limited area. This may place too great a strain on the bullet trap locally. It is expedient to design bullet traps that make it possible to replace only the part of the steel that is most worn. Alternatively, rotation of the steel plates in the bullet trap may also work well.
It is common to use grades of steel comparable to Hardox 450 or harder in steel bullet traps. Softer steel can wear out very quickly. Even though Hardox is hard steel, over time, such steel will also show signs of wear. The wear is greatest from unleaded ammunition, somewhat less

with ordinary sharpshooter ammunition, even less with lead-tipped hunting ammunition and least of all from .22 calibre ammunition. Armour piercing ammunition should not be used with steel bullet traps, as it may cause significant damage that can be costly to repair.

All steel bullet traps need some form of protective cover in the front. Most of them need this to prevent shatter and blow back, but it is also necessary to prevent rain, leaves and other debris from getting into the bullet trap. All materials that lend themselves to cover the front will be subject to wear and must be maintained. Wear varies with different types of ammunition and, for that reason as well, the pros and cons of different materials on the front of bullet traps should be studied in greater detail.

Helical bullet traps are sophisticated and also have several moving parts, as well as lubricants. To work properly, such a bullet trap has to be carefully maintained. Consequently, it is assumed that such bullet traps are not especially appropriate on shooting ranges operated by volunteer organisations that have no special expertise.

Lamella bullet traps works exceptionally well on ranges with relatively small calibres firearms and wide dissemination of the rounds. It must be expected that precision shooting with rifles can cause more wear on such bullet traps. Rotating the lamellas is therefore relevant maintenance on such bullet traps. The work is not complicated, but it is difficult because the steel plates are heavy. Beyond this, the cover on the front of the bullet trap must be maintained on a regular basis. Lamella bullet traps with conveying screws in the bottom can feed all the metal fragments from the bullets directly into containers that can be transported by motor vehicle. With the right equipment, this is highly effective. Without a conveying screw, the solution will require more manual labour, which can be heavy-going.

Bullet trap cassettes are very simple structures. That translates into simple maintenance. Maintenance calls for plate rotation and maintenance of the front cover. This work is also straightforward, but heavy due to the weight of the steel plates. Bullet fragments must be purged relatively often because they can be heavy to lift otherwise. This is manual labour.

So far, the need for maintenance on the bullet traps with vertical steel plates has proven to be relatively modest. It must be expected that the metal in the wear and tear zone behind the targets will have to be replaced eventually. Accordingly, the bullet trap at Byrkjelo is designed so that the plates can be lowered down and replaced by new ones. After one season, there are still no signs of crevices in the steel, which may indicate that the steel will not require replacement for many years. The thickness of the steel may be of importance here, but it will take more research to determine the optimal thickness.
The two bullet traps with vertical steel plates have a gutter that collects bullet fragments. The work is the same as with the bullet trap cassettes. Bullet traps with vertical steel plates are conducive to being fitted with a conveying screw to feed bullet fragments directly into a container.

### 3.3.4 Environmental factors

The great advantage of steel bullet traps is that the bullet fragments do not mix with other materials in the bullet trap. Granted, to certain extent debris from the plates or the front cover of the bullet trap will be dragged along, but the amount is small. This means that the bullet fragments can be sent to recycling fairly easily.

Bullet traps with enclosures will capture almost 100% of the bullets. When bullets shatter, they produce fragments of different sizes. The smallest fragments are a fine particulate matter.

This dust has an exceptionally large surface area relative to the volume of the metal, meaning it will corrode quickly if exposed to moisture. If water gets in, the pollution could be washed out into the environment. This means that even just a few percent (by weight) of the bullets in the form of fine particulate matter can have a significantly larger environmental impact than if whole bullets are left intact, buy lying outside in nature. Thus, the helical bullet traps are the most favourable in the sense that the bullets are preserved almost intact. In the other steel bullet traps, we have examined, the bullets are shattered, so it is important that these bullet traps are sufficiently closed to keep the dust inside the bullet trap. It is therefore important to have a front plate that is as impenetrable as possible. In addition, a fan with a filter that exerts negative pressure on the bullet trap may be a solution that warrants further consideration.

Emptying bullet fragments from metal bullet traps always entails a certain risk of spillage and the spread of heavy metals. The risk is modest in bullet traps with conveying screws to convey the bullet fragments directly to a container that can be covered with a lid and lifted right onto a vehicle and driven away to recycling. The greatest risk of spillage and the spread of heavy metals will be with bullet traps that have to be emptied manually outdoors. In this context, it is important to establish particularly good routines. It is also important for those who perform the purging process to wear appropriate personal protective equipment (PPEs).

Noise from steel bullet traps will sometimes be an environmental issue. Bullets make noise when they strike the metal plates, a well-known phenomenon when firing at steel targets. Generally speaking, noise from steel bullet traps will be significantly lower than the firing noise itself, so the issue probably has somewhat limited relevance. Shooting noise reflected in bullet traps, back to the area behind a well attenuated firing point, will probably be the greatest problem in many places. Such reflected noise can be a problem, especially with bullet traps that have a large vertical enclosure around them.

### 3.3.5 Costs

Generally speaking, steel bullet traps are relatively expensive. This is both because high-quality steel is costly and because bullet traps can only partially be built using volunteer labour. The costs of setting up a steel bullet trap can vary considerably, and the estimated expenses below must be considered only as rough estimates.

Helical bullet traps for 10 + 10 targets with the requisite collateral structure for outdoor use in Norway's climatic conditions, are estimated to cost roughly MNOK 7, incl. VAT. Maintenance must be performed by qualified personnel, but maintenance costs are nonetheless assumed to be moderate, considering that one gets paid for the metal delivered to recycling.

Lamella bullet traps for 10 + 10 targets, equipped with a conveying screw and the necessary collateral structure are estimated to cost roughly MNOK 4-5, incl. VAT. To a large extent, maintenance can be performed without any need for specialist expertise. Thus, costs will mainly be related to the cover material and, in the longer term, to the replacement of worn steel plates. Maintenance is not expected to cost significantly more than the money earned from delivering bullet fragments to recycling.

For a range with 10+10 targets, bullet trap cassettes lined with steel plates could cost roughly MNOK 1, incl. VAT. In addition, there will be the costs associated with enclosures and ricochet safety or concrete walls if the bullet trap cassettes are to be immediately in front of earthworks to satisfy the safety standards. Total costs can be expected to add up to MNOK 1.2-1.8, incl. VAT.

Bullet traps with a vertical steel plate for 10+10 targets carry a cost of roughly MNOK 2, incl. VAT. Where L elements of concrete have been used, the way the Norwegian Defence Estates Agency has done, it is possible to save a great deal of money. The solution is also so simple that some of the work can be done by volunteers, which may cut costs significantly. Maintenance costs are relatively small as most maintenance can be done through joint volunteer efforts.

In terms of both lamella bullet traps and bullet traps with vertical steel plates, a conveying screw in the bottom of the bullet trap can lighten the workload a great deal by handling the residual bullet fragments. A conveying screw may add a couple of hundred thousand NOK to the cost of two bullet traps.

# 4 Comparison and assessment of bullet trap solutions

## 4.1 In general

Information retrieval shows that there are an exceptional number of solutions for bullet traps, including both commercially available and do-it-yourself variants. Discussions of all conceivable varieties are beyond the scope of this report. For instance, bullet traps made of shock-absorbing concrete (SACON), bullet traps of thick granulated rubber blocks, bullet traps of hanging chains, and bullet traps of wooden stumps with the end section towards the shooter have been omitted. These are all bullet traps that can work from the perspective of safety, but they are considered impractical due to price, environmental impact, maintenance, etc.

