Recommendations on how to extinguish peat fires in drained peatlands: the Russian experience

Edition adapted for global perspective

GREENPEACE

ВИПКЛХ

2022

CONTENTS

FOREWORD

Peatlands are one of the planet's most important climate regulators. The degradation of peatlands, including that which results from drainage and fires, triggers the transformation of peatlands from carbon sinks and absorbers into an ecosystem that could potentially release carbon that has been stored for thousands of years. The release of carbon can take place at a rapid rate. What can and should be done to preserve and restore peat ecosystems?

This manual will:

- Help you to detect and extinguish peat fires in a timely, efficient, safe manner using modern technology.
- Teach you how to retain water in ditches to extinguish fires.
- Explain how to reduce the fire hazard of an area of peatland by bringing its hydrological regime closer to the conditions before drainage.

We have accumulated this knowledge and worked out these recommendations over many years of effort in the practical prevention and suppression of peat fires, as conducted by Greenpeace Russia and voluntary forest firefighting teams. By the end of 2020, we contributed significantly to the reduction of the number of catastrophic Russian peat fires by more than 90 % (compared to the long-term annual average during the years 2002 to 2017), and our peat fire extinguishing expertise is among the best in Russia.

This manual does not aim to be an international guide for peat-fire management. Instead, it is an adapted description of a successful experience in modern Russia, which we hope will be useful in the context of other countries as well. The original Russian edition was published in Moscow in 2020.

The manual is intended for a wide range of readers, including:

- Professional and volunteer firefighting teams in countries that face the problem of peatland fires.
- The international scientific community focused on the challenges of wildland fire management and peatland rewetting.
- Activists and nonprofit organizations involved in practical mire conservation and the suppression of peat fires in those regions.
- Land users as well as regional and municipal administrations in regions where peatlands and peat fire hazards are part of local landscapes.

What is unique about the manual?

In our opinion, this is the great combination of theoretical and practical knowledge, which is essential for field firefighting in peatland landscapes in effective, nondestructive ways.

The basics of peatland science and hydrology, description of peat extraction methods and land use in drained peatlands, measuring the surface of the land and the water, and formulas for calculating water flow in a channel comprise the basic theory supporting informed peatland management with competence and insight regarding the current processes.

Detailed recommendations are given with respect to the use of modern technology in firefighting, including drones for fireground reconnaissance and water-retention techniques to extinguish peat fire points and/or reduce the fire risk in particular areas of peatland.

About the English edition

A wide range of scientific and practical literature in Russian, together with German-language sources, was applied in the production of this issue. This is because we adapted the national experience for an international audience based on Soviet, Russian, Belarusian and German peatland studies and industry.

The specifics of peatland management, including fire suppression and the construction of various facilities, are closely associated with regulatory legal instruments, official codes of practice, regulations and national standards. The original Russian edition contains references to documents relevant to Russia, but those references are intentionally omitted from the English adapted edition.

All photographs in this manual were taken in the regions of Russia where the Greenpeace Russia team, authors and volunteers have worked on extinguishing peat fires or rewetting drained peatlands.

Team of authors

The recommendations related to river and ditch hydraulics, calculation of flow velocity, volumes of retained water and ditch designs were written jointly with Dmitrii Isaev, Head of the Department of Hydrometry at Russian State Hydrometeorological University (RSHU, St. Petersburg), Candidate of Sciences in Geography.

The recommendations on firefighting tactics were made by Grigory Kuksin, the Wildfires Unit Head in Greenpeace Russia, jointly with Nikolai Korshunov, the Head of Forest Pyrology and Forest Fire Protection Department at the All-Russian Research Institute for Silviculture and Mechanization of Forestry (VNIILM), Candidate of Sciences in Agriculture. In 2013 to 2017, Nikolai Korshunov headed the Department of Forest Fire Protection at the All-Russian Institute for Advanced Training of Forestry Leaders and Specialists (VIPKLH).

Recommendations on technologies and methods of water retention as well as on peatland data collection, understanding the water balance in the mirs and peatlands, hydrology and water supply, and indicators to help identify potential water-retention areas were compiled and written jointly with Frank Edom, a German hydrologist and peatland scientist.

Recommendations on technologies and methods of manual water retention and appropriate measurements as well as the description of ditch blocks designs were made by Ivan Semenov, the Greenpeace Peatland Rewetting Program Head from 2018 to 2020.

Legal recommendations were made by Mikhail Kreindlin, the Greenpeace Protected Areas Program Head.

Recommendations for the use of drones, including those equipped with thermal imaging cameras, in fireground reconnaissance missions, were made by Yulia Petrenko, Greenpeace lead video producer from 2019 to 2020.

Recommendations on possible biotechnical measures to attract beavers to the areas that require rewetting to reduce fire hazards were written in consultation with Nikolai Zav'yalov, the Head of Science at Rdeisky Nature Reserve and Doctor of Sciences in Biology.

Acknowledgments

Our sincere thanks go to our colleagues in the Greenpeace Wildfires Project as well as the employees and volunteers of public and governmental organizations who made it possible to collect materials for this manual.

Extinguishing hundreds of peat fires, analysis of many space images, data collection and analysis, consultations on equipment and work methods, measurements, calculations and experiments, and conducting scientific research and surveys was accomplished by a large number of people without whom this publication would not have been possible.

We would like to express special thanks to Maria Vasilieva, Alexey Yaroshenko, Ilona Zhuravleva, Sofya Kosacheva, Natalya Maksimova, Mikhail Levin, Vasily Aksenov, Olga Kanishcheva, Anton Beneslavsky, Maksim Sergeev, Egor Volodin, Vladimir Kastrel and all the volunteers who helped extinguish fires, gained hands-on experience building ditch blocks and patiently endured the hardships of life and work in the field.

We would also like to thank our wonderful photographers and illustrators who understand in detail the intricacies of peat fire suppression.

Our special acknowledgement goes to Oksana Ilyushina, editor-in-chief of the Russian edition, and the team of editors.

The team of authors and editor-in-chief of the English edition

INTRODUCTION

The total area of drained peatlands in Russia is at least five million hectares. Most drained peatlands have long since become abandoned land, and some have undergone secondary paludification [paludification is the process in which soils change when peatland has been drained and is under the influence of constant excessive moisture or flooding, eventually leading to the formation of a mire]. The industries for which peatlands had been drained have either ceased to exist, as is the case with peat energy, or have suffered hardships, as is the case with agriculture and forestry.

Records are not kept with respect to abandoned drained peatlands and many documents that had been collected in the past have been lost. However, drained peatlands pose the greatest threat because they are the areas in which peat fires most often occur.

Each year, an increasing number of Russian regions experience peat fires. Increasingly frequent low-snow winters and summer droughts, coupled with the now-illegal tradition of dry-grass burning, have resulted in more fires and correspondingly greater destruction to the environment, infrastructure and settlements.

The number of peat fires in western regions of Russia — including those contaminated by radiation from the Chernobyl disaster — is growing. Massive fires have erupted in the peatlands of eastern Siberia. Extensive peat fires have become a reality for southern regions as well. It is predicted that, in the near future, climate change will lead to an even greater increase of fire risk in peatlands.

An ongoing peat fire is a constant source of heavy smoke, and increases the risk of wildland fires spreading to adjacent areas including to nearby settlements.

Peat fires put people's health and lives at greater risk than forest fires because the smoke exposure produced by peat is much higher and longer lasting than from forest fires. Health risks are amplified if smoke from peat fires drifts over megacities and densely populated industrial areas because it will exacerbate the impact of existing air pollution from traffic and industry.

Peat fires are particularly dangerous in areas that remain contaminated with radioactive waste from the 1986 Chernobyl radioactive disaster because the soils contain trace levels of pollution. During a fire, radioactive substances that have persisted since the accident are re-emitted into the atmosphere as the contaminated peat smolders, risking inhalation through the smoke produced.

Peat fires in their early stages can be extinguished with little effort without risking the health and lives of firefighters, because such fires develop more slowly than other type of fire. This is particularly true for compressed peat of high density, which is wide spread in Russia. If left untreated, a peat fire will move deep into the drained soil and spread over a large area, and the effort needed to extinguish the fire becomes much greater than would be needed to extinguish a forest fire covering a similar sized area.

A peat fire not extinguished in time will divert firefighting resources throughout the fire season, most often on dry and hot days, when such resources are needed to extinguish other fires.

There are particular challenges in extinguishing peat fires. Those challenges comes from — the fire origin, the type of peatland, the method and purpose of peatland drainage and the past use of the peatland. Appropriate, timely action can almost always prevent an emergency from developing.

This manual describes the ways to detect and properly extinguish peat fires in their early stages. All recommendations are based on successful experience in extinguishing hundreds of peat fires, almost always in their early stages and usually by small teams of volunteers with lightweight, relatively inexpensive equipment.

PHOTO BY: MARIA VASILIEVA/GP

A forested bog in Central Russia.

During dry seasons, natural and semi-natural forested bogs are quite susceptible to peat fires. This is proven by peat fires in Hohenleipisch (South Brandenburg, Germany) in 2020 and Dubring (Saxony, Germany) in 2021.

GLOSSARY

The acrotelm is the upper active layer of a mire. It contains mosses, grasses and roots of herbaceous and grass — sometimes bush and tree plants. Peat-forming and water exchange processes take place here, i.e., water infiltration, its absorption by plant roots and evaporation, and near-surface runoff. During peat mining, the acrotelm is removed.

Bituminous resins are hard resinous substances (waxes) contained in the peat. These are complex chemical compounds containing paraffins, hydrocarbon compounds, acids and other substances.

A depression curve is a free surface curve in the plane of the drawing [34].

Depression surface is the free surface of seepage flow [34].

Free surface is a hydromechanical term meaning the surface of the liquid not limited by the walls of the vessel or stream bed. When exposed to external forces, the free surface in a state of equilibrium of the liquid acquires a form in which the surface is perpendicular to the action of these forces. At the same time, the equilibrium state corresponds to a minimum of potential energy, which is why the free surface area is reduced to the minimum possible value under the action of the forces of intermolecular interaction, also called the force of surface tension.

The groundwater table is the level below which the soil is saturated with water.

Hydrogeological windows are filtration windows, i.e., sections with increased permeability in the impermeable rock that separates groundwater horizons (aquifers).

A hydroseal is a structure that opens, closes, and regulates the water flow through the opening of a sluice structure. It can be in the form of flat, solid moving shields with lifting mechanisms and stops made of wooden or steel beams laid horizontally on top of each other.

Inert peat is the peat in deposits, i.e., the peat that has not been extracted. It is located below the acrotelm.

Mineral islands in mires or in peatlands are protrusions of the mineral bottom of the mire or peatland, i.e., remaining elevations not buried under the peat layer.

A peat borer is a special borer for taking peat samples and determining the structure of the body of a peat deposit.

Peat coke (semi-coke) is the solid product of thermal decomposition of peat. It is characterized by a high reactivity, including ignition reactivity.

A peat deposit is natural stratification/layering of different peat varieties from the surface down to the mineral soil or lake deposits (gyttja) [35].

A peat deposit site is a geological formation consisting of layers of one or more types of peat, characterized in its natural boundaries by excessive moisture and a specific vegetation cover. It can be an object of industrial or agricultural use, depending on its size and peat reserves.

A peat field: In the milling method of peat production, it is a production area of the peat enterprise limited by the ditches of the drainage system.

A peat fire is the underearth ignition of a mire or peatland, drained or natural, as a result of arson or negligent handling of fire. (see also chapter 3.1).

A peat forest fire is a soil fire (ground fire) where a part or all of peat soil burns.

A peat pile is a temporary storage unit, a place and method of temporary storage of peat as part of the milling method of peat mining. It is a ridge of triangular cross-section, up to 7–8 m high and up to 75–80 m long.

Peat production field: in the milling method of peat production, it is a part of the peat field bounded by two adjacent field ditches.

A pool is a part of a river, ditch, water reservoir, or another water body adjacent to a hydrotechnical construction.

Structures that can have pools include dams, gateways, hydropower stations and others. The upstream pool is located upstream of the hydrotechnical construction. The downstream pool is on the other side of the hydrotechnical construction. The upstream pool is often a water reservoir.

Pyrolysis is thermal decomposition under a lack of oxygen.

Raw peat is the peat in its natural deposit.

Gyttja (sapropel) are bottom deposits of freshwater bodies. It consists of of organic lake sediments like dead water vegetation, residues of living organisms, plankton, soil humus and inorganic lake sediments (f.e. carbonates, clay, silt, sand) in highly combination with the called organic sediments [46, 48, 49, 54]. Sapropel is highly impermeable, but under artesian groundwater-pressure can be macropores with water-flow.

Paludification is by [44], p. 82. The formation of waterlogged conditions, also refers to peat accumulation which starts directly over a formerly dry mineral soil.

Secondary paludification is by [44], p. 84. The renewed spontaneous formation of waterlogged conditions in a formerly drained peatland, which also can lead to a new/secondary start of peat formation. In Russian-speaking countries "secondary paludification" also refers to rebuilding of such conditions by rewetting measures, means not only spontaneous [12]].

CHAPTER 1. MIRES, SWAMPS, PEATLANDS AND PEAT: GENERAL CONCEPTS

Chapter 1 gives a basic understanding of mires and peatlands, how peat is formed, and the properties it has. The chapter does not aim to replace comprehensive textbooks on peatland science. Nevertheless, some knowledge of peatlands will give us a better understanding of how to prevent and extinguish fires in drained peatlands, including by raising water levels.

There are many definitions of mires and peatlands that take into account the varying thicknesses of peat deposits or the mire or swamp vegetation. One of the definitions of a mire (the Russian term "*boloto*") adopted by the Soviet scientific school is "an excessively wet land area where non-decomposed organic matter accumulates, subsequently turning into peat." [3]

German wetland scientists Succow and Joosten [54, p. 2] give a broader definition of the German term "*Moor*": "Moore are landscapes ... where peat is forming or a surface peat layer has already formed. The term 'moor' also includes habitats that do not have significantly thick peat layers ... but ones where peat can form."

Relevant English definitions vary slightly [44]:

- A **peatland** is "an area with or without vegetation with a naturally accumulated peat layer at the surface."
- A **mire** is "a peatland where peat is being currently formed and accumulating."
- A **swamp** is "a wetland usually dominated by reeds or other tall grasses, sedges or rushes."

According to the Ramsar Convention, **wetlands** are defined as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static, flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters." [47]

All these definitions show that the terms in different countries and periods of scientific history are not the same and not synchronic to translate. Terminology in some countries and languages is more differentiated whereas some terms do not even exist in the others. Therefore, the English word "*mire*", Russian "*boloto*" and German "*Moor*" do not always refer to the same ecosystem.

Within the framework of this manual we focus on the key distinction:

1. there are mires in which peat is forming (these are active, growing mires);
2. there are fully formed peatlands (wet or dry, with or without actual peat production);
3. and there are drained peatlands in which the hydrological regime has been altered.

According to the official soil classification in Russia, peat is an organic soil that is formed as the result of natural die-off and incomplete decomposition of mire vegetation in conditions of high humidity and lack of oxygen, thereby containing 50 wt% or more of organic matter [35, p.8]. In other countries, soils with less than 50%wt of organic matter is called "peaty". For instance, German "*Anmoor*" or respectively "*Antorf*" is a soil with a peat layer that is not sufficiently thick (usually less than 30 or 40 cm) or with a carbon concentration not sufficiently high (usually under 15% and in Germany under 30% by dry weight) to be called peat, according to Succow & Joosten [54].

See Appendix 1 (*Table 5)* for more details.

1.1. MIRE CLASSIFICATION AND PEAT TYPES

1.1.1. CONCEPTS OF FEN, TRANSITIONAL MIRE, BOG AND PEAT

There are different classifications of mires. The most common is the division of natural mires into fens, transitional mires and bogs. Within the framework of this manual these terms are used as the translation of the German and Russian terms "*Hochmoor*"/"*verkhovoye boloto*" (translated into "bog"), "*Übergangsmoor*"/"*perekhodnoye boloto*" (translated into "transitional mire") and "*Niedermoor*"/"*nizinnoye boloto*" (translated into "fen"). The origin, etymology and historical or modern use of the terms in the three languages are not always the same, and the Russian terminology has closer connection with the German terms rather than with the English ones.

The concepts of bog and fen came from eighteenth-century Netherlands terms and initially only reflected the terrain relief specifics. Bogs are forming higher uplands and fens are located in depressions and lowlands.

Vegetation-related information was added subsequently. Sphagnum mosses predominate in bogs, whereas grassy vegetation (reeds, sedges), hypnum mosses and black alder forests are more common in fens. Gradually, scientists realized that the type of water supply matters. Mire vegetation and upper peat layers that are fed by atmospheric precipitation, which does not contain any minerals, it is oligotrophic nutrition (most often in bogs). A mire fed by mineral water (groundwater, soil water, slope water, river or lake water, seawater), is referred to as mesotrophic or eutrophic or mesotrophic nutrition (most often in fens).

The concept of intermediate stages, the so-called "transitional mires", with mixed (most often mesotrophic) water supply and nutrition, was introduced later. Transitional mires were mostly identified in the plains.

Gradually, scientists realized that the specific parent vegetation resulting from different types of mire nutrition and water supply will form different types of peat.

The types of peat reflect the nutritional and hydrological (water supply) conditions under which they are formed.

1.1.2. TYPES AND VARIETIES OF PEAT

In Russia (and, historically, the former Union of Soviet Socialist Republic (USSR)), it is customary to classify peat by its chemical properties and botanical composition but not according to the type of water supply and nutrition of the original mire ecotope. Classification into bog, transitional mire or fen depends upon the varieties and types of peat present. The real type of water supply can be determined by conducting particular hydrogeological and hydrological surveys, including detailed water-balance calculations.

Twenty-six types of peat are classified into 12 groups based on chemical and botanical laboratory studies, according to the classification of peat varieties [24, p. 39, see also *Fig. 104* in Appendix 1].

Under field conditions, we as firefighter volunteers do not determine the fen, transitional or bog type of peat. Instead, we determine the botanical composition of peat visually with its major and minor constituents, naming everything else as admixtures. Examples include sphagnum moss, brown moss, coarse sedge (Carex) and other types of peat *(Fig. 1)*. Field surveys are usually carried out by means of hand drilling with a peat borer. The variety of peat is visually determined in the core of the peat borer *(Fig. 2)*.

To identify peat varieties in the field, a peat substrate guide was published in Germany [46] with photographs and explanations for each type of peat and the keys to determine peat types. The guide has been translated into English [48, 49]. It is openly available online.

1.1.3. PHASES OF NATURAL PEATLAND DEVELOPMENT

A single peatland usually consists of more than one variety or type of peat. Mires change over time depending on vegetation, peat, topographical relief [which means the elevation of the land] and type of water supply. Often mires change over time because in the first stage of development, more water is from ground sources than from precipitation, such as rain. As the volume of peat increases, the mire changes its form, which in turn drives changes in water source. A greater volume of peat means that ground or any other mineralized water may not feed the surface of the mire any longer. If the precipitation dominates above evaporation the dominant source of water supply for the upper layer of peat is precipitation. This drives changes in plant composition. Usually the direction of peat development is upwards, ranging from fen peats to chemically poorer bog peats. (In other types of mires there can also be changes of dominant type of minerogenic water-supply and nutrition, which result in different types of peat.)

The development of mires in to bog peat is only possible if the difference between precipitation and evapotranspiration is positive, meaning that less moisture is lost from evapotranspiration than is gained by precipitation and — so there is a net accumulation of water. Then, as the thickness of the mire deposit increases, less groundwater rises to the surface, and precipitation plays an increasingly important role in the upper layers. In the lower parts of peatland, subsurface (groundwater) and slope water supply will still be important but will not reach the surface and will filter down to the receiving water body or along the slope of the lower edge of the peatland.

PHOTO BY: IVAN SEMENOV / GP

Fig. 1. Studying a soil profile of a drained peatland and sampling for analysis

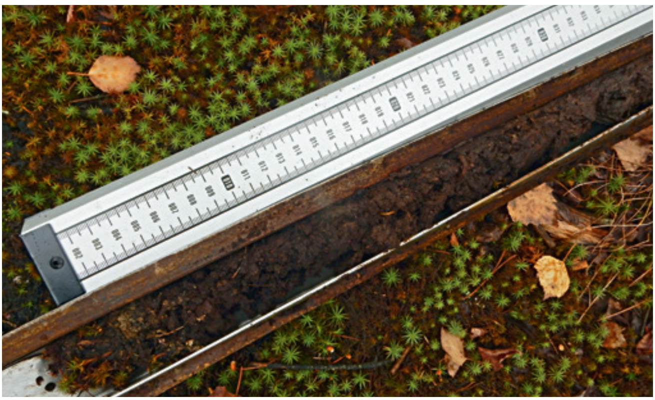


PHOTO BY: IVAN SEMENOV / GP

Fig. 2. A core (a soil sample) in a peat borer

Descriptions and classifications of the natural development phases of specific mires can be found in regional literature or in peat exploration data. You can find the example in *Fig. 105* in Appendix 1.

1.1.4. CLASSIFICATION OF PEAT DEPOSITS IN RUSSIA

A bog, a transitional mire or peatland, or a fen are defined either by the existing vegetation cover or by the upper layer of bog, transitional, or fen type peat. If the mire type is associated with water supply/nutrition, then the water supply/nutrition relates to either the actual vegetation or the upper peat layers.

A peatland, the so-called peat deposit, often consists of different types of peat. The type of peat deposit is determined in accordance with the predominant type of peat. There are the following types:

1. **Fen peat deposits.** More than half of the depth profile consists of fen peat varieties. Above the fen peats, there may be transitional and bog varieties of peat, but fen peats are predominant. The thickness of bog peat is no more than 0.5 m.
2. **Transitional peat deposits.** More than half of the depth profile consists of transitional peat types. The thickness of bog peat is no more than 0.5 m. There may also be fen peats below the transitional peats. This means that transitional peat deposits can be either transitional mires or bogs.
3. **Mixed peat deposits.** Includes deposits with fen or transitional peat in the bottom layer, and an upper layer of bog peat more than 0.5 m thick but not more than half of the total depth of the deposit. This means that almost all mixed peat deposits are classified as bogs.
4. **Bog peat deposits**. The bog peat types take up more than half of the profile, with bog peat on the surface. Almost all bog peat deposits are also bogs.

More details on the division into types, subtypes, and varieties of deposits can be found in the books by P'yavchenko [20] and Tyuremnov [35].

Historically, the terms “bog”, “transitional” and “fen” with respect to mires, as well as “peatlands and peat deposits”, imply different phenomena and processes in peatlands. They characterize the landforms and/or the types of peat-forming vegetation as well as the types of top peat layers and the type of water supply, and they describe the overall peat deposit. In each case, it is important to understand exactly which characteristic is being referred to.

1.2. TYPES OF MIRE WATER SUPPLY. HYDROGENETIC MIRE TYPES

To extinguish peat fires and retain water, it is important to have an understanding of past and present water supply types, and of ways to identify them from the structure of the peat deposit. For example, if at one stage of peatland development the area was fed by a particular source of water, it is possible that the water supply still exists or that it could be restored through rewetting or other management measures.

There are two main types of peatland water supply:

- **Ombrogenic or atmospheric** (rain, snow, hail, condensation).
- **Minerogenic** Water that has already had contact with mineral soil after a precipitation event. Depending on the source, minerogenic water is subdivided into lithogenous (groundwater), soligenous quiescent (soil/quiescent) water, soligenous moving (soil/slope) water, fluviogenous (riverine) water, limnogenous (lacustrine, pond) water and salt (talassogenic) water. Most peatlands have mixed water supply consisting of different types.

Water properties are important for the occurrence of typical mire vegetation, trophication/nutrient content (availability of nitrogen and phosphorus) and acidity (pH).

In terms of nutrient content (trophication), the water is classified as oligotrophic, mesotrophic and eutrophic. In terms of acidity, water can be acidic, neutral or alkaline (Appendix 1, *Fig. 103*).

Atmospheric water is generally considered oligotrophic in areas with clean air, with no volcanoes or industrial, agricultural or other anthropogenic sources of air pollution. The quality of minerogenic water depends on the quality of mother rock, vegetation and the anthropogenic use of the area around the peatland.

Different sources of water supply in peatlands contain different soluble substances. Water can transport mineral particles (sand, silt), eroded peat or dead organisms (plants, animals, plankton). Water from different groundwater horizons usually varies significantly in terms of water quality and chemical composition. For example, there are usually more nitrates in the upper horizons but more iron in the deeper horizons.

The water source determines the fluctuation of water supply, which also influences the vegetation types and the process of peat formation. Precipitation and soil water are subject to greater fluctuation. However, the fluctuation of groundwater supply decreases as the depth, capacity and width of the aquifer (groundwater horizon) increase.

Water from different sources will change in quality as it passes through mires and peat deposits. Vegetation and peat filter out nutrients and other substances (such as humic acids). Some substances are deposited in naturally wet mires, whereas other substances, particularly in drained peatlands, are washed out, diluted or concentrated.

For example, low-mineralized water from nutrient-poor (sandy) groundwater horizons or forested slopes often becomes oligotrophic after passing through a mire, even though the source (of water supply) is minerogenic. Consequently, there are oligotrophic parts of a mire, for which the vegetation or peat type is referred to as being of the bog type, although the mire itself is a fen type in terms of water supply. It is incorrect to determine the type of peat solely on the basis of the type of water supply.

The German peatland scientist Michael Succow created a mire classification system, based on different types of water supply and nutrition, mire vegetation and peat [52, 54] and introduced the concept of hydrogenetic mire types and ecological mire types. These types take into account the water supply, the water movement in or above the peat column, and the types of peat formation. For more details on this classification, see Appendix 1 *(Table 7)*.

1.3. HYDROLOGICALLY RELEVANT SPATIAL STRUCTURE OF MIRES AND PEATLANDS

Scientists regard peatland and the area around it as a whole, understanding that the mire not only depends on its surroundings, but also influences it. Any anthropogenic change or a natural development of the peatland or its surroundings will affect the system as a whole.

Mires and fire hazardous drained peatlands have topographic, hydrological and hydrogeological surroundings that affect them and are affected by them now, before drainage and after rewetting. A mire or a peatland and its surroundings have a **hydrologically relevant spatial structure or a hydrostructure.**

We need to study the hydrostructure of the area before we extinguish the fire by raising the water level and before we start planning the peatland rewetting. It is important to understand the hydrostructure to assess the hydrological situation and state of degradation of a mire or peatland.

Peatland rewetting and mire restoration activities are long-term projects and are highly demanding. Knowledge of the hydrostructure is essential to facilitate predictions of the future development of a peatland complex.

Internal hydrostructure is the peatland itself, the mire or a portion thereof. An understanding of the internal hydrostructure gives us insight into the ways (or potential ways) water moves in the peatland and where the peatland water table is located.

The external hydrostructure is the environment outside the internal structure that affects the mire or the peatland; that is affected by the peatland, or will be affected after rewetting. Identification of the external hydrostructure is crucial for fire suppression or water retention.

The elements of hydrostructure can be identified through the analysis of topographic materials, including archival materials and land use history records (see Chapter 2), and by analyzing geodetic, geological, hydrological, pedological and geobotanical data (see Chapter 4).

CHAPTER 2. PEATLAND DRAINAGE AND TYPES OF LAND USE

According to the Food and Agriculture Organization of the United Nations (FAO), approximately 15% of the world's peatlands have been drained mainly for agriculture, grazing, forestry, and mining, leading to long-term degradation [42].