An assessment of which bullet trap is the best solution for individual needs will vary greatly from one situation to the next. Elements that play a part in this context are, e.g., the number of rounds fired annually, the type of shooting activities, the types of weapons and ammunition used, site-specific susceptibility to pollution, safety conditions, types of user groups, mode of operation, climatic conditions, ground conditions and, not least, finances. Perhaps precisely because of all these parameters that can lead to vastly different conclusions in different situations, the literature available on different types of bullet traps is fairly limited. The most relevant literature will be reports from the Norwegian Defence Estates Agency and the Norwegian Defence Research Establishment. Not surprisingly, manufacturers want to advocate for their own proprietary solutions, and rifle clubs have limited resources to spend on comparisons and documentation. One formidable challenge is that different shooting activities call for different solutions, and it is difficult to set expedient limits for this work. It is challenging to strike a balance between delving into sufficient detail and casting a sufficiently broad net.

The purpose of learning more about bullet traps is to get an overview of potential solutions. This will furnish a good foundation for assessing potentially favourable bullet trap solutions that focus on the environmental perspective. This project is being carried out under the auspices of DFS, and the assessments are based on some of the distinctive features of the organisation and the rifle clubs. In this context, the following factors deserve special mention:

- Activities are based on volunteer efforts
- Rifle clubs often have members with expertise in building and construction
- Strong focus on safety throughout the organisation
- Limited revenues mean limited possibilities for major investments or high maintenance costs

A comparison of different types of bullet traps takes its point of departure in the following assessment points: safety, the need for maintenance, environmental factors and costs. Even though the environment is a key part of this project, the assessments must be made against the background of the distinctive features of our organisation and the rifle clubs. For instance, there would not be much point in focussing on solutions that are environment-friendly, if there is no money for investment or operations. This means the costliest solutions have to be rejected even though they may be the most environment friendly. For the same reason, complex solutions that call for professionals to perform maintenance will not be relevant for the rifle clubs affiliated with DFS.

This report systematises the bullet traps, according to which energy-absorbing material they use. Especially when it comes to granular/synthetic bullet traps and steel bullet traps, we see that there are certain variations which, for a variety of reasons, are not appropriate for DFS ranges. To narrow the number of bullet traps to be considered against each other, we will therefore start by excluding some variants. The remaining solutions will then be considered and compared with a view to safety, maintenance, the environment, and costs. Against the backdrop of these assessments, we will identify a selection of solutions considered most relevant for use on DFS ranges. Finally, we will examine the opportunities for improving existing bullet traps and for developing/adapting new types of bullet traps for DFS ranges.

## *4.2 Excluding variants of bullet traps*

Some bullet trap solutions have distinctive features that limit their relevance for use on the outdoor rifle ranges affiliated with DFS. Going forward, we will therefore exclude these from further discussion, with a brief explanation for each of them. Exclusion can be based on any of the four assessment criteria: safety, maintenance, the environment and costs.

<u>Soil/sand bullet traps</u>
Soil/sand bullet traps are currently used on almost all the ranges affiliated with DFS. Other types of bullet traps are only used in exceptional cases. Chapter 3.1 shows examples of such bullet traps. In most cases, such bullet traps work well with a view to safety as long as they are well maintained. However, some factors have been identified and should be avoided:

- Bark and sawdust are not especially well-suited for bullet traps, since bark and sawdust can rot, and because they can potentially be a fire hazard during very dry summers.

- Tyres to reinforce the soil may, under certain circumstances, entail a danger of ricochets and should generally be avoided.

- Bog soil does should not be used in bullet traps because it is often acidic and contains a lot of humus. This can cause lead contamination to leach out to a substantially higher degree than from bullet traps with pH-neutral soil containing a modest degree of humus.

- Building boxes to keep the soil in place in bullet traps, in locations with challenging terrain or difficult ground conditions, is not an ideal solution. The solution limits how much soil/sand it is possible to have in the bullet trap, and wear and tear will eventually lead to violations of the Safety Provisions.

<u>Granular/synthetic bullet trap</u>
Some granular/synthetic bullet traps are considered less relevant for rifle clubs affiliated with DFS:

- The Stapp bullet trap is of high quality and must be considered to be environment friendly. The distinct disadvantage of this bullet trap is the cost, which may be more than what a rifle club is able to handle. The Stapp bullet trap is considered more feasible for use on facilities for military users or for commercial actors that have the finances to manage the relatively high costs of installing and maintenance.

- Bullet traps based on vertical lamellas of synthetic material, conveyor belts and the like, are excluded owing to the need for extensive maintenance. In rifle shooting, most of the bullets hit in a concentrated area, meaning this type of bullet trap is not well-suited.

- Cylindrical bullet traps may be well-suited for indoor shooting ranges. As far as it goes, such a solution may also work outdoors, but it requires some sort of roof over it and back wall, so less expensive solutions may be more feasible.

Steel bullet traps
There is one type of steel bullet trap in particular that is considered out of the question on the ranges of rifle clubs affiliated with DFS:

- Helical bullet traps are well-suited indoors on ranges with a lot of shooting activity, especially on commercial facilities. However, the cost is far too high for rifle clubs. Moreover, the solution is not well-suited for outdoor use in the Norwegian climate.

## *4.3 The assessment of solutions*

The following assessment will examine safety, maintenance, the environment and costs related to the solutions that have been described earlier and not excluded above.

### 4.3.1 Safety

The Safety Provisions from 1988 describe bullet traps made of natural masses like soil, turf, sand and bark. However, these are merely examples of the materials used, and other bullet trap configurations must also be acceptable as long they satisfy the intentions underlying the requirements. The requirements include the following aspects:

- Dimensions in height and width as seen from the firing point
- The slope of the bullet trap relative to the trajectory of the bullet
- Safety against shooting through
- Protection against ricochets, spatter and blow back

In addition to a bullet trap, a natural background is required to limit the size of the danger zone. The hight of the background terrain shall normally extend 4 degrees above the so-called base line. Under certain circumstances, a natural background of 3 or 2 degrees can be accepted, but then shooting is not allowed at frozen bullet traps (including all types of bullet traps that can cause ricochets from hits in the area which, according to the Safety Provisions, is to be ricochet-free).

In locations where there is not high enough natural background, a backstop berm can be made. An artificial backstop can be built with an extra high and wide bullet trap and extra safety berms or screens on each side of the range. Shooting at an artificial backstop is only allowed when the bullet trap is frost-free.

**Traditional bullet traps of soil/sand** are tried and true when it comes to safety. A well-maintained bullet trap works well for firing with leaded ammunition. Frost in the bullet trap represents only a moderate danger of ricochets if the bullet trap is well maintained. This is because ricochets from leaded ammunition rarely have an angle of more than 22°; if the angle is greater, the ricochet will have minimal residual energy. With an angle of 30°, all ricochets are caught while they still have a great deal of residual kinetic energy. The situation is different with the Armed Forces' steel core ammunition since this ammunition can ricochet at an angle of more than 30° and still retain high kinetic energy. Accordingly, a frozen soil/sand bullet trap can cause both ricochets and blow back of bullets towards the firing point when shooting with the Armed Forces' steel core ammunition. A cover over a soil/sand bullet trap can protect it from water infiltration and possibly keep frost out of the bullet trap. However, moisture can come up from the ground and fail to evaporate as a result of the cover. This may in turn lead to frost in the bullet trap. Accordingly, a cover over the bullet trap is not an automatic solution for avoiding frost in the bullet trap. DFS's firing activities mainly take place during the part of the season when there is no frost in the ground, and a potential limit on firing activities due to frost is primarily a problem on ranges that are rented out to the Armed Forces at ranges with less than 4 degrees natural background hight.