When a peatland is drained, its hydrostructure is changed significantly. The changes affect the risk of fire in the peatland, the ways in which peat fires are extinguished and artificial water retention (water retention is artificial because it has been brought in for the purpose of extinguishing fires). In a drained peatland, the groundwater table drops, whereby the types of water supply and the volumes of water entering the peatland change. For example, some of the slope water and groundwater will not reach all area of drained peatland because it drain through the ditch whereas in other places, water filters into the ground.

In the central and northwestern regions of Russia, mining peat as fuel for power plants and industry was the most common use of peatlands. In Russia (then known as the USSR), peat was mined on a very large scale from the turn of the twentieth century until the 1980s. Peat began to lose popularity as a fuel source in the 1970s, when gas became a more cost-effective option. Now, in the 2020s, only a few mines remain active. Peat is no longer used as a fuel on any significant scale. The use of peat today is primarily in agriculture, as a substrate for gardening and horticulture, and the volume of peat mining is much lower than in the previous century.

In recent decades abandoned peatlands have burned because the peatland bog constantly drains and dries up. When grassland in the surrounding fields is because the peatland constantly drains and dries up. When grassland in the surrounding fields is burned, or the fire escapes from other intentional or accidental fires, the dried peat easily catches fire. Abandoned former peat mines as well as peatlands in the Baikal region in southeast Siberia that were drained for agriculture (abandoned or still in use), are burning or are at risk of burning. Little is heard in regard to burning peatlands that were drained for land melioration in forestry in recent years, but fires sometimes occur in these areas as well.

There is also "unnoticeable drainage" caused by. Settlements and groups of summer houses (dachas) that have been built around drained peatlands and on mineral islands where the groundwater level has fallen as a result of melioration. Here, people not only use the groundwater, diverting it from the peatlands but, they also build houses with cellars and basements. The construction of houses with basements can lead to problems with the water supply because during the construction of basements, house builders often arrange drainage of the surrounding area so that the houses do not flood. The combination of new houses, digging wells and boreholes to supply water to the houses, and creating water supplies for cities drives the groundwater level to drop in the peatland.

This means there will not be enough fire water, particularly in the dry parts of peatland. If we can learn about these details of land improvements in advance, we can better plan for fire suppression and water retention.

2.1. PEAT MINING METHOD DRAINAGE-NETWORK DESIGN

There are three main methods of fuel-peat mining in Russia: quarrying, hydraulic (hydropeat mining process), and milling. Each has its own corresponding method of peatland drainage, the specifics of which must be taken into account when extinguishing a fire. A single peatland may have been exploited through the use of more than one such method.

2.1.1. QUARRYING METHOD

Quarrying (and hydropeat mining, which is explained in section 2.1.2) replaced manual small-scale digging at the beginning of the twentieth century when industrial peat mining began. Quarrying was replaced by milling in the 1960s. Peat was dug from small, individual quarries in close proximity and transported to special drying fields along the perimeter of the peatland or quarry.

Different methods of extracting peat from the deposit can be classified as quarrying:

- Cutting method: peat was mined manually, with a special spade.
- Elevator method: peat was mined manually, and lumps of peat were lifted from the quarry using an elevator conveyor.
- Dredging method: peat was mined with a bucket-chain excavator.

In Russia, peat quarries were up to 4–5 m deep and 4–10 m wide. As a general rule, one drainage ditch was dug across the center of the peatland. Quarries were dug on both sides of the ditch.

When a quarry filled with water, mining stopped and peat extraction moved to the next quarry. A separation wall 1–1.5 m wide was left between the quarries and it is these quarry walls and peatland margins that burn in a peat fire.

Abandoned quarries are usually already overgrown with a floating “mat” of vegetation. The “mat” is the floating layer of mosses, mostly *Sphagnum*, that builds up over time to cover the water surface at disused quarries. If the mat of vegetation is taken away the water is exposed and can be used for firefighting. On satellite images the exploited peatlands look like parallel green stripes. The stripes are trees that have grown on the separation walls between the rows of quarries *(Fig. 3)*.

2.1.2. HYDROPEAT MINING PROCESS

The peat deposit was washed out by powerful water jets, and the resultant flowing peat mass was pumped over to the drying fields around the peatland margins.

Exploited peatlands of this type are separate, slightly curved rectangular quarries, 120–200 m long, separated by a grid of earthen walls *(Fig. 4)*. In many places, the separation walls eventually collapsed, and the quarries merged into one large water body.

With this mining method, peatlands were not drained. However, they still contain separation walls, roads over peat and process areas that can burn.

2.1.3. MILLING METHOD

Milling is the main method of peat mining that is used today, in the few mines that remain operational. Milling is the most mechanized, productive method of fuel-peat mining. Before milling takes place, the peatlands must be extensively drained, which is a highly destructive process and is the most damaging of all peat mining methods. The peatland surface is carefully prepared: trees and bushes are cleared away, the top layer (acrotelm) is removed, and leveling is carried out. During mining, the top layer of the peat deposit, which can be up to 30 mm thick, is loosened by milling drums and left to dry in the sun and wind. Dry peat is collected and transported for temporary storage in peat piles, and then the milling and drying cycle is repeated.

The main drainage network as part of the milling method consists of main outfalls (the largest ones), main ditches, and field channels *(Fig. 5)*.

Fig. 3. The section of the peatland in which peat quarrying was conducted

Fig. 4. The section of the peatland in which the hydropeat mining process was conducted

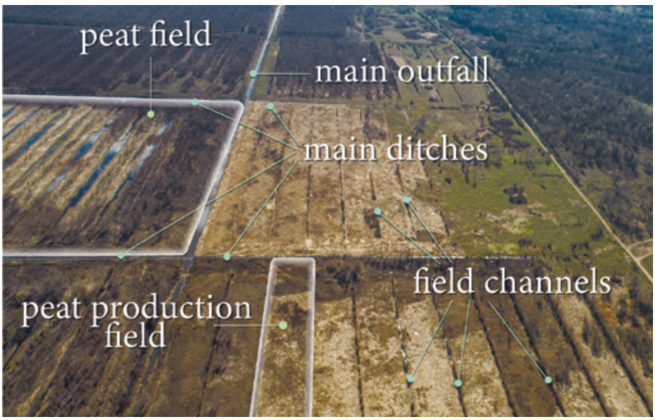


Fig. 5. Channel and ditch network structure for the milling extraction method (without hillside ditches, interceptor ditches, or other ditches)

The **main outfalls**, or so-called magistral channels, discharged water from the peatland to a receiving water body — usually a river with a strong current or a straightened bed.

Main channels/ditches flow into the main outfalls and divide the peatland into separate peat fields. Several pipe culverts enter the peat field across the main ditch.

Collecting channels are similar to main ditches. They collect water elsewhere and divert it to the main outfalls.

Field ditches divide the peatland into individual sections (peat-production fields) and divert water from production fields into the main ditches. At the beginning and the end of each production field, pipe culverts were made for tractors across field ditches. Piles of extracted peat were also placed in these areas.

Along the perimeter of the peatland, **hillside ditches and interceptor ditches** were dug, which cut off the inflow of surface water and groundwater, respectively. The interceptor ditches designed for interception of confined water (hydrostatic pressure) could be located not only along the boundaries but also inside the peatland. In addition, fire water supply ditches were sometimes made [10].

The Soviet Union drainage approach was based on standardization, and so the distance between ditches suggests the type of peatland drainage.

For example, for milling, the standard size of a peat-production field in a bog deposit is 20 × 500 m; in a fen deposit it is 40 × 500 m. Therefore the distance between field ditches would be 20 m and 40 m, respectively. The difference is because the filtration coefficient of bog peat is less than that of fen peat, that is, bog peat is less permeable to water.

The distance of 60–70 m or more between the ditches indicates peatland drainage for agriculture or afforestation *(Fig. 6)*.

However, because some agricultural drainage ditch intervals are less than 60 m, for example 20 m or 40 m, it is not possible to determine the exact use and type of deposit by distance alone, particularly in abandoned overgrowing peatlands. If the peatlands have long been abandoned, small field ditches may no longer be visible on satellite imagery.

More about different peat mining methods in Russia: Panov et al. [23]

SPACE IMAGE GOOGLE EARTH

Fig. 6. A bog drained for afforestation

Peatland changes in appearance and structure following any peat mining method. The peat stratification changes, with the lower, older layers, types and varieties of peat turning up on the surface. What was once a bog or a bog deposit may become a transitional peatland or a fen in terms of surface peat type or deposit type. Ditches or quarries open hydrogeological windows into which water filters quickly from the peatland or, conversely, rises quickly from confined groundwater horizons. The type of water supply also changes.

2.2. EXTRACTION OF OTHER RESOURCES FROM PEATLANDS

Peatlands were drained not only to mine peat. Other resources have also been found in peatlands, including gyttja (sapropel, which is a sediment rich in organic matter), vivianite (iron phosphate), and bog ore.

Glass sands, building sands, gravel, and clay were often mined near peatlands, which significantly altered the groundwater table and the type of groundwater supply, often making the peatlands drier.

We need this data to assess the external hydrostructure of the peatland and its changes. If there are quarries left over after mining, we can consider them as sources of fire water.

2.3. PEATLAND DRAINAGE FOR AGRICULTURAL NEEDS

In Russia, preparation of peatlands for agricultural use as hayfields, pastures and croplands was performed in two ways:

- Fens were drained (to take advantage of nutrient-rich fen peat soils and the diversity of water supply and nutrients).
- After peat mining, peatlands or sections with the remaining peat layer were taken over for agriculture (as a type of land recycling).

In the former case (fens), a drainage network and a system of water-regulating structures (such as sluices, weirs, culverts.) were created, and the land was cultivated. In the latter case (mined peatlands), the drainage network that existed during peat mining was reconstructed, and new hydrotechnical constructions were created *(Fig. 7)* — usually on main outfalls — because it was important for agriculture to drain the area and to regulate water levels during dry periods.

MARIA VASILIEVA / GP

Fig. 7. An active hydrotechnical construction with a lift gate

Draining peatland to create agricultural space significantly degrades peat soils, which become very compacted and saturated with nutrients. Drained and nutrient-rich peatlands will release their stores of carbon and nitrogen as carbon dioxide gas and nitrous oxide into the atmosphere, contributing to climate change and global heating. The degradation of peat soils affects the patterns of fire propagation and the properties of peatland during fire suppression or water retention. Peat soil has low permeability and must be repeatedly dug up and mixed with water to extinguish a fire.

The diffusion of oxygen and flue gases in the soil is minimal, and any gases present are rich in nitrogen. For rewetting, it is better to remove the complex soil layer or create a hydrogeological window system and only rewet the area from above.

When retaining water for the purpose of extinguishing fires, we can use abandoned or active hydrotechnical constructions to raise the water level or to redirect water to the area of the peatland where it is needed.

2.4. MELIORATION IN FORESTRY

Melioration in commercial forestry is aimed at improving land quality and creating conditions for the construction of road infrastructure. Unless it is carried out in the area of former peat mining, of former agricultural use or in areas of road construction, melioration in forestry results in less peat compaction than do agricultural land amelioration and milling peat mining. Unlike peat mining and the agricultural use of peatlands, heavy machinery only enters a peatland for digging or clearing ditches/channels, for planting trees and, decades later, for felling.

Pristine peat has mostly high porosity, low density, contains a large quantity of organic matter and facilitates free movement of water. By contrast, drained, degraded and compacted peatland has low porosity and high density. In drained peatland, tree roots can cause a potential fire risk because the roots can cause a fire to spread fast and deep into the peat. When the peatland has been drained, tree roots make holes in the peat mass. When the peat is dry, fire can develop along the roots much more quickly than through undrained, pristine wet peat with fewer tree roots. There is a difference between the degree of compaction and porosity of peat in peatlands drained for forestry than in peatland drained for agricultural reclamation and drainage for milling mining. The difference in compaction is because forestry plantations are usually left alone for decades or longer periods than for agricultural land. (See also chapter 3.2)

The settlement of peat due to drainage is more pronounced when peat compaction is low. Wide low level areas are formed along the ditches, sloping toward their beds. If there is no possibility to construct high, wide dams to cover such terrain depressions across the width of the low level area, rewetting should be performed by means of cascades of narrow dams that cover only the ditch beds.

The design of drainage networks was based on the knowledge and experience of workers, who took local conditions into account. Therefore, when extinguishing a fire or rewetting a peatland it is necessary to study the local archival and historical records concerning drainage of the peatland. It is important to find, if possible, the people who worked at the peat enterprise. If no information can be found, then local maps, ground reconnaissance, satellite imagery and drone footage can be of assistance.

When forests are drained, the fire risk increases. To create the conditions to prevent fires from spreading, firebreaks and clearings are made in forested peatlands along ditches in addition to weirs and sluices on drainage ditches, water-supply ditches and fire ponds.

The ditch network is often neglected and overgrown with swamp and mire vegetation, occasionally with *Sphagnum* mosses. Soviet and Russian scientists call it secondary paludification [26 and 37].

German scientists consider this process as a stage of mire self- regeneration [41 and 57]. If water from these ditches is required for fire suppression, all vegetation in the area near the motor pumps will have to be locally cleared from the ditches.

Thus, we have two alternatives for the handling of such ditches: (1) clear the wetland vegetation — for the ditches to be conveniently used as a source of fire water; (2) accelerate the overgrowth of such ditches — for secondary paludification (self-regeneration of the mire) to reduce the fire risk and raise the groundwater level. In areas that were drained for forestry needs, the second option is generally preferred for fire control.

CONCLUSIONS

The standards and recommendations for peatland drainage in Russia have changed over time and were not always followed by land users. (The situation may be different in other countries.) Additionally, drainage systems may have been altered during land recycling. What we see on satellite images or from a drone (for example, the distance between ditches) can only give us a general idea and assumptions about what this peatland was, how it was drained and what it was used for. Next, we will search for more information and survey the peatland itself (Chapter 4).

CHAPTER 3. WILDLAND FIRES IN SWAMPS, MIRES AND PEATLANDS

3.1. TYPES OF WILDLAND FIRES IN SWAMPS, MIRES AND PEATLANDS

In this book we talk specifically about peat fires, and often this term is only understood to imply the processes related to smoldering peat. However, many different types of fires occur in swamps, mires and peatlands. For example, grass or forest can burn on the mire/peatland surface, resulting in multiple locations of smoldering peat. Conversely, a peat fire started by a campfire can cause a forest or grass fire.

- **Ground fires** can develop in forested and unforested areas. The Russian approach to fires classification distinguishes two types of ground fires: humus fire and peat fire.

  Humus fires develop in forests with thick forest litter and soils rich in organic matter, often accompanying a crawling fire. Generally, humus fires are shallow (rarely deeper than 20 cm). They often ignite from an unextinguished campfire or a cigarette butt. Burning tree roots can cause trees to fall and flames to spread.

  Peat fires on drained peatlands are a special case of ground fire. They develop in peat soils, forested peatlands or open spaces, such as abandoned peat mines that are often taken over by summer houses (dachas), as well as abandoned peatlands that have been drained for agriculture. Burning tree roots can cause trees to fall and flames to spread.

- Large numbers of peat fires begin as **grass or reed fires**, especially by open burning in areas of dry grass. In Russian practice, setting fire to dry grass is illegal (and yet traditional for many regions). The practice of burning of dry grass from the previous year is undertaken by local residents primarily for agricultural purposes to accelerate grass growth in pastures and get rid of unwanted grass, weeds and unclaimed straw in hayfields. Peat smoldering can also result in a secondary grass fire, which is grass burning from the edges of the smoldering point.

- **A forest crown fire** can happen in drained peatland and be accompanied by peat smoldering and falling trees.

- **A crawling forest fire** on top of peat soil can easily turn into a peat fire. Conversely, a peat fire can develop into a crawling fire.

- **A swamp or mire fire** is a fire in an undrained swamp or mire during a period of drought or sometimes in winter if the grass is dry. Dry mire grass vegetation and mosses, litter and acrotelm (active layer) burn. Acrotelm burns according to the pattern of a peat (ground) fire. Acrotelm is characterized by high soil porosity, meaning that the fire will spread more rapidly than in dense peat conditions.

Fire spread rates have been studied extensively and presented in the tables of forest pyrology textbooks [27].

3.2. CHARACTERISTICS OF PEAT AS A COMBUSTIBLE MATERIAL

Peatlands and peat deposits are diverse, and peat fires are difficult to detect and extinguish. What characteristics of peat as a combustible material need to be understood and considered to properly extinguish a peat fire?

- Peat has a high content of bituminous resin, which boils when smoldering. The resin evaporates and condenses in the nearby cold (non-burning) areas of peat, thereby impregnating them. As a result of the bituminous resin condensation, the surface and boundaries of the smoldering area often become almost impermeable to water.
- The combustion process under oxygen deficiency produces semi-coke and peat coke. These are solid hydrophobic formations, often forming layers in the lower section of the fire point in peatland. They are characterized by a low ignition temperature and high heat of combustion. Peat may smolder beneath them in the fire point. However, this is extremely difficult to detect and extinguish because peat coke prevents water infiltration and retains heat and smoke, which allows fire points to be detected.
- Drained peatlands conceal enormous reserves of combustible materials. Up to 1 metric tonne of combustible material can burn on 1 m^2 of drained peatland per season (the average depth of fire points is 1.5 m).
- Peat can smolder, given its relative humidity of as much as 72%.
- The air reserve (oxygen in the air) in the dried peat allows smoldering to continue for a long time without access to an external oxidizing agent.
- The spread of the peat fire point in soil and its breathing, that is, the diffusion of oxygen and removal of combustion gases, depends on the porosity of the peat, which is determined by its degree of density. The acrotelm and the upper layers of natural mires have high natural porosity. The peat is heavily compacted after milling or agricultural use, during which heavy machinery passes over it repeatedly. It can become further compacted under the access roads and former narrow-gauge railway that have been used to transport the peat. Different mechanisms of the spread of peat fire points in soil follow from this.

  There is a concept of peat macroporosity. Macropores are animal burrows or cavities around tree roots, which are often larger in peat than in mineral soil. There are examples where ground fires spread along animal burrows (such as those of beavers) or along tree roots *(Figs. 8 and 9)*. Fires develop underground relatively quickly, fire points proliferate, and an underground burning cavity emerges into which firefighters could fall when attempting to extinguish a fire.

  Cavities can develop from cracks in heavily drained peat or from weight loading as well as near the margins of the peat fire point *(Fig. 10)*.
- Combustible gases are released during a process called pyrolysis (smoldering under oxygen deficiency). The gases burn in hidden cavities and animal burrows in the peat and are particularly dangerous in branched burrows, which have air inflow and draft. In beaver burrows along the banks of drainage ditches, the peat fire points often extend for tens of meters. Firefighters can easily fall into such underground cavities. Moreover, the development of fire points in burrows can cause tree roots to burn even if they are located some distance away from visible fire points.
- The main difficulty in extinguishing peat fires is that smoldering can resume very easily. Smouldering can start at temperatures of between 60°C and 65°C in a fire point that has not been fully extinguished, where peat has already been transformed by pyrolysis and smoldering. Smoldering can easily

PHOTO BY: FRANK EDOM

Fig. 8. Linear spread of the peat fire point along the tree roots. The photo was taken a year after the fire

PHOTO BY: MARIA VASILIEVA/GP

Fig. 9. Animal burrows and cavities under tree roots are good conductors of fire

PHOTO BY: FRANK EDOM

Fig. 10. Peat fire points in peat cracks

reoccur after incomplete fire suppression due to contact with insufficiently cooled areas. When extinguishing peat fires, the maximum acceptable temperature of fire suppression is taken as 40°C — it is important to use scientific instruments to measure the temperature because visual control is not reliable. Ensuring that the peat temperature does not exceed 40°C prevents the areas from re-igniting.

- It is difficult to determine the actual boundaries of a peat fire point. Peat burns out unevenly, and overhanging fire edges can form above the burned spot.
- When a peatland that is overgrown with trees begins to burn, the entire tree stand dies and falls quickly because the tree roots burn, creating debris. The debris can ignite when it comes into contact with smoldering peat, causing a secondary open fire that facilitates the spread into new areas. Most but not all trees fall with their tops toward the center of peat fire points. Extinguishing a peat fire without first clearing the debris and removing hazardous trees (with burned roots) is dangerous and generally unproductive.
- Smoke from pyrolysis and low-temperature combustion produces large quantities of hazardous substances that are harmful to health. Of all types of wildland fires peat fires produce the most carbon monoxide and products of incomplete combustion of organic compounds. At high humidity and in the absence of wind and powerful ascending air flows (convection columns), combustion products are not vented away from the fire location, thereby covering the burning peatland with a cap of white, opaque smoke.

3.3. THE FORMATION AND DEVELOPMENT OF PEAT FIRE POINTS DURING THE FIRE SEASON

Most peat fires occur in spring as a result of dry grass burning on abandoned agricultural lands and on the surfaces of drained peatlands *(Fig. 11)*.

For Central Russia, peat fires usually occur in April and May, just after the snow melts and floodwaters recede. During spring, small sporadic peat fire points often emerge. The small fires are difficult to detect quickly in the vast burned areas after grass fires. When the soil is still wet, smoldering occurs first on the elevated areas that dry out first on the piles around ditches *(Fig. 12),* uplands, and former peat storage sites *(Fig. 13)*. Smoldering areas of peat are very likely to form along the walls of old burned spots.

Peat fire points that emerge in spring develop slowly, usually growing several centimeters a day but sometimes tens of centimeters. Areas of burning peat are usually surrounded by burned areas of grass. Secondary open burning is possible only from the outermost peat fire points along the boundaries of the area that has been exposed to open fire. Not much smoke is produced from peat fire points, and therefore it is usually most visible in the evening before fog and dew appear, and in the early morning after rain during periods of high humidity.

Peat fire points often grow slowly until the summer months. Dry weather contributes to increasing the area of peat that can burn and increases the risk that open burning can resume at the fire edge *(Fig. 14)*. By summer, there may no longer be traces of dry grass that have been deliberately burned.

As a general rule, fires in places that are almost never visited create the impression among local residents that peat fires either self-ignite or are deliberately set on fire. No one remembers the spring grass fire that started elsewhere and spread. To establish the root cause of the fire and find other possible peat fire points, one should carefully search for traces of spring burning of dry vegetation and other fire points within the boundaries of the area in question.

ILLUSTRATION BY: TATYANA KHAKIMULINA

Fig. 11. Cross section of a typical, long-standing, active peat fire point. The state of the peat fire point is typical for summer season

PHOTO BY: MARIA VASILIEVA/GP

Fig. 12. Typical peat fire point at the pile of a drainage ditch in spring. Evidence is visible of dry grass that was deliberately burned, which caused the peat to catch fire

PHOTO BY: NATALYA MAKSIMOVA/GP

Fig. 13. A peat fire on a former peat pile that originated from grass that was deliberately burned in the spring. The photo was taken during the second half of summer

PHOTO BY: MARIA VASILIEVA/GP

Fig. 14. A typical peat fire point in a forested area. The state of the fire point is typical for summer. The resumption of open burning can be seen at the fire edge

PHOTO BY: FRANK EDOM

Fig. 15. An active peat smouldering point in winter. An open fire has emerged beneath the roots of a tree

In summer, new peat fires can result from campfires, cigarette butts and crawling forest fires.

Both in fall and in spring, multiple new peat fire points can emerge when areas of dry grass are deliberately burned. In the spring period, fires can emerge in small areas that are drying after snowmelt more quickly than the main peat mass. In the fall, the entire surface of the peatland can be dry and peat fire points can emerge over a wide area. This is because the peatland in fall is dry not only on local elevations, such as soil on ditches, but also over its entire surface. Fortunately, peat fires that occur in fall usually do not have time to form deep fire points and to start releasing intense smoke before the sustained precipitation of the fall/winter period. However, in extremely dry years there have been instances of peat fires in the fall or of secondary propagation of earlier peat fires to the new areas due to burning dry grass, which can cause serious smoke problems in settlements.

Peat smoldering gradually subsides in winter. Smoke emissions from individual peat fire points may continue until spring. Snow thaws and hidden peat fire points form under the snow. Peat smoldering stops completely only during the active spring snowmelt. However, in some low-snow years, peat fire points can outlive the winter and continue growing the following season *(Fig. 15)*. Such long-lived underground fires have been called "zombie fires".

As a general rule, a certain number of fire points will outlive winter in the areas that are insufficiently infiltrated by floodwaters, such as on former peat piles, narrow-gauge railway embankments, under the roots of large trees, in areas with developed turf, theedges overhanging far over the fire point, and in areas located high along the edges (piles) of ditches. Such peat fire points must be fully extinguished in spring.

3.4. ABOUT SPONTANEOUS COMBUSTION OF PEAT

There are no known cases of spontaneous peat combustion in deposits, even in drained and exploited peat deposits or in undrained mires.

Spontaneous peat combustion is a process that occurs exclusively in milled peat with a moisture content of approximately 35 %. Spontaneous peat fires occur only during the year of mining. The process is preceded when peat reaches a critical temperature of 60 to 65°C (in some cases the peat has self-heated).

Self-heating peat involves complicated physicochemical and biological processes (aided by bacteria) that take place during artificial storage of peat in a pile with a height of more than 2 to 3 m at a distance of 1 to 1.5 m from the surface of the pile. The self-heating process is very slow and can be counteracted by mixing self-heated peat with wetter, colder peat or by covering the heated area with layers of wetter peat. The peat pile where self-heating took place will need to be removed from the storage location immediately.

The processes that led to peat self heating are described in more detail in the scientific reports and proceedings of the All-Russian Research Institute of Peat Industry (VNIITP) and in scientific papers [28].

Peat fires in individual peat piles occur because the peat has reached the critical temperature of 60 to 65°C in the first few months after the peat piles were made. The subsequent heating from 65°C to the point of combustion takes a few days.

There are no known cases of self-heating peat piles in subsequent years after mining, even if the peat has not been removed and the peat pile has remained in the field where the peat was mined. Peat piles that are more than one year old can burn but only when ignited by external sources *(Fig. 16)*.

CHAPTER 4. INFORMATION REQUIRED FOR PEAT FIRE SUPPRESSION MANAGEMENT

4.1. ANALYSIS OF PEATLAND INFORMATION

Before starting to extinguish a peat fire, information about the drained peatland and the history of its development must be gathered and analyzed.

If there is a stable phone or Internet connection, this information can be gathered on the way to the fire scene. However, if you are engaged in fire safety for areas with drained peatlands, it is best to gather information in advance. This will involve making deliberate, rational decisions on the tactics of firefighting, and it will help predict the emergence and development of fires.

The following information is required.

1. **The timing and method of peatland drainage, and the type of intended land use (e.g., peat extraction).** This determines the structure and functional purpose of the drainage-network elements that can be used as water sources and barriers to the spread of an open fire. At the same time, these elements make it difficult to move the fire engines around.
2. **Whether peat extraction has been performed: if it was, one should know how much peat and what type of peat remains in the deposit.** This determines the actual terrain relief and depth of the peat deposit.

   Also, the depleted milling fields and quarries may be lower than is indicated on the maps. It may be possible to fill them with water by blocking some of the runoff. It is important to understand the thickness and type of the remaining peat. This determines whether the peat will burn out quickly before reaching the mineral bedrock or whether the fire will be deep and difficult to extinguish.
3. **What method of peat extraction was used?** This determines the structure of the drainage and road networks, including narrow-gauge railways.

PHOTO BY: MARIA VASILIEVA/GP

Fig. 16. A partially burned, abandoned peat pile

In the final decades of the peat mining industry in Russia, from the 1950s to the 1980s, the milling method was used for peat extraction. The mined areas are flat peat fields bounded by main channels and divided by field ditches into separate, identical extraction units called peat production fields. Each peat field has one or more pipe culverts across main channels for machinery access. Field ditches also end with pipe culverts. Extracted peat piles were placed at the boundaries of peat production fields, and stumps or tree roots extracted from the peat were stored at the boundaries of larger peat fields *(Fig. 17)*. It is particularly difficult to extinguish the fires on the peat piles and stump piles that have not been removed.