**Sloped granular bullet traps with covers over them** work in the same way as soil/sand bullet traps, but with a different energy-absorbing material. Although the danger of ricochets is relatively low, these bullet traps also require regular maintenance. One challenge with the cover on these bullet traps is that it is not possible to see the condition of the bullet trap under the cover. In some cases, after long-time use, bullets can aggregate into lumps representing a risk of ricochets. With regular maintenance, this is not a major problem. Generally, safety is considered well in hand with bullet traps like this. The Armed Forces have found that when firing in the winter, such bullet traps must be cleared of snow to prevent bullets from rolling, ricocheting or being blown back. Congestion of bullets in the bullet trap can also cause a risk of ricochets and blow back. A concrete back wall and roof will virtually eliminate these issues.

**Bullet traps that use tyre chips** as an energy-absorbing material are porous at the same time as they can be built with a steep slope. Such bullet traps are safe to use with all types of ammunition all year round.

**Steel boxes with granulated rubber** placed immediately behind the targets have a vertical front, and bullets that strike this front will not be able to ricochet. If a bullet strikes the edge of the box, there may be a ricochet. To satisfy the requirements for bullet traps, the box must then be enclosed by a bulletproof and anti-ricochet wall or possibly be recessed into the earthworks. Certain materials in the front plate can cause blow back, especially of bullets with low kinetic energy. A softer front plate may have problems keeping the granulate in place, so more detailed examinations need to be made if such a solution is to be chosen.

**Lamella bullet traps of steel** will often not be large enough to cover the entire requirement for a bullet trap in height and width. A lamella bullet trap must therefore be supplemented by an enclosure that is bulletproof and ricochet-free. If there are hits on the edge of the lamellas, it must be expected that the bullets will shatter and there may be some spatter. To prevent this spatter from getting out, there has to be a cover in front of the bullet trap. The cover must be at a certain distance from the lamellas, and it must be robust enough so that the shatter does not get out of the bullet trap. At the same time, the cover must not be so strong that it prevents shooting through with a .22 calibre. The example of a lamella bullet trap shown earlier in this report is enclosed by a building. This is conducive to ensuring safety and protecting the conveying screw mechanism.

**Bullet trap cassettes with steel plates inside** are similar to cassettes with granulated rubber, except the bullets are shattered and end up in a drawer. Such cassettes shall also be framed or recessed into earthworks to avoid ricochets and satisfy the requirements for bullet traps.

**Bullet traps with vertical steel plates** are equipped with shatter-proof, anti-ricochet material in the front. In the impact area, the material used must both allow the bullets to penetrate and prevent spatter from getting out again. In the two examples shown, Regupol plates are used as front plates. The bullet trap works well with hunting ammunition, sharpshooter ammunition and the Armed Forces' unleaded ammunition. It is not known if Regupol is suitable as front plate material when shooting with .22 calibre ammunition. This should be tested. Outside the impact area, impregnated wood may be used for ricochet protection. A durable steel plate is only required in the impact area. The rest of the bullet trap can be made of concrete, but the details must be considered on a case-by-case basis up against the wear on the concrete that comes from bullets missing the target. The simple design means that it is not particularly difficult or cost-driving to satisfy the requirements for height, width, bulletproof safety and ricochets. Thus, this solution may also be appropriate for use together with extra safety berms or screens in places where an artificial background (a high manmade backstop berm) is required.

**A cover or front plate** is needed for many bullet traps. One central point that applies to all bullet traps with covers or front plate is how they work with different types of ammunition. The bullets must penetrate so that they cannot be deflected, but spatter and dust must not be allowed out.
Sloped bullet traps with covers require covers that are UV-resistant and get the fewest possible holes from firing. Big holes in the cover could allow a great deal of water to seep in, meaning the cover would not work entirely as intended. Steel bullet traps and cassettes containing granulate require a front plate. It can be challenging to find materials that work well over time with all types of ammunition. The following issues must be addressed:

- Many types of hunting ammunition have lead points, which tear huge holes in some types of front plate materials
- .22 calibre rifles will have trouble getting through thick front plates. Covers are not usually a problem, but other materials can cause blow back or cause bullets to get stuck in the plate. If .22 calibre bullets are left stuck in the front plate, this can lead to spatter and end up on the outside of the bullet trap.
- Ordinary sharpshooter ammunition made of lead with a full metal jacket easily pierces relevant types of front plates and will also shatter without too much wear on the steel plates in steel bullet traps.
- Steel core ammunition can easily pierce all types of front plates but may cause more wear on the steel plates due to the considerable hardness of the steel core. Bullets that are impacted and rolls before hitting the front plate may have problems piercing the front plates, and they may make big holes. The problem is small when vertical front plates are used.

The challenge is to find a material that can be pierced by all bullets, is durable, and does not give off lead dust and splinters.

**Firing with tracer ammunition** should not ordinarily be done on DFS ranges, but if someone were to use such ammunition, it would be particularly problematic if the energy-absorbing material is flammable.

### 4.3.2 Maintenance

**Soil/sand bullet traps** are generally easy to maintain. Regular maintenance will involve topping off the soil, sand, fine gravel etc. in the crevices that form where the most bullets strike the bullet trap. This should preferably be done at least once a year to maintain a bullet trap's full functionality. While the work is not complicated, it can be heavy if it has to be done manually. Along with the occasional lack of understanding of the importance of maintenance, the heaviness of the work may be one reason maintenance is neglected. The consequences of a lack of maintenance generally involve a higher danger of ricochets. On ranges rented to the Armed Forces, this is more critical than on ranges where only leaded ammunition is used.

Maintenance in the form of mass replacement is reasonably priced. Costs rise if an excavator has to be rented, but normally it just takes a few hours of work with an excavator if maintenance is limited to filling crevices in the bullet trap.
Bullet traps that are poorly built or built on a weak foundation can settle and thereby lose height. In such cases, maintenance can be more comprehensive, but also in such cases, several hours with an excavator and some loads of fine gravel are often enough to restore a bullet trap's function.

In the USA, the authorities recommend reclamation of bullets from the soil in what they call a 'backstop berm'. A backstop berm consists of soil or sand moved into a berm by bulldozer or similar equipment. This earthworks behind the targets have the same safety function as a more sophisticated bullet trap. In the USA there are many companies that perform such reclamation. The theory is that regularly removing lead from the soil will prevent pollution, but it has not been possible to find documentation that this is an environmentally better solution than letting the bullets remain in clearly defined bullet traps and replacing the mass on the bullet traps with anti-ricochet mass.

**Sloped granular bullet traps** that are well designed work so that the bullets can sink down through the granulate. That means it takes a lot of shooting before the accumulation of bullets is excessive. Steel core ammunition is lighter than leaded ammunition, so it accumulates more readily in the impact area instead of migrating down through the granulate. Consequently, the granular bullet traps used by the Armed Forces may call for more maintenance. Regular maintenance involves ensuring that there are no crevices in the granulate and no bullets building up in the impact area. In addition, the cover over the bullet trap has to be inspected and, if need be, repaired to prevent excessive infiltration by water. At certain intervals, bullets must be purged from granular bullet traps. The frequency depends a great deal on how much the range is used, what kind of ammunition is used, how deep the layer of granulate is and the type of granulate selected. Purging bullets does not lend itself to collective voluntary efforts but is a job that ought to be left to professionals who know how to handle heavy metals safely. Special equipment may also be needed to separate the metal from the granulate adequately for the metal to be eligible for paid recycling instead of being left with a mixture of granulate and metals destined only for delivery to a landfill.
With a bullet proof back wall and roof over a sloped granular bullet trap of considerable depth, there can be a great deal of shooting before there is a need to purge the bullets. Nor will it be equally crucial to make frequent repairs of the cover on top when there is a roof over

the bullet trap. Thus, such a bullet trap has a limited need for maintenance, but the structure itself must be maintained like all other structures.