4. **The condition of the access roads to the peatland.** Information about the roads within the peatland and its access roads, their condition and the places where passage is difficult or impossible allows one to properly plan the fire extinguishing operations.

5. **The current state of the drainage network.** It is important to know the present condition of the drainage network and fire ponds. Is there a possibility of regulating the quantity of water by using the remaining or newly constructed hydrotechnical constructions (i.e., sluices, gates, dams, pipe culverts)?

   For example, hidden drainage was built for the purposes of forestry and agriculture. The drains and wells of this network can be used as water sources. After the completion of peat extraction and other activities, the drainage network and the network of fire ponds and ditches may have been partially overgrown, collapsed or blocked by beaver dams. Occasionally, this causes the present water flow to deviate from the design made by land-improvement specialists at the time of drainage-network creation.

   Fire ponds have always been designed for the supply of water for extinguishing and filling the ditches to be sufficient to put out fires. They were usually equipped with ramps and piers for fire engines. It is important to have an understanding of the extent to which the firefighting network of a peat enterprise can be used in fire suppression.

6. **Where and when did peat extraction or agricultural activities cease and forest overgrowth of the peatland begin?** This allows us to predict how easy it will be for machinery to pass through the areas as well as to estimate the volume of burned tree debris.

7. **Peat characteristics, i.e., composition, degree of decomposition, density, porosity, moisture, ash content and others.** For example, peat that is looser and drier burns several times faster than dense, wet peat. The peat fire points with high ash content appear to be shallower than they actually are, with a thicker layer of loose ash. This may cause an accident if the actual depth of the peat fire point is underestimated.

PHOTO BY: PAVEL LUZAN

Fig. 17. Stump storage in the fields of an active peat enterprise

- **The type and condition of vegetation on the peatland surface.** This will suggest the areas of fire spread and its speed.
- **The geological structure where the peatland and its surroundings are located.** Examples include a terminal or ground moraine, outwash plains, fluvial terraces and piedmont alluvial plains. When we know the geological conditions, we can make assumptions about possible options of water supply or water losses in the peatland.
- **The previous fires record.** This will help us predict the locations in which peat fire points are most likely to reoccur.

  The edges of old burned peat spots catch fire most often because they more easily dry out with exposure to the sun. Additionally, the previous fires record can suggest how much peat remains, how forest overgrowth proceeds, and whether old debris of burned and fallen trees will be encountered.
- **The land use category and the current land use regime.** This is important to understand what services and resources could be involved in fire suppression.

  Some of the necessary information about the mire or peatland can be obtained from public sources. Maps and satellite images, data on land ownership and land use categories, and boundaries of forest districts are available on the Internet. Certain information about the history of peatland exploitation and drainage operations, as well as about peat extraction, can be found online.

  The municipal district administrations that are interested in extinguishing peat fires can help locate the necessary information. It is useful not only to request data on an individual mire or peatland but also to request the results of other geological surveys in the area, such as those pertaining to water levels in wells and boreholes.

If the necessary data is not readily available from documentary sources, some information can be gathered through independent exploration using a peat borer to obtain a visual assessment of soils and the groundwater table by examining the walls of the deepest ditches.

4.2. SOURCES OF ARCHIVAL AND GEOLOGICAL INFORMATION ON THE PEATLAND

Information on the history and geology of the area, its peat reserves and peat deposits, groundwater table and other information should be gathered before it becomes necessary to extinguish a peat fire. Data can be found in archives (including those of the district administrations), in open sources available on the Internet, in geological funds, and in the records of federal and regional agencies that hold information on swamps, mires, peatlands and peat deposits. State geological archives (geological funds) are particularly important and are a very useful source of information. For example, in Russia the geological archives areheld by the Rosgeolfond, and in Germany geological archives exist in every federal state. Looking at geological maps and details of local geological surveys of peatlands, hydrogeology and fuel can help you to understand the geology beneath the peat.

When contacting an archive office, it is helpful to know the full name of the organization that performed drainage or exploited the peatland. Many archive offices in Russia have their own websites with electronic catalogs or collections of scanned paper documents. If searching the website does not help, contact the archives by e-mail or phone.

In addition to publicly available archives, there are those of various peat exploration or land improvement agencies and their customers. Scientific institutes that have dealt with or are dealing with swamps, mires or peatlands will have archive material. Highly detailed documents can sometimes be found there, but occasionally access has to be negotiated.

The Internet is the fastest, most accessible source of information and enables collecting and analyzing maps and satellite images for relevant information for the area in question as well as to request search assistance on specialized websites. Below are examples of Internet resources used in Russia:

- http://nakarte.me: topographic maps;
- http://etomesto.ru, http://starayakarta.com/: historical maps of the area of interest. By comparing maps from different times with contemporary maps and satellite images, it is sometimes possible to learn about the history of land use and about the previous natural state of the swamp or mire;
- http://geokniga.org/maps: geological maps of different types and scales. Geological maps at a scale of 1:200 000 are particularly useful: a hydrogeological map, a Quaternary deposit map, a Pre-Quaternary deposit map, with explanations. Of all the maps on the scale 1:200 000, the hydrogeological map is the most important and useful for fire-prevention measures or for planning rewetting measures (that is, if a map to that scale exists and is available in the region in which you are working);
- http://www.geolkarta.ru/: more modern geological maps, the 1:200 000 maps are also of interest here;
- Google Earth Pro offers high-resolution satellite imagery, including those of previous years. It is best to download the app and install it on a computer or a tablet.

Useful historical, geological, geographical and other information can be found in the local history sections of regional and district libraries, local history museums, archives of forestry authorities and other governmental organizations concerned with drainage and land melioration.

One can obtain a lot of interesting information about the functioning of the peatland drainage system from former employees of closed peat enterprises or employees of the organizations that were involved in peatland drainage. Sometimes they keep maps and charts with information on the operation of peatland drainage systems.

4.3. ELEMENTS OF THE HYDROLOGICAL REGIME AND WATER BALANCE OF A PEATLAND

Water balance is the ratio of all water that enters and leaves a peatland *(Fig. 18)*.

The knowledge of water balance and hydrostructure (see paragraph 1.3) allows us to understand where the water comes from in different types of swamps, mires and peatlands as well as the ways and means it escapes. On that basis, we can develop measures to retain water or reduce water losses in the drained peatland.

The way water enters a mire or peatland:

- As precipitation, i.e., rain, snow, hail or condensation.
- As a result of groundwater inflow from an underground hydrological catchment, possibly from different groundwater horizons.
- As surface runoff or interflow from higher terrain (slope water) or from the surface hydrological catchment.
- When a stream or river flows into the peatland area.
- During temporary flooding from adjacent rivers, lakes or seas.

The ways in which water escapes a mire or peatland:

- As runoff through ditches, channels and earth-pipes of the drainage network or through the rivers and streams flowing out of the mire or peatland.
- As transpiration, that is, evaporation from the surfaces of tree leaves, grasses and mosses during the plant life cycle, being imperceptible but intense (especially in summer); depending also on solar radiation and wind.
- As physical evaporation from the open water surface of ditches and low, excessively wet areas (also depending on insolation, that is, the level of solar radiation and wind: the higher they are, the stronger the evaporation will be).
- As physical evaporation of the precipitation retained by plants (interception).
- Filters into underlying permeable soils through the peat deposit or the bottom of ditches deep enough to reach sand layers.

Depending on the difference in the volume of water entering and leaving the peatland, so that based on a positive or negative water balance, the water level increases or decreases.

Given certain initial data, it is possible to calculate the elements of water balance and the nature of their change during the year. (That is called “hydrological calculating” or “hydrological modeling”).

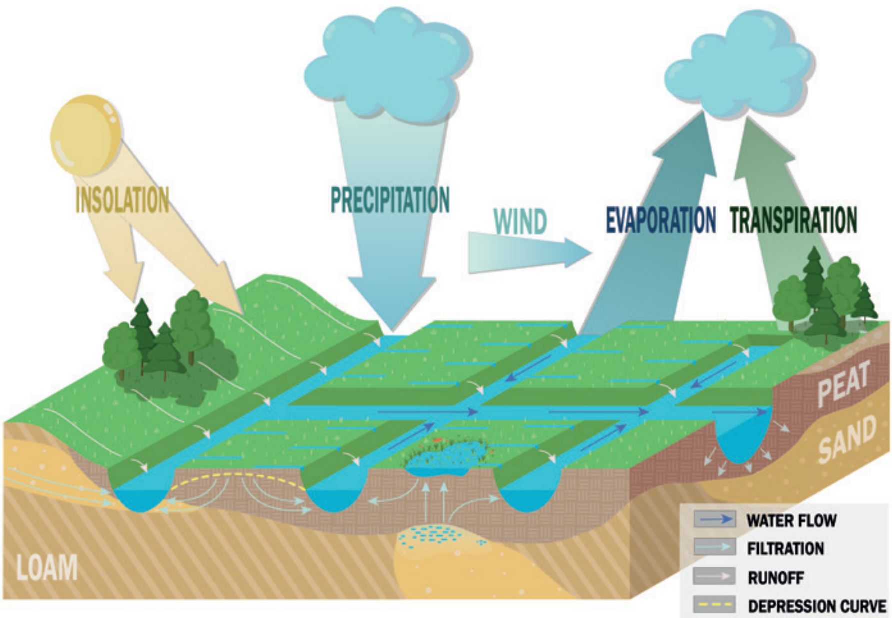


ILLUSTRATION BY: OLESYA VOLKOVA

Fig. 18. Elements of the hydrological regime, water balance and hydrostructure of a peatland

4.4. TYPES OF MIRES AND PEAT DEPOSITS: BOGS, TRANSITIONAL MIRES AND FENS

Types of mires, peat and peat deposits (bog, transitional and fen), and types of water supply of the upper layers of peat deposits and vegetation have been addressed in Chapter 1. Let us now consider how this information helps us draw conclusions that are important for the management of peatland fire-suppression activities. We will be able to assess the most likely locations of water sources to extinguish fire and then consider options for rewetting the area.

The type of water supply for a drained peatland can be inferred from the map, the drainage network layout, the peat composition and the degree of stratification.

4.4.1. FEN PEAT DEPOSITS

Natural fens and peat deposits are characterized by the prevalence of minerogenic (that is, underground, slope, riverine and/or marine) water supply. Fen peat deposits are usually located in depressions in valleys, floodplains and river deltas as well as near lakes and seas *(Fig. 19)*.

The peat of fens is mainly formed by the remains of sedges, reeds and hypnum mosses. Fen peat may contain the remains of cereals and fragments of tree roots (often black alder). In comparison to bog peat, fen peat is often denser when dry, the degree of decomposition (amount of humus) is usually higher, and the ash content is higher (5 % and more), the porosity is lower and the mineral composition is richer. A more detailed description is given in paragraph 1.1.

The burning temperature of fen peat is lower than that of bog peat, but the bitumen content is generally higher. The peat has a dark color and as a result, fen peat leaves black marks on the hands. The peat ash is produced as a deep, loose layer and is generally a mottled, irregular color, and can be red, reddish, brown, yellow or gray.

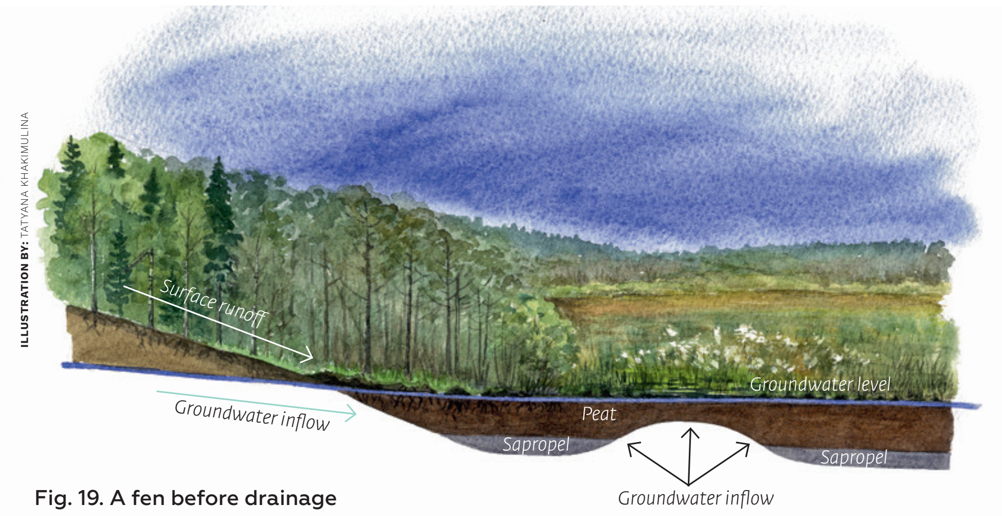


Fig. 19. A fen before drainage

During the main period of industrial peat mining, fens were drained by drainage networks that were built in the fen itself. Hillside ditches were made at the fen's boundary and the higher terrain, which served to intercept and divert the surface, slope and subsurface runoff that fed the fen horizontally. Interceptor ditches could also be created, using deeper ditches to intercept the deep groundwater supply of the fen *(Fig. 20)*. For more information, see paragraph 2.1.

If we are extinguishing a fire in the upper part of a drained fen, it is advisable to keep water in the hillside and interceptor ditches by creating a cascade of dams and blocking them at the drain pit.

If the fire is in the lower part of the fen, it is advisable to create dams on field and main (collecting) channels and main outfall channels (in Russia, these are called "magistral [main] channels"), using large channels that divert water directly from the peatland to obtain water *(Fig. 20)*.

Occasionally, springs are formed on a slope at groundwater outlets and in places where the water-impermeable layer is disrupted (at the so-called "hydrogeological windows"). Such groundwater outlets are not necessarily associated with depressions and slopes visible on the surface. They can be identified visually according to characteristic moisture-loving vegetation or abiotic features (Appendix 1, Table 7).

Groundwater outflow locations can also be identified by the characteristic color of iron oxides: red and brown stains on ditch slopes, in puddles, or in ditches *(Figs. 21 and 22)*. More abiotic signs of spring waters can be found in Table 7 (Appendix 1). Such excessively wet areas with large groundwater inflows become the best places for temporary fire ponds and wells.

4.4.2. BOG PEAT DEPOSITS

Natural bogs are characterized by the prevalence of atmospheric water supply of the bog vegetation or of the upper horizons of the peat deposit.

Such mires or peatlands can be located in watersheds. They may be at a later stage in the succession of a former fen, in which the layer of overgrown moss, primarily various species of *Sphagnum* and peat deposits from it, has grown to such an extent that it is elevated above the surrounding terrain and the water supply of peat-forming vegetation has become predominantly atmospheric *(Fig. 23)*.

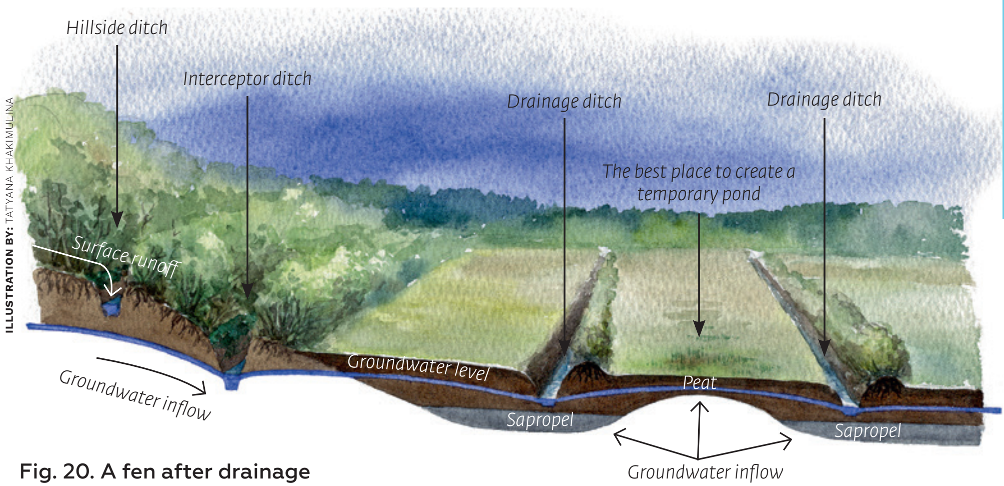


Fig. 20. A fen after drainage

PHOTO BY: FRANK EDOM

Fig. 21. Outlet of ferruginous groundwater in a ditch

PHOTO BY: FRANK EDOM

Fig. 22. Outlet of ferruginous groundwater in a depression on a ditch bank

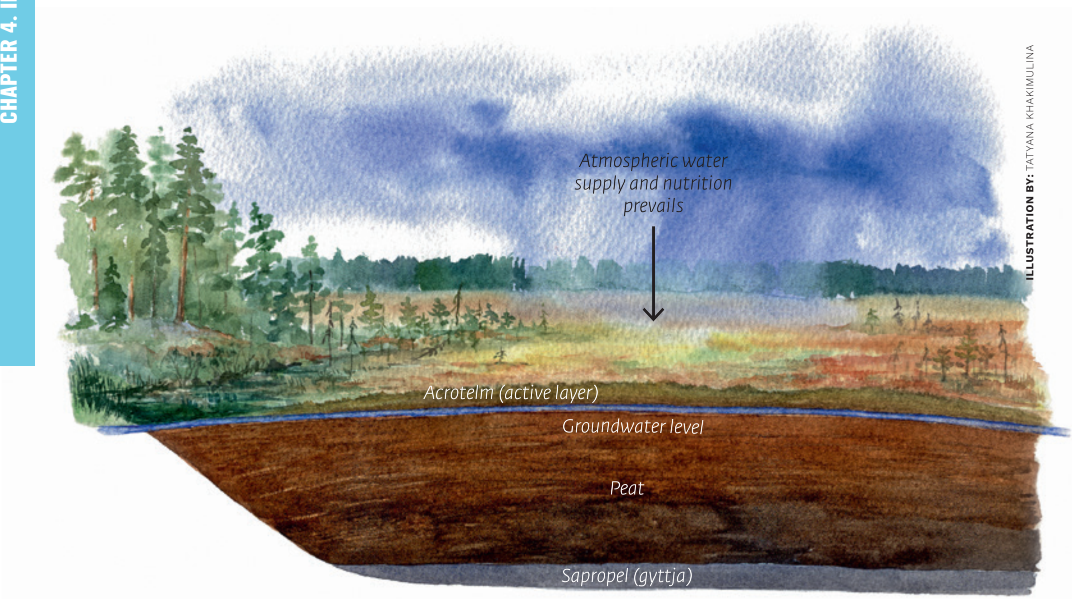


ILLUSTRATION BY: TATYANA KHAKIMULINA

Fig. 23. A bog before drainage

In such a mire, the wetter parts are usually at the margins and the drier part is closer to the center. There may be isolated wet areas in the center (e.g., hollows and pools) .

The peat of a bog is mainly formed by the remains of *Sphagnum* mosses, often with a mixture of cotton grass, with the remains of bush and tree roots (most often pine trees).

Bog peat, as compared to fen peat, is loose, more porous, its ash content is low (1 % to 3 %), the calorific value is higher, and the mineral composition is poorer. Bog peat was most often used as fuel. When burned, it produces little ash (non-combustible mineral residue) because rain and snow have few minerals and a bog has no other mineral source.

The combustion of bog peat is more likely to produce semi-coke and peat coke. The color of the peat is brown or even yellowish brown. Peat ash is usually of a single color such as white or light yellow.

The drainage network on a bog peat deposit consists of main outfalls, main channels, and field ditches *(Fig. 24)*. Main channels often pass through a watershed, that is., the peatland is drained in two directions. The water collected by field ditches is discharged into main channels and then into main outfall-channels (magistral channels), from where it enters receiving water bodies (lakes and rivers — so-called receiving streams), often with straightened, deepened riverbed for quicker water discharge.

Most bogs developed from a fen or a transitional mire or peatland, which often surround areas of bog peat. Hillside ditches and interceptor ditches may have been constructed for drainage along the margins of a bog, disrupting the connection between the drained bog and the adjacent wetlands. In low-snow winters and dry summers, the surface of bog peatland dries out and becomes a fire hazard.

When extinguishing fires on bog peat deposits, the goal is usually to retain rain and water from snow in the main outfalls and main channels by creating dams. It is not recommended to deepen the ditches and channels.

If we encounter transitional or fen peat in the peat deposit below the bog peat

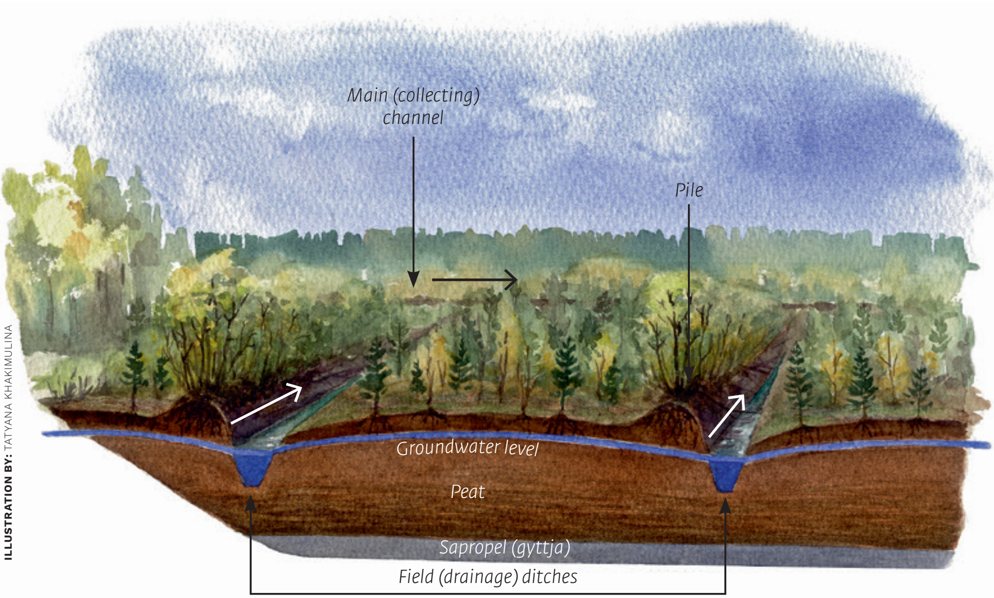


Fig. 24. A bog after drainage

(or see it after peat mining), there may be minerogenic (underground, riverine, slope) waters in the ditches, apart from atmospheric water. They should also be retained in summer because groundwater supply is usually more permanent and stable than the atmospheric water supply.

Layers of gyttja (sapropel) — i.e. organic bottom sediments of plant remains, especially highly decomposed water plants and algae (see [49]) — may be found in the lower layers and at the bottom of a bog peat deposit (if they were formed from an overgrown water body). The gyttja layers are mostly impermeable to water. If previous surveys show some areas where the sapropel layer at the bottom of the mire or peatland is interrupted with hydrogeological windows and other soil types, such as sand, these areas are best suited for groundwater extraction. It is worth the effort to drill and dig temporary fire ponds, wells and boreholes.

If peat fires require water to be pumped into artificial temporary ponds near the smoldering peat fire points, the nature of the underlying soils should be taken into account when creating such ponds. If the soil is sand or sandy loam, which are highly permeable to water, it is necessary to leave a water-impermeable layer of highly decomposed peat (or peat from degraded layers) at least 0.5 m thick or clay at the bottom of the pond. Do not dig down to the sand, or the water will escape.

For example, bog peat deposits formed on large, sandy plains were often drained by large ditches that reached the mineral water-permeable soil (sand), thus greatly increasing the filtration from the bog peat down into the mineral soil [14]. When extinguishing fires or rewetting, the appropriate course of action is to keep water in the large ditches by building dams instead of attempting to deepen them.

In peatlands with deep ditches that reach down to permeable mineral soil, drilling deep boreholes and firewater wells should be avoided because it will accelerate filtration of water into the mineral soil.

4.4.3. TRANSITIONAL PEAT DEPOSITS

In a natural transitional mire or peatland, the water supply and nutrition of vegetation and upper peat layers is mixed. Generally, transitional mires and peatlands constitute a transitional stage between a fen and a bog.

If we are dealing with a drained transitional peat deposit, it is worth looking at the drainage network layout and terrain relief in each particular case and examining data from previous geological and topographical surveys.

When extinguishing fires in transitional mires and peatlands, it may be necessary to retain and extract water using methods relevant for fen and bog peat deposits.

4.5. CONVENTIONAL PEAT FIRE DETECTION TECHNOLOGIES

The only reliable way of detecting peat fires in a timely manner is through regular ground patrols. The next most important way of detecting fires is to use the data of remote sensing and aerial observation.

4.5.1. GROUND PATROLLING

Ground patrolling is reasonable at intervals of three to seven days. The peat fire points in dense peat will not have enough time to grow extensively during periods of less than one week. One can travel on foot, by bicycle, motorcycle, quad bike (swamp buggy) or automobile, depending on road conditions and the length of the route. Smoldering peat fire points are detected visually and by the characteristic odor of peat smoke. When patrolling by car, all windows should be kept open to smell the smoke. The best time to patrol is in the morning and evening, when dew is on the grass and smoke is more easily visible. It is preferable to examine the area against the sun so that any smoke can be seen more easily.

4.5.2. REMOTE SENSING DATA

Satellite fire monitoring, also used in Russia, provides reliable detection of large, active fires covering more than 10 ha *(Table 1)*.

It is not always possible to detect smoldering peatlands through the use of publicly available satellite imagery with medium (Landsat) and low (MODIS) resolution. However, such data can indicate where in the drained peatlands the open burning of vegetation is observed across the surface, and whether the fire is grass or forest.

Data on thermal anomalies on the ground surface (hotspots) is published daily by the Fire Information for Resource Management System (FIRMS). Information on many fires, with the exception of very small and low-intensity fires, is included in the daily statistics of FIRMS.

When it is necessary to monitor peat fires over large territories (jointly with the hotspots data), a vector layer of conditional boundaries of drained peatlands comes in handy.

In some cases, it is possible to see smoke plumes from smoldering peat fire points from air reconnaissance data and publicly available satellite images of medium and even low resolution.

For the most accurate early detection of fires, we recommend that simultaneous data from several sources is used regularly. Even if smoke is not visible on satellite images but you have remotely detected an area of a drained peatland exposed to fire (a hotspot or a visibly burned area of a different color), ground inspection is recommended.

In Russia, before going out to inspect hotspots and burned areas on the ground, one should call the fire department responsible for the area and agree on a joint inspection or a procedure for sharing information on detected fire points from volunteers to state agencies.

4.5.3. AERIAL OBSERVATION

One of the most effective methods of peat fire reconnaissance is aerial reconnaissance from a manned aircraft, or from a drone. The use of manned aircraft is expensive, so drones are increasingly used to survey swamps, mires and peatlands.

During aerial reconnaissance, peat fire points can be detected visually or with thermal imaging cameras.

4.5.4. GROUND INSPECTION

Reasons for ground inspection:

- Hotspots that appear within the boundaries of a drained peatland or a nearby area as well as hotspots at a distance not exceeding the error of determining the coordinates of the fire for this type of monitoring.
- A burned area detected in a peatland during the analysis of recent satellite images of medium and high spatial resolution.
- The results of photographic and thermal imaging surveys during aerial observation.
- Information from local residents, the media, and Internet about possible peat fires.

All areas with signs of surface fires are first identified during the inspection: signs of grass that has been deliberately set alight, forest fires. Once areas have been identified, they should be inspected in detail.