**Bullet traps made of tyre chips** must be refilled when crevices occur. The steel cord will also eventually rust, reducing the stability of the bullet trap. The ongoing maintenance of a bullet trap with tyre chips is modest, but at certain intervals, one must expect to have to fully remove the tyre chips that show signs of wear and tear, along with bullets and rubber dust. Intact tyre chips can be refilled along with new tyre chips, while the residual mass has to be sent to a landfill. Professionals can purge the bullets. It is assumed that full refurbishment of a bullet trap made of tyre chips must typically be carried out at intervals of 5-7 years.

**Granulated rubber in a box with a vertical front** will fill with bullets as time passes. This lead increases the pressure on the container. After some thousands of rounds, the bullets therefore need to be recovered by being purged from the granulated rubber and delivered to recycling. In addition, the front plate will need to be replaced. Professionals should purge the bullets.

**Lamella bullet traps of steel** are generally durable with a simple, robust design. It may be necessary to rotate the lamellas since the wear and tear is clearly greatest immediately behind the targets. This is not complicated, but the lamellas are heavy. Also, the front cover of the bullet trap must be replaced at certain intervals. The solution is often to use covers on a roll that can be rolled out to rotate them so the wear can be distributed across the cover. This means the cover will have a substantially longer useful economic life. With a conveying screw in the bottom of the bullet trap, the bullet fragments will be fed directly into a container that can be loaded onto a vehicle and driven to recycling. Lamella bullet traps should have an enclosure around the bullet trap, and it must be maintained like all other structures.

**Bullet trap cassettes with steel plates** that shatter the bullets are simple structures. Maintenance consists of rotating and, if need be, replacing the steel plates. It is not complicated to empty them, but they should be emptied regularly so that the bullet fragments do not get too heavy to handle. Maintaining and emptying the bullet trap cassettes can be done with voluntary efforts as long as the appropriate protective gear is used to protect the personnel from contact with lead and the inhalation of lead dust. The front plates must also be replaced when they are worn, so that lead dust does not escape the bullet trap during shooting activities.

**Bullet traps with vertical steel plates** shatter the bullets, which subsequently land in a drawer or a gutter with a conveying screw to take them to a container. It is not complicated to handle bullet fragments, but if this is done through joint volunteer efforts, personal protective gear is required. The bullet fragments contain little foreign matter and can be delivered to recycling. The front plates must be replaced when they are worn. By making a system for rotating the plates, many years will pass before the plates have to be replaced. Wear on the plates varies a great deal depending on the type of ammunition used, and leaded hunting ammunition leads to the most wear. Using impregnated wood for the enclosure, this should last for about 10 years before it has to be replaced. The steel plates appear to stand up to use well, but we lack the experience needed to determine how long it will be possible to shoot before the plates have to be replaced.

The common denominator for all metal bullet traps is that the use of armour-piercing ammunition can do a great deal of damage. Such use must therefore be strictly forbidden.

### 4.3.3 The environment

The environmental footprint of a shooting range depends on a number of factors. While the bullet trap is important, it is far from the only factor. The number of bullets captured by a bullet trap is a major factor, but perhaps equally important is what happens with the bullets that are not captured and the extent to which metal pollution can leach out of the bullet trap.

Measurements of pollution on older ranges with bullet traps made of soil and sand often cannot distinguish where the runoff comes from. One example that illustrates why pollution originating from a bullet trap on a shooting range can be incidental is shown in the figure below, excerpted from a technical environmental survey of a shooting range (Weholt, 2018).

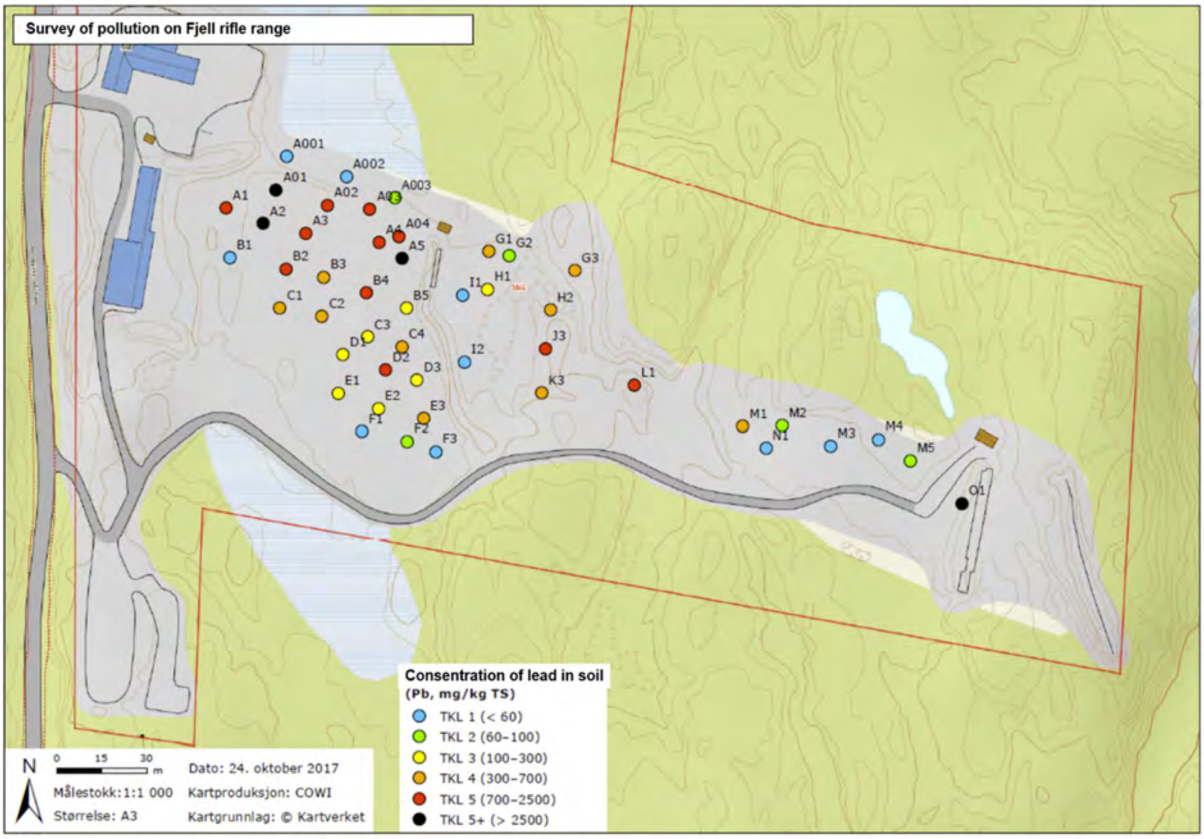



*Figure 30 Survey of pollution on a rifle range (Weholt, 2018)*

The measurements of lead concentration show high readings around the range area. This means that the runoff from the bullet trap alone may account for a limited part of the total runoff. Measures to improve the bullet traps on this range will not in themselves have any appreciable impact on the possible the spread of environmental pollution.

Among other things, this shooting range has been hired out to the police who have shot handguns, using the bog right in front of the firing point as a 'bullet trap'. In addition, there has been field shooting at steel targets at several different locations on the range. Steel targets shatter the bullets into small fragments and lead dust, thus spreading pollution on the ground surface. These small metal particles have a large overall surface area, so they corrode far more rapidly than the more intact bullets caught in soil/sand bullet traps.

The ground pollution on shooting ranges may also be influenced by pollution from bullet casings, gunpowder, and percussion caps. Pollution originating from activity during the second World War has previously been found on several shooting ranges. It is hard to tell how a shooting range was used such a long time ago. In some cases, shooting ranges have been rebuilt and considerable construction work may have dispersed polluted masses from old bullet traps across large areas.

Based on the issue discussed above, three questions emerge as absolutely decisive when it comes to the environment and bullet traps:

1. What percentage of the bullets is captured by the bullet trap?
2. What happens to the bullets not captured, and where do they end up?
3. What happens with the bullets that are captured?