Elevations, ditch piles, narrow-gauge railways embankments and old spots consisting of burned peat should all be checked for fire points. If it is not possible to find smoldering peat fire points in the most likely locations but there is suspicion that the peat is smoldering (there is a characteristic smell, signs of intense burning), sweep all suspicious areas.

To accurately conduct a survey, the area should be divided into conditional squares with sides of 250 m to 500 m. Search teams

Table 1. The sources of remote sensing data used in Russia

Data from the ISDM Federal Forestry Agency information system (official source)	https://public.aviales.ru/main_pages/public.shtml
FIRMS data Here you can download hotspots in KML format to view them in Google Earth.	https://firms.modaps.eosdis.nasa.gov/active_fire/
Sentinel satellite imagery, medium resolution This is a handy tool to clarify the boundaries of fires and burned areas.	https://apps.sentinel-hub.com/eo-browser/
Planet Explorer: current satellite imagery of Earth's surface The system requires registration on the website.	https://planet.com/
Landsat satellite imagery This allows us to see burnt areas, starting from a few hectares.	https://landsatlook.usgs.gov/explore
Geoportal fires.kosmosnimki.ru Current and archived data on hotspots can be viewed here. The boundaries of Russian federal and some regional protected areas are publicly available.	https://fires.ru/
MODIS satellite imagery This is used to convey the details, understand the location of fires by their smoke plumes, the location of large burned areas and assess the weather forecast.	https://lance.modaps.eosdis.nasa.gov/
European Forest Fire Information System (EFFIS)	https://effis.jrc.ec.europa.eu/
Greenpeace Global Fire Dashboard	https://maps.greenpeace.org/fire_dashboard/

will need to be sent out, with at least two people per team. The activities must be coordinated to ensure that no area is left uninspected. It is advisable to have a satellite navigator in each search team so that the supervisor can collect all tracks of the conducted survey and see whether there are any areas that have not been inspected for smoldering fire points.

The use of handheld thermal imaging cameras and drones with thermal imaging cameras significantly increases the probability of finding all fire points.

The fire points thus identified are marked on the ground (with signal tape on a pole or branch), a waypoint is marked in the navigator, and the survey continues. Indicate the location of water sources suitable for installation of motor pumps and fire engines, and places for possible water retention. Attention should be given to the condition of roads and pipe culverts, their suitability for passenger cars and trucks (fire engines) as well as the availability of turnaround areas. Decisions on further action should be based on the results of the ground inspection.

4.6. AERIAL RECONNAISSANCE OF PEAT FIRES BY MEANS OF AN UNMANNED AIRCRAFT (DRONE)

Important!

If you or your team own a drone, you need to study the regulations and follow the rules under which this aircraft may be used in your country.

A combination of reconnaissance with a quadcopter/drone and on foot usually gives the best understanding of the fire situation and the maximum number of peat smoldering fire points is detected. If possible, supplement quadcopter reconnaissance with on-foot reconnaissance to double-check the result, and vice versa.

4.6.1. GOALS OF AERIAL RECONNAISSANCE DURING A PEAT FIRE

During reconnaissance, the main objectives are to examine the area and understand the general fire situation; to find smoke, fire points and water.

Smoke may indicate smoldering peat fire points, aerial peat fire, open fire on the edge of the peat fire point or burning dry grass that may immediately threaten the peatland. Thus, the first order of business is to examine the horizon and assess the situation *(Figs. 25 and 26).*

Fig. 25. Smoke from burning dry grass. Deliberately setting fire to grass risks setting the peatland on fire

Fig. 26. Smoke from a large cluster of peat fire points

Peat fire points *(Fig. 27)* should be located and mapped. The result of good reconnaissance is a map with the coordinates of peat fire points. It is also useful to assess and map the outline of the burned area.

Fig. 27. A peat fire point

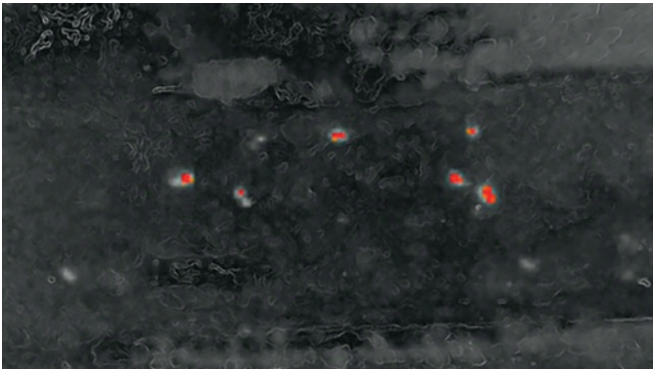
Water. We search for water to extinguish the peat fire points and take photographs of the ditch network. It is best to take a panoramic view of the drainage network from a high point — this information will be useful later if water retention is considered for fire extinguishing purposes *(Fig. 28)*.

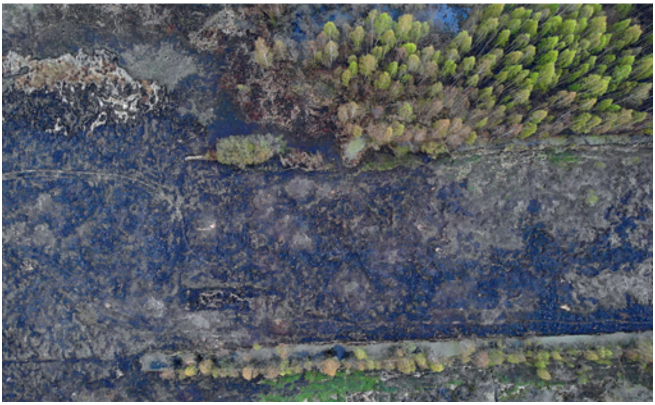
Fig. 28. A system of ditches in a drained peatland. The glow and the dark color show us the ditches that do and do not have water

4.6.2. THE REQUIRED EQUIPMENT

Different types and models of unmanned aircraft are used for reconnaissance. The described technique involves quadcopters with optical cameras of the DJI Phantom and DJI Mavic series or the DJI Mavic 2 Enterprise Dual quadcopter with optical and thermal cameras. The specifics with respect to other drones may differ.

Different quadcopter models may be equipped with a standard (optical) camera, a thermal camera or both types. The best results are achieved by using both cameras *(Figs. 29, 29a)*.





Figs. 29, 29a. Peat fire points photographed in thermal imaging and visual modes

4.6.3. PREPARATION FOR RECONNAISSANCE

Collecting information

For aerial and on-foot reconnaissance, it is necessary to carry a laptop with images and cartographic materials or a paper map.

Up-to-date satellite imagery from the website https://apps.sentinel-hub.com/eo-browser often makes it possible to determine the areas where grass has burned and the peat may have caught fire. If there is a good recent image that clearly shows burned areas, one can plan in advance the order in which areas should be inspected and how the drone operator can reach them. This will help orient oneself in the field more easily and ensure that large burned areas are not missed *(Fig. 30)*.

Fig. 30. The satellite image shows burned areas taken at different times. (In SWIR mode they appear reddish and are clearly visible). Initially, the burned area is dark. The color lightens over time as it becomes covered with fresh grass

Any remote monitoring data must be verified because the actual burned area may be larger than that recorded by the satellite.

If your team has worked on the peatland before, check the reports from previous years. This will help identify the hazardous areas with old peat fire points that are likely to have caught fire again if deliberate burning of dry grass has occurred.

Legality of flights

Be sure it is legal to fly in the airspace. Where required by applicable regulations, obtain permission to fly.

Weather conditions

Always check the weather forecast before you leave on a field trip. The weather is crucial for the possibility and effectiveness of a quadcopter reconnaissance mission. Keep track of weather changes.

Adverse weather conditions:

- Precipitation. A quadcopter is never used during precipitation because moisture may cause a short circuit in the drone's electrical circuits and result in damage.
- Wind. It is highly undesirable to use a drone in strong winds. See the manufacturer's instructions for the model's limitations. Be aware that wind strength increases with altitude. The drone may be blown so far away by a gust of wind that you cannot return it by flying into the wind. The battery life and speed of the drone are significantly reduced when flying against the wind. During windy weather, do not fly far from the remote control.
- Cold. The use of a drone in sub-zero temperatures reduces battery life. The combination of sub-zero temperatures, high humidity and freezing fog conditions can result in blade icing while in flight, as a result of which the drone will crash.

Favorable conditions:

- In visual mode, the smoke from peat fire points is best seen during the morning or evening, against the light or when the sun is low.
- In thermal mode, peat fire points are best seen under heavy cloud cover, in the evening or early morning or when the ground is cold and the sun is low.

On a clear sunny day, reconnaissance with a thermal imaging camera is ineffective (see paragraph 4.6.4).

Preparing an unmanned aircraft

- Upload a satellite image, outlines of burned areas or the coordinates of known peat fire points into the quadcopter's remote control in advance (if you are going to check on the quality of fire suppression).
- Be sure the quadcopter is in working condition and properly charged, and that its memory card has enough free space.
- Take extra batteries u. It helps to be able to recharge the remote control and batteries from a generator, an inverter in the car, or a powerful external battery.

To avoid an explosion, always allow the battery to cool for 20 to 30 minutes after the flight before recharging it.

4.6.4. DETECTION OF PEAT FIRE POINTS

In visual mode, the following can be seen and assessed with a regular video camera:

- Smoke *(Fig. 31)*.
- The locations of large peat fire points.
- Signs of an active peat fire point:
  - Smoke, fresh ash: color or light stains.
  - Traces of burning on the edges, change of vegetation color, for example, spots of dried brown vegetation against the background of green vegetation, or young, bright green grass against the background of dry grass *(Fig. 32)*.
- The boundaries and the size of the burned area will appear as fresh black burn spots that lightens over time, but older burn spots may be characterized by bright green grass or brown leaves on trees.
- Presence of water in the ditches.

A quadcopter with a thermal imaging camera allows the following:

- Conduct a detailed survey (sweeping) of the area and locate the peat fire points, including those that are shallow, smokeless and unseen in visual mode *(Figs. 33, 33a)*.
- Determine whether a smokeless fire point is active.
- Control the quality of fire-point extinguishment *(Figs. 34, 34a)*.

If your quadcopter is equipped with optical and thermal cameras, remember to switch between the modes to take advantage of both cameras.

A quadcopter with a thermal imaging camera can often find more fire points than can be found during inspection on foot, particularly if the burned area is large and difficult to walk through. However, the best option, as we have said, is a combination of reconnaissance on foot and with a quadcopter.

Setting up the thermal imager

A thermal imager detects infrared radiation. In addition to fires, the thermal imager allows one to see objects and areas heated by the sun as well as reflected solar radiation.

<u>Temperature</u>

For thermal drone reconnaissance, the best conditions are a temperature contrast whereby the ground is cold and the fire points are hot and clearly detected. This is possible in conditions of heavy cloud cover, or in the evening or early morning when the sun is low and has not had time to heat up the earth's surface.

At times, aerial reconnaissance will be ineffective. For example, on a clear day, when the sun is at its zenith and the black burned areas have heated up considerably when solar radiation is reflected from the ground straight into the thermal imaging camera.

Fig. 31. A fresh peat fire point after a dry grass fire will have clearly visible smoke

Fig. 32. If a peat fire point that was detected visually is not producing smoke, pay attention to the areas next to its edge. If the vegetation at the edges is different in color, shows signs of recent burning (black surface) or fresh ash, it is likely that the peat fire point is active, at which stage an additional ground inspection or thermal reconnaissance is required

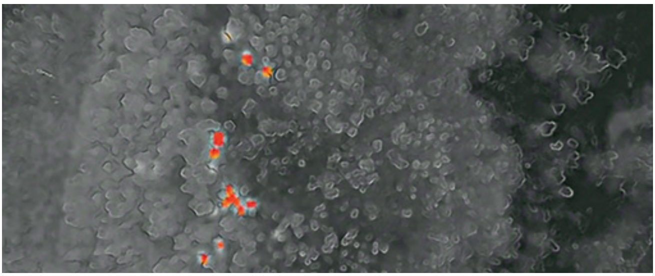
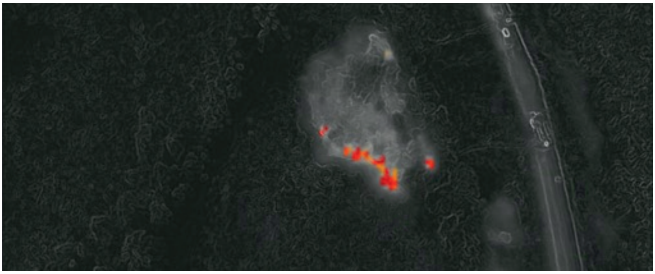


Fig. 33. A cluster of small peat fire points in rugged terrain

Fig. 33a The fire points are not visible in the visual mode



Figs. 34, 34a. Quality control of fire-point extinguishment. The thermal image shows the hotspots that need to be completely extinguished

At an average ground surface temperature above 25°C according to the sensor (not the actual ground temperature because the sensor indication takes into account the scattering and reflections), reconnaissance is less effective, and closer to 40°C it is ineffective. There is a chance of missing small and low-temperature peat fire points (which is important if the fire is recent). In this case, one should wait for the sun to go behind a cloud or down to the horizon and for the ground to cool a little.

The lower the average temperature of the ground surface (according to the sensor), the more visible the fire points and the more effective the reconnaissance e. The parameters may differ with respect to the situation and the quadcopter model.

At night, thermal imagers can detect peat fire points as far as 100 m. However, in the visual mode their size and the edge of the burned-out area are not visible, so such reconnaissance is ineffective.

There are several factors that affect the accuracy of a thermal imager, including air humidity, ambient temperature, convection currents and wind. The thermal imager therefore needs to be set up each time.

Different quadcopter models may have different functionality, but the basic principle is to set the range of visible temperatures so that only the peat fire points are clearly visible on the screen *(Figs. 35 and 36)*.