**Soil/sand bullet traps** will, if they are of the correct dimensions, capture almost all the bullets, even misses. Misses that go under the target will hit the target mound, which should have a similar ability to catch bullets as the bullet trap. If a bullet trap is poorly maintained, the probability of ricochets and the accumulation and shattering of bullets increases. Readings taken by NIVA (Rognerud, 2009) showed that leaching from three DFS ranges amounting to less than 1% of the lead added annually. These ranges had bullet traps that are considered representative of ranges featuring ordinary good maintenance of the bullet traps.
When new mass is filled into the crevices in the bullet trap on a regular basis, the bullets are slowed down and lose most of their energy before eventually striking bullets that are already in the bullet trap. The bullets can be severely deformed, but not shattered into fine particulate material. Of course, the less shattered the bullets are, the less surface is exposed and can corrode. A large part of what does corrode will bond with the soil in the bullet trap.

In Denmark, a survey was carried out in 1997 on the lead concentration in the soil below an acidic bullet trap that had been in use for shooting with .22 calibre ammunition for 30 years (Astrup, Boddum, & Christensen, 1998). It was found that the lead concentration dropped to the reference level already 1.2 metres under the bullet strike zone. Similar results have also been reported in other places. This indicates that the transport of lead through soil takes place only to a very modest degree, and that leaching is therefore primarily ascribable to the infiltration of water near the surface of the bullet trap. This also affirms that regular maintenance of soil/sand bullet traps, and any measures that prevent water from getting into bullet traps, may help keep the leaching of lead at a low level.

**Sloped granular bullet traps** can be a good environment-friendly choice. If it is big enough, a bullet trap can capture almost all the bullets. The caveat here is that the bullet trap has to be well maintained. Many holes in the cover over the bullet trap may cause lead to be washed out. Any accumulation of bullets can lead to shattering and the exposure of a larger surface area. A closed bottom and a drain are measures that may to some extent compensate for a lack of maintenance because they can help manage any runoff. If the bullet trap is placed in a closed structure with a roof over it, the infiltration of water can be eliminated entirely, minimising the risk of leaching. The challenge with granular bullet traps is that they have to be emptied by professionals with appropriate equipment to ensure that not the lead does not leach into the environment when the bullet traps are emptied.

**Bullet traps made of tyre chips** will generally prevent the bullets from shattering, so they will corrode more slowly. If it is big enough, a bullet trap can capture almost all the bullets. Since tyre chips are highly porous, they will not impede the infiltration of water from precipitation. The bullet trap can give off metal pollution from the bullets and PAH, phthalates and microplastics from the tyre chips. Water that infiltrates the bullet trap should therefore be guided to a sedimentation basin or a drain to prevent runoff to recipient areas from reaching harmful levels. Bullet traps made of tyre chips will be subject to wear and the steel cord in the tyres will rust. For that reason, at some point in time, tyre chips have to be removed and purged before being put back into place. Such cleaning should be carried out by professionals with qualifications that guarantee that both fine particulate material from the tyre chips and the bullets are removed in a satisfactory manner and delivered to recycling.

**Granulated rubber in boxes with a vertical front** will capture the bullets that strike the box, but it will not capture the bullets that miss the target. Therefore, for safety-related reasons, a bullet trap needs an enclosure or the like that captures bullets and prevents ricochets. Due to the pressure from the granulate in the box, a relatively rigid front plate may be needed, preferably a 5-7 cm thick HDPE plate. It is uncertain whether a plate that is strong enough to retain the granulate will allow pure lead bullets to pierce it, especially .22 calibre bullets that have little kinetic energy. One prerequisite for using such boxes of granulate is that there has to be a solution that works with all relevant types of ammunition. Like other granular bullet traps, these must be emptied and cleaned by professionals to ensure that no lead gets out into the environment in connection with emptying the bullet traps.

**Lamella bullet traps of steel** must be enclosed to ensure that precipitation does not get into the structure. With an appropriate enclosure and preferably equipped with a conveying screw in the bottom of the bullet trap, bullet fragments can be fed into a container automatically. The container can be loaded right onto a vehicle for transportation to recycling. An extractor fan with a filter can ensure negative pressure in the bullet trap and thereby prevent lead dust from getting out into the environment. With a well-designed enclosure, a bullet trap like this one is considered virtually non-polluting.

**Bullet trap cassettes with steel plates** that cause bullets to shatter are usually dimensioned in proportion to the size of the target, and they will capture all the bullets except the misses. Therefore, for safety-related reasons, a bullet trap needs an enclosure or the like that captures bullets and prevents ricochets. If a front plate is used that allows all types of bullets to pierce it and prevents spatter and dust from getting out, the percentage of bullets captured will be high. The work to empty the bullet trap is manual labour, and routines have to be devised to ensure that this process can be carried out to ensure that lead contamination does not get into the environment during the purging process.

**Bullet traps with vertical steel plates** shatter the bullets, then the fragments end up in a drawer or a gutter with a conveying screw to take them to a container. Bullet traps can be designed to ensure compliance with the requirement for a bullet trap's size, ensuring that almost all the bullets are captured. If no conveying screw is installed, the work of emptying the bullet trap must be done manually. Then procedures have to be devised to ensure that this can be carried out to ensure that lead contamination does not get into the environment during the emptying process. With a conveying screw, the container with bullet fragments can be loaded right onto a vehicle for transportation to recycling. If an extractor fan with a filter is used, making negative pressure in the bullet trap, the spread of lead into the environment is almost eliminated.

### 4.3.4 Costs

**Soil/sand bullet traps** can often be very reasonable solutions, especially if the terrain is easy and there is good access to soil that is free of rocks. In such cases, the costs of building a bullet trap primarily consist of the hours of earthmoving equipment rental. If the ricochet-free mass has to be purchased and transported to the shooting range, costs may be substantially higher. Complex terrain behind the targets may also be a strong determinant of cost.
The highest costs related to soil/sand bullet traps will be incurred the day the bullet trap has to be removed. Currently, this is done only when a shooting range is being closed down and the area is designated to be used for other purposes. The cost of remediating a typical DFS range with 10+10 targets is typically MNOK 2-4, but there are major differences in this context. The remediation of the bullet trap *per se* is often just a small part of the overall costs. Costs related to the remediation of pollution spread to large areas as a result of firing at steel targets, previous excavation work in polluted mass etc. may be substantial.

**Sloped granular bullet traps** with covers over them are not necessarily so expensive, but to ensure that they are clearly superior to bullet traps of soil/sand in terms of the environment, they may require upgrades that increase the cost of the bullet trap significantly. Bottom sealing, drainage, sedimentation basins and filters can be expensive. The operation and cleaning of a bullet trap can also be costly. If one invests in a built-in bullet trap with a bulletproof roof, operating costs can be reduced substantially, but the investment costs will be higher than most rifle clubs can afford.

**Tyre chips** are reasonably priced. The cost of building bullet traps of tyre chips is therefore largely related to transportation and bottom sealing, drainage, sedimentation basin and filters, if any. Operating costs are low, and maintenance is simple until the wear and tear is substantial enough to call for remediation and the rebuilding of the bullet trap. This work must be done by professionals.

**Granulated rubber in boxes with vertical fronts** have an investment cost that might conceivably be justifiable. However, they need some type of enclosure to prevent ricochets and capture bullets that miss the target. Total costs depend on which solution is found to satisfy the safety requirements. For rifle clubs, operating expenses can be the biggest problem. The boxes have to be emptied relatively often because of the build-up of pressure since the content increases with every bullet fired. Cleaning the granulate is difficult to do on a voluntary basis without sophisticated equipment, and it is expensive to hire professionals.

**Lamella bullet traps of steel** are expensive to buy because they contain a lot of steel and must have a sturdy structure around the bullet trap. Even though the operating expenses are not particularly high, the initial investment is so high that a rifle club could probably not justify it.

**Bullet trap cassettes with steel plates** that shatter the bullets have a cost *per se* that might be possible for a rifle club to justify. However, they need some type of enclosure to prevent ricochets and capture the bullets that miss the target. Total costs depend on which solution is found to satisfy the safety requirements. The bullet trap cassettes can be emptied through joint volunteer efforts, provided appropriate equipment is available and there are good routines to ensure that lead contamination does not get into the environment.

**Bullet traps with vertical steel plates** call for a substantial investment cost. However, at locations where the terrain is complex, a bullet trap like this one might be the most reasonably priced solution since the bullet trap can comply with the safety requirements without additional measures. If it is possible to find used concrete elements that lend themselves to the purpose, the investment cost can be reduced substantially. Maintenance costs are moderate as long as maintenance and emptying of the bullet trap can be done through joint volunteer efforts. The bullet trap cassettes can be emptied through joint volunteer efforts provided appropriate equipment is available and there are good routines to ensure that lead contamination does not get into the environment. A conveying screw in the bottom of the bullet trap adds to costs but simplifies emptying and can offer extra protection against lead contamination in the environment.

## 4.3.5 Overall assessment

An overall assessment of the bullet trap solutions takes its point of departure in the previously mentioned distinctive features of rifle clubs affiliated with DFS. Difficulties justifying high costs and people's willingness to work on a voluntary basis will impact the assessments, which are based on bullet traps for 100 m and 200/300 m rifle ranges. Other actors may arrive at entirely different overall assessments.

### 4.3.5.1 Existing shooting ranges

For the most part, existing shooting ranges feature bullet traps of soil/sand. Usually, this type of bullet traps is exceptionally good in terms of safety, the need for maintenance and costs. There are more environment-friendly solutions, but the solutions that leave a smaller environmental footprint are all expensive to build, and/or operating/maintenance costs are substantially higher than what an ordinary rifle club can manage. In the vast majority of cases, it is therefore considered more feasible to examine possible improvements to existing soil/sand bullet traps than to demolish existing bullet traps and make new bullet traps.

### 4.3.5.2 New shooting ranges

On new shooting ranges, there may be reasons that suggest that bullet traps other than those of soil/sand would be most expedient. The following variants of bullet traps are considered to be the most relevant under certain circumstances:

**Sloped granular bullet traps with bulletproof back walls and roofs** is a good solution when it comes to safety, maintenance and the environment. With the right design, such bullet traps would entail almost no lead contamination. The distinct disadvantage is the cost of such a bullet trap, which can only be justified if the situation dictates that zero-emissions are required.

**Tyre chips as bullet traps** can be feasible in locations where it is especially important to have anti-ricochet bullet traps all year round. Regular maintenance is simple but cleaning every 5-7 years must be done by professionals. Bullet traps like this should have some type of runoff control measures.

**Steel cassettes with interior steel plates** can be considered for ranges where there are bullet traps/backstops immediately behind the cassettes to ensure compliance with the safety requirements. Otherwise, this would call for an enclosure that would drive the costs so high that other alternatives are probably more relevant. Maintenance is simple and can be done on the basis of collective voluntary efforts. The cassettes do not capture bullets that miss the targets, meaning they do not offer a zero-emission solution. Cassettes used as bullet traps may be a good solution on temporary ranges since it is easy to move the boxes.

**Vertical steel plate bullet traps** offer a solution that is simple, safe and calls for a moderate degree of maintenance that rifle clubs can perform themselves. The solution is somewhat expensive, but under certain circumstances, it may turn out to be less expensive than other bullet traps, especially in locations where the terrain slopes near the targets. This solution is sound from the environmental perspective, but it could hardly be described as a zero-emission solution.

**Optical targets** have arrived on the market. Such targets do not use covers, so they require a superstructure that ensures that the background behind the target is so dark that the middle of the target appears to be black. To achieve this in actual practice, a superstructure must be built around the targets. If such a superstructure has to be built anyway, it would be natural to take a closer look at building a granular bullet trap or a type of steel bullet trap since the superstructure already accounts for a large part of the costs.

#### 4.3.5.3 Field shooting

Field shooting takes place in temporary areas and is often moved from time to time. If the area is accessible by tractor, it may be possible to lift steel cassettes lined with steel plates into place. Such boxes are heavy, though, and it is often not possible bring in machinery that is big enough, effectively eliminating all the bullet trap solutions described in this document.

## 4.4 Further development

This stage of the work with environment-friendly bullet traps has involved the acquisition of information and knowledge about different bullet trap solutions. Assessments have been made of the various solutions used on 100 m and 200/300 m rifle ranges for rifle clubs affiliated with DFS. For other actors that use different firearms, have different shooting programmes, different financial situations and/or have a higher degree of professionalism, the assessments may be entirely different.

The next stage of the Environment-Friendly Bullet Trap Project will involve planning and testing possible improvements to bullet traps, which may in turn result in a guide for bullet traps that shows potential solutions for different situations. The following is a proposal for studies on improvements in bullet trap solutions that may be relevant in the next stage.

### 4.4.1 Improving bullet traps of soil/sand

Regular maintenance is crucial for maintaining the function of bullet traps made of soil and sand. Any crevices in the bullet trap should be refilled as needed to prevent the accumulation of big lumps of lead in the bullet trap. Before filling in the crevices, it might be wise to check whether any lumps of lead have formed and, if so, to remove them. Every few years, the entire bullet trap should be covered with an extra layer of ricochet-free mass to maintain its no-ricochet status and to ensure that new bullets do not strike old bullets. Thus, the bullet trap will slowly grow towards the targets, requiring that there be enough space to accommodate this. The figures below illustrate the maintenance:

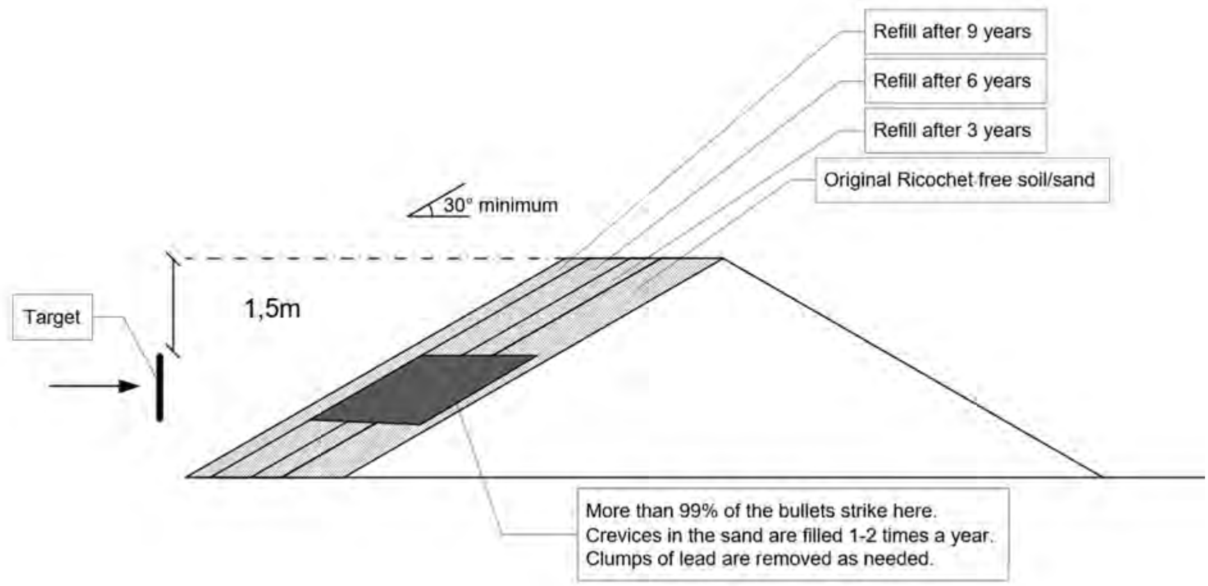



*Figure 31 Maintenance of soil/sand bullet traps*

Experiments have been performed by placing barrels of sand in the bullet trap with the opening immediately behind the target where the majority of the bullets strike. The idea was that after many years of use, the barrels could be removed and delivered to recycling.

Unfortunately, the experiments showed that the bullet trap mound settled to some extent, meaning that the bullets after some years failed to strike the barrel.

A cover over the bullet trap will keep rain from infiltrating. How this works, and the possible consequences of the cover, might lend themselves to testing.

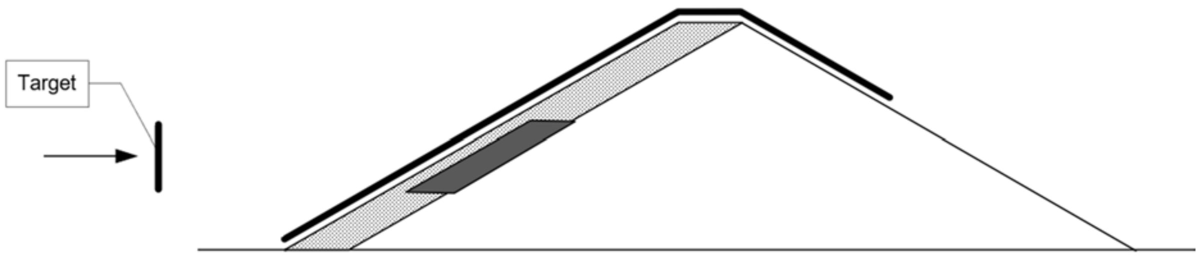



*Figure 32 Illustration of a covered bullet trap*

A roof structure over the bullet trap may limit water infiltration and will thereby limit the possibility of runoff. Such a roof must endure both wind and snow pressure, meaning it may be relatively costly. If a roof structure is to be feasible, it is important to find a cost-effective solution.

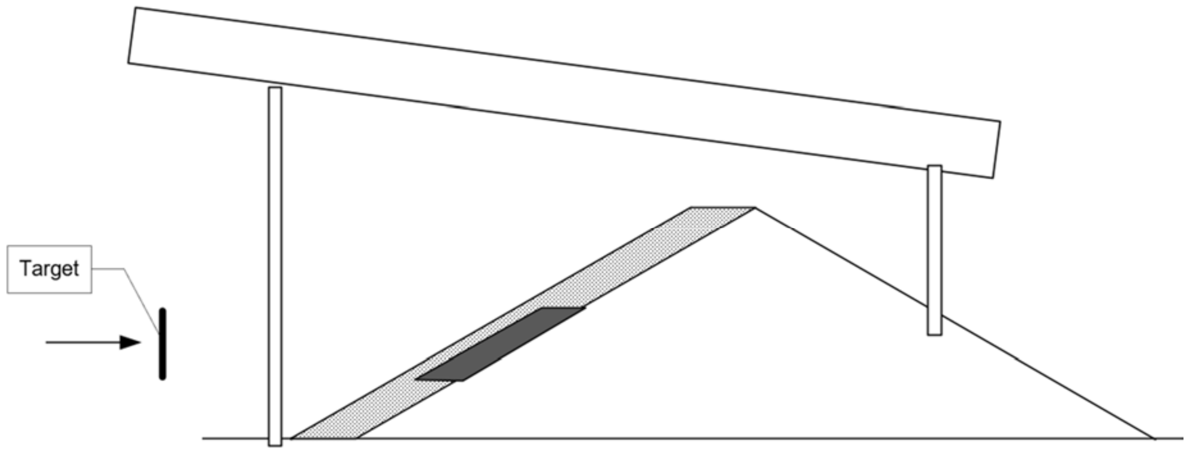



*Figure 33 Schematic diagram of a roof over a bullet trap*

Bullet traps of soil/sand that are immediately in front of rising terrain may be exposed to significant amounts of surface water that run from the terrain and into the bullet trap. Such surface water is unfortunate as it can carry away large amounts of lead pollution. The figure below shows a schematic diagram of how this situation can be improved by adding a drainage ditch behind the bullet trap and possibly a cover over the bullet trap

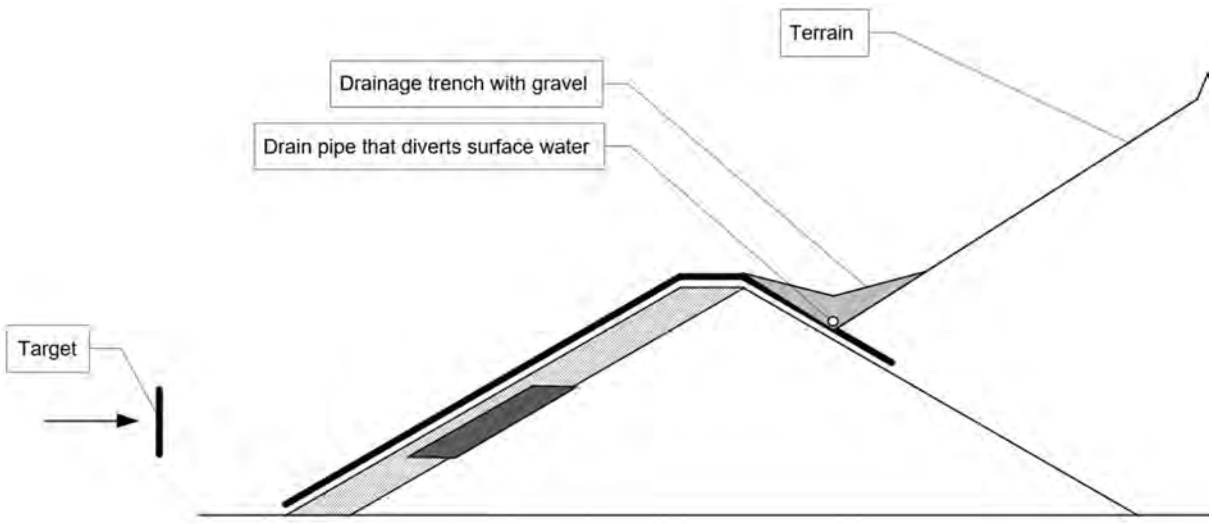



*Figure 34 Diversion of surface water from bullet traps located immediately in front of rising terrain*

An old bullet trap that is covered like this to prevent moisture from infiltrating it will not cause lead to leach. In especially vulnerable situations, for example, close to sources of drinking water, one possible solution would be to cover the old bullet trap and build a new bullet trap on top of it. The new bullet trap can have a cover over it, a means of capturing seepage, and a filtration tank for cleaning and sampling.

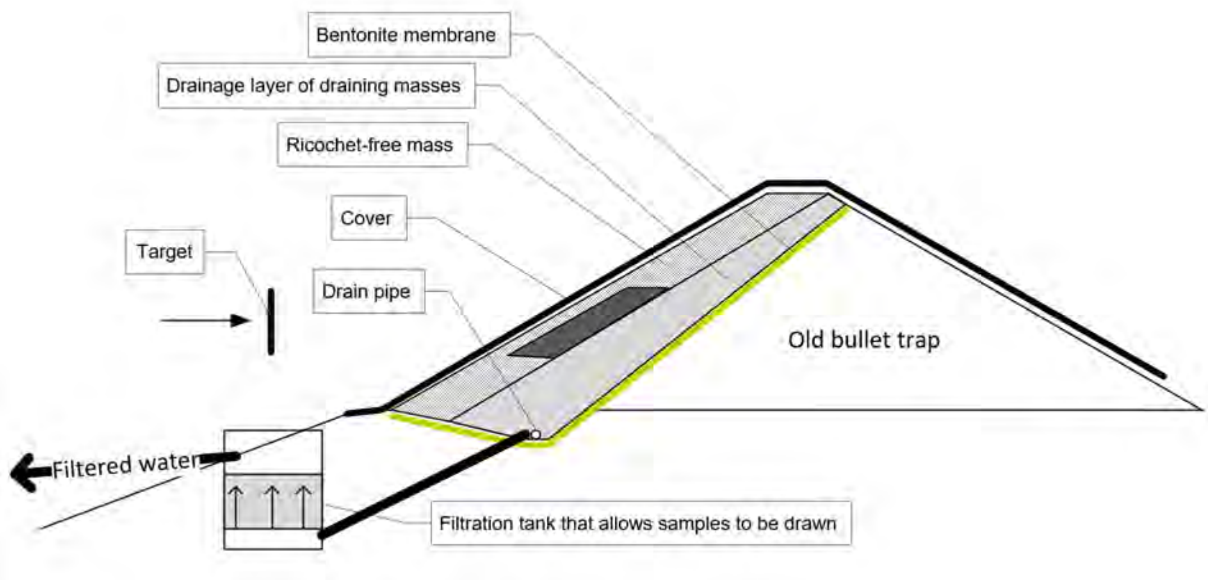



*Figure 35 Schematic diagram for sealing an old bullet trap and building a new bullet trap on top of it*

Tests have been made on many different cleaning agents. Using relatively simple solutions, it has been possible to clean 80-90% of the lead from water. Such cleaning lies outside the scope of this project.

### 4.4.2 New bullet traps

Our knowledge acquisition indicates that some bullet trap solutions are tried and true while others are less well tested. A bullet trap with a vertical steel plate is a simple design that many rifle clubs can manage to build and maintain themselves. To the best of our knowledge, the solution has only been tested at two locations. The results indicate that this is a sound solution, although there have also been some problems discovered in relation to such bullet traps. In particular, there has been wear and tear on the stanchions that hold the front plates. Details related to lead collection can probably also be improved, and the possibility of installing a conveying screw to feed the lead into a container should be explored. It is recommended that the next step in the project be to design and build a prototype of such a bullet trap, then to test it on a busy range so that any need for improvement can be recognised quickly.

Using different types of ammunition is a challenge when bullet traps have front plates intended to prevent dust and metal splinters from escaping the bullet trap. There is held to be a great need for testing different front plates to identify the properties of the plates when using different types of ammunition. In particular, tests should be performed to determine how HDPE plates of different thicknesses and Regupol plates work with a view to durability. Studies must be conducted to determine whether the bullets pierce the plates, and whether the bullets shatter or get stuck in the plates. Attention should also be devoted to studying other materials that might potentially be relevant. Different front plates can be tested on a steel cassette lined with steel plates to acquire experience of such a bullet trap.

When testing new types of bullet traps, it should be possible to keep an exact list of how much shooting is done with different kinds of ammunition, to weigh what is removed from the bullet trap, and thus to calculate what percentage of the bullets is captured. For this to work, it is imperative that no one shoots at the bullet trap without the activity being recorded. The metal fragments must also be separated from particles of front plate material, etc. Any worn metal from the bullet trap *per se* must also be taken into account and adjustments made accordingly. Accomplishing this requires tightly controlled conditions.

### 4.4.3 Field shooting bullet traps

Our acquisition of knowledge has not resulted in any solution for field shooting that is light weight enough to be deployed in the field without using a tractor or similar equipment. It is assumed that the lightest possible bullet trap solution for field shooting may be a reinforced plastic box with granulated plastic and a front cover, or sacks made of rubber cloth stuffed with granulated plastic. The plastic material RUTEC R5000 is the lightest energy-absorbing material we have found that has proven properties for use in bullet traps, and it might be appropriate in this context. It helps a great deal if one manages to capture 90% of all bullets from field shooting, and it is recommended that more detailed studies be made regarding the possibility of making such a light-weight bullet trap for field shooting.

# 5 Conclusion

The question we aspired to answer by making this report was:

***Is it possible to find some clearly preferable bullet trap designs for outdoor rifle shooting that satisfy safety requirements and represents an environmental improvement compared with the bullet traps currently in common use?***

## 5.1 Preferable solutions?

The bullet trap concepts discussed in this report have been assessed with a view to safety, the need for maintenance, environmental conditions and the cost of building, operating and maintaining them.

Environmental factors are closely related to the degree of annual leaching of lead. One factor is what percentage of the bullets are captured. Equally important as the question of how much of the lead is captured, is determining what happens to the lead that is not captured. With some bullet trap solutions, there will be a fine lead dust that disappears. Such dust will often have a potential for leaching that is far more serious than from bullets that are intact.

Traditional bullet traps of soil and sand work well when it comes to safely, cost little and are easy to maintain. Readings have been taken earlier from lead runoff from bullet traps; NIVA estimated that the leaching is less than 1% of the lead added each year. If one's environmental ambition is higher than the reading taken at that time, further measures will be required. There are many possible solutions, but they need to be adapted to local conditions in order to work. Different challenges related to water infiltration require different solutions.

Granular bullet traps may work well, but they require good deal of maintenance. If they are not emptied often enough, ricochets can occur when bullets strike lumps of old bullets that have aggregated in the bullet trap. The granulate must be kept in place, and with a cover over a sloped granular bullet trap, water infiltration through any holes in the cover may possibly present a challenge. Thus, it may be appropriate to have a roof over the bullet trap to minimise lead runoff.

In many ways, steel bullet traps, where the bullets are captured without mixing with granulate or other 'pollution', are a favourable solution. One challenge may be that they are expensive to install. Other challenges include the spread of polluting lead-dust, noise from the bullet trap, etc. Helical bullet traps can prevent bullets from shattering, and they are environment friendly. However, they are difficult to use outdoors in the Norwegian climate.

Our acquisition of knowledge has shown that some bullet traps are better for the environment than today's bullet traps of soil/sand. For the most part, these are extremely costly solutions that rifle clubs affiliated with DFS are unlikely to be able to afford. Costs for operation/maintenance are also high for some of the solutions that are best from the environmental perspective. The conclusion thus far is that strong emphasis on maintenance and possible new initiatives on existing bullet traps may improve the situation so that lead leaching can be reduced significantly. In addition, it looks as though bullet traps with vertical steel plates may be a good solution for new ranges, which, in some cases, can also be cost-effective relative to other types of bullet traps. It is therefore recommended that further efforts be invested in improving soil/sand bullet traps and bullet traps with vertical steel plates. It is also important to test the materials in the front plates of bullet traps.

## 5.2 Next stage – Further development

In the next stage of the Environment-Friendly Bullet Trap Project, it is suggested that further work be done to improve existing soil/sand bullet trap solutions, while examining solutions for new bullet traps.

For existing bullet traps, it is relevant to take a closer look at whether installing a cover or a roof can reduce the leaching of lead from the bullet trap. Further, it is relevant to study drainage and the diversion of water from bullet traps located immediately in front of a rising terrain. Such initiatives should be followed up with measurements of lead pollution. This is complicated to do in a way that leads to reliable documentation, but it is desirable to try.

The further development of bullet traps with vertical steel plates is considered a priority. The design process should be initiated, and a prototype should be built to test different materials. The possibility of installing a conveying screw in the bottom of the bullet trap should also be considered.

Many bullet traps depend on having a cover to prevent water, debris and the like from getting in, and dust and spatter from bullets from escaping. This could be different rubber covers, HDPE plates or Regupol. These must be tested with different types of ammunition to check their durability, whether the bullets pierce them, the danger of blow back, etc. It is proposed that the front material be tested on a bullet trap that is a steel box lined with steel plates, so that this solution is tested at the same time.

## 5.3 Last stage - Bullet trap guide

The last stage in the Environment-Friendly Bullet Trap Project will be to draw up a guide to bullet traps. The guide to bullet traps must be a practical document that shows relevant solutions that are appropriate in different situations.

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