Refer to the average surface temperature to set up the thermal imager. **Anything that is 7-10°C warmer than the ground temperature must be double-checked.** Accordingly, it is better to set the visible temperature range so that this difference remains noticeable.

The calibration of the thermal imager can be adjusted by the first peat fire point detected. In this case, it is easy to find the right sensor settings and the optimal flight altitude at which the fire point is clearly distinguishable.

For example, at a ground temperature of 15°C, a detected point of 25°C needs to be examined further. To understand whether an abnormal point is a fire point, it should be examined for signs of a fire point in a visual mode. It also helps to keep the quadcopter as low as possible so that the thermal imager can determine the temperature more accurately *(Figs. 37, 37a)*.

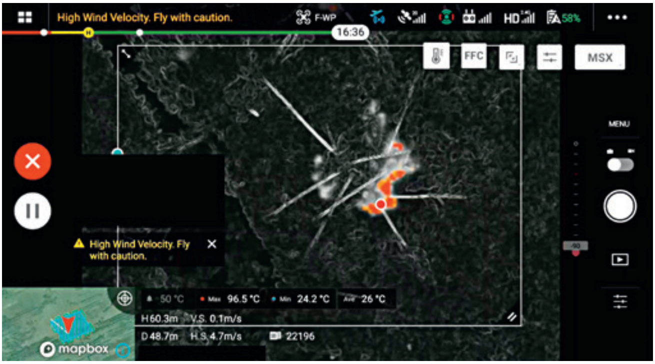


Fig. 35. The thermal imager is set up correctly, and the fire point stands out. The typical shape can be seen, the hotter areas show red and those that are not as hot show as white areas but are still distinguishable from the cold black earth. In the video, this kind of fire point shimmers a little

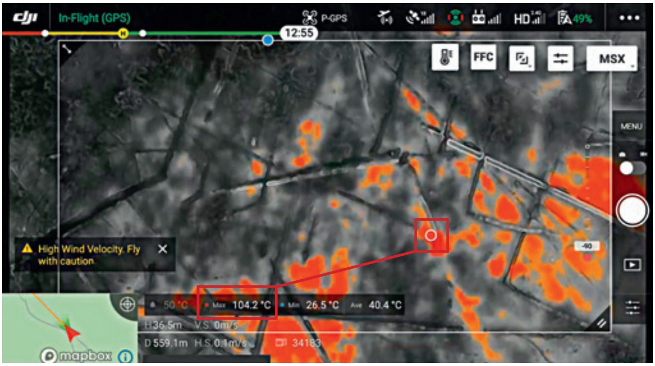
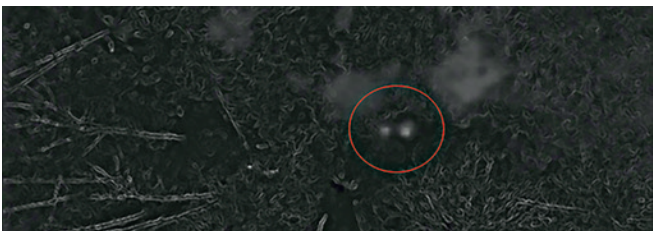


Fig. 36. The thermal imager is not set up properly: apart from the 104.2°C fire point (the red dot), spots of heated earth are visible (most red spots)



Figs. 37, 37a. Occasionally, fire points exist under a cold cover of peat and do not register a high temperature. Fire points can only be noticed on the basis of a slight difference from the average ground temperature

All suspicious points whose origin is not clear must be double-checked by reconnaissance on foot.

Height

The closer the thermal imager is to the surface, the more reliable the readings. The optimal height for locating peat fire points is 35–40 m, but the terrain relief and the height of trees must be considered to avoid encountering obstacles.

In good conditions (early morning, evening twilight, cloudy weather), it is acceptable to increase the altitude of the quadcopter. However, one should be particularly careful when monitoring any points with anomalous brightness and descend to double-check the situation.

If you move the quadcopter away from its remote control, you may experience poor connection at altitudes of up to 35–40 m. This is due to signal shielding by trees or landforms. Thus, the operator should be on an elevation and inspect the burned area in small sections while changing the takeoff point. Move to a new point after 1 km area is inspected and then inspect another kilometer.

Camera position

Keep the camera below the horizon. If the thermal imager is in automatic mode and you point it at the horizon, it will go blind and you will not be able to see the peat fire points. If the thermal imager is set up manually, the horizon will not be an issue but the usable area of the frame will be reduced.

Some fire points under tree roots or under peat cover are only clearly visible at a certain angle. Therefore, it is better to periodically change the camera's angle during sweeping, from 45° (camera at an angle) to 90° (camera down). Look carefully at any suspicious points from different heights and at different angles *(Figs. 38, 38a, 38b, 38c)*.

Recording the coordinates

Create a photographic record of the coordinates of the detected peat fire point. Each fire point should correspond to one photograph; large clusters of fire points can be circled with a track of the quadcopter by flying it around the cluster.

The coordinates are displayed on the remote-control screen. If necessary, the coordinates can be immediately handed over to the ground team. To capture the exact coordinates, the camera must face straight down, so that the fire point is in the middle of the frame. The lower the quadcopter, the more accurate the coordinates and the easier it will be for the ground team to find them *(Fig. 39)*.

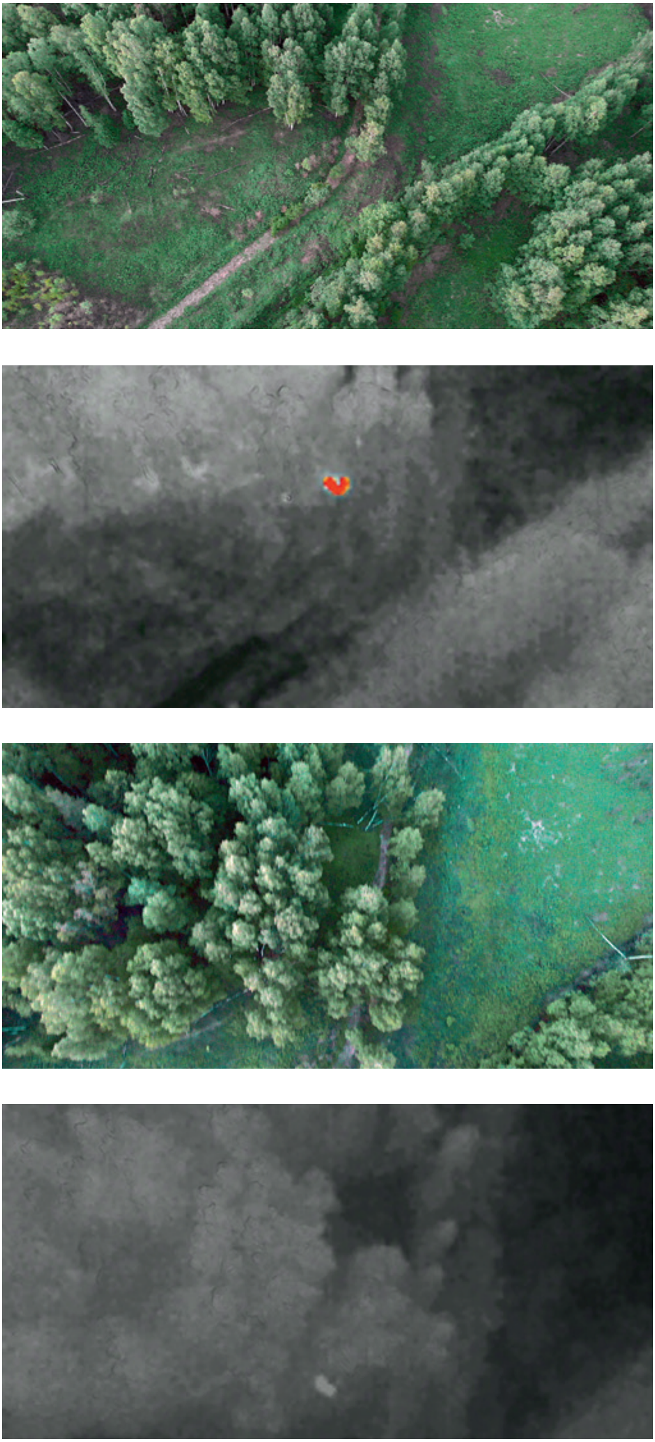
4.6.5. AERIAL RECONNAISSANCE TACTICS

The first flight should always be performed in visual mode to assess the general fire situation.

Air reconnaissance is similar in principle to reconnaissance on foot. If resources are sufficient, it is more effective to thoroughly inspect (sweep) the entire burned area by flying over it section by section. If time is short and the burned area is large, assess the overall situation, carefully inspect the most likely fire points, and inspect the remaining area in less detail.

Characteristic locations where peat often catches fire:

- Banks of ditches, ditch piles *(Fig. 40, 40a)*.
- Areas with old fire points (information about them can be found when preparing for the field trip by reviewing the reports from previous years).
- Uplands, peat piles that are drier than anything else around them.
- Under the roots of large trees, in places with old debris *(Fig. 41, 41a)*.



Figs. 38, 38a, 38b, 38c. The same fire point under birch tree roots from different angles

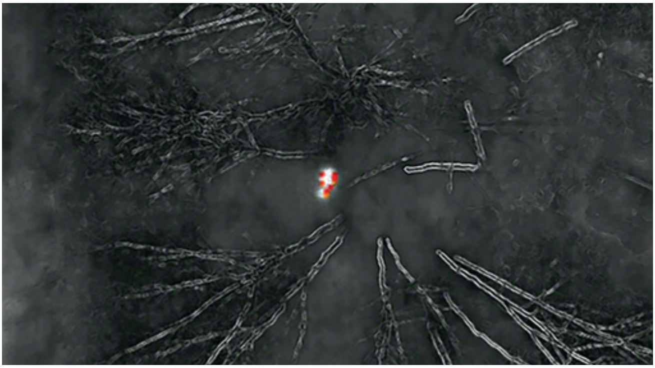


Fig. 39. Correct positioning of the quadcopter to determine the fire-point coordinates

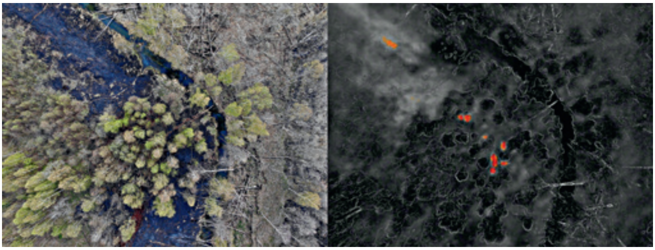


Fig. 40, 40a. Fire points along a ditch

Fig. 41, 41a. A fire point under birch tree roots

Sweeping

For sweeping, divide the area into small squares, using ditches and roads as boundaries, and inspect them one by one. Depending on the quadcopter model and the situation (such as time available, battery life, shape of the fire edge, size of the burned area and terrain ruggedness), automatic or manual mode can be used for sweeping *(Fig. 42, 42a)*.

It makes sense to first fly over the fire edge in visual mode, circle the area along its outline, and then sweep the inner area in search of peat fire points. To see where we have already flown and where we have not yet flown, we check the track of the quadcopter. An additional flight should be made over hazardous areas (see Characteristic locations where peat often catches fire) *(Figs. 43, 43a)*.

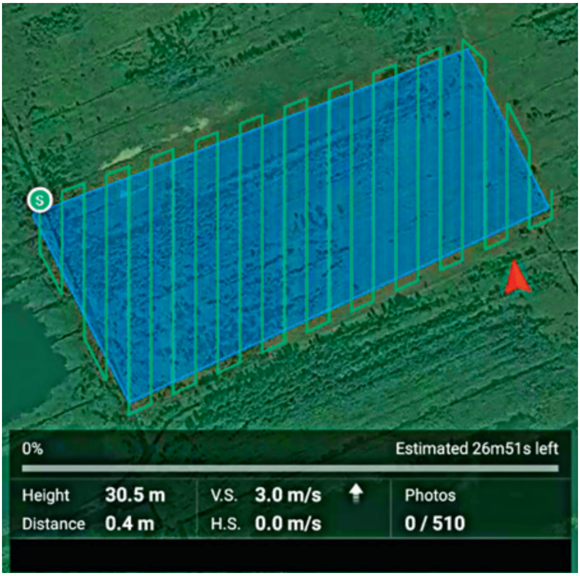


Fig. 42. Automatic sweeping mode

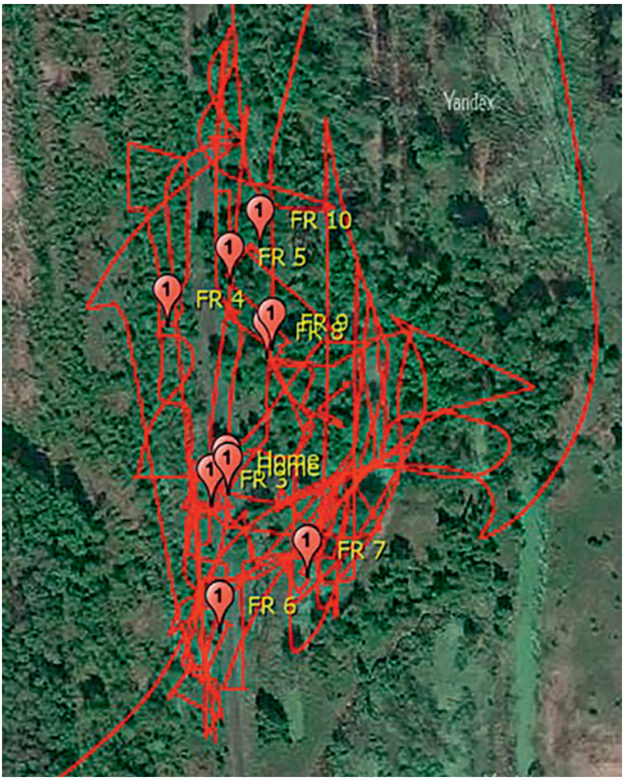


Fig. 42a. Manual sweeping mode

Fig. 43. Peatland fire survey map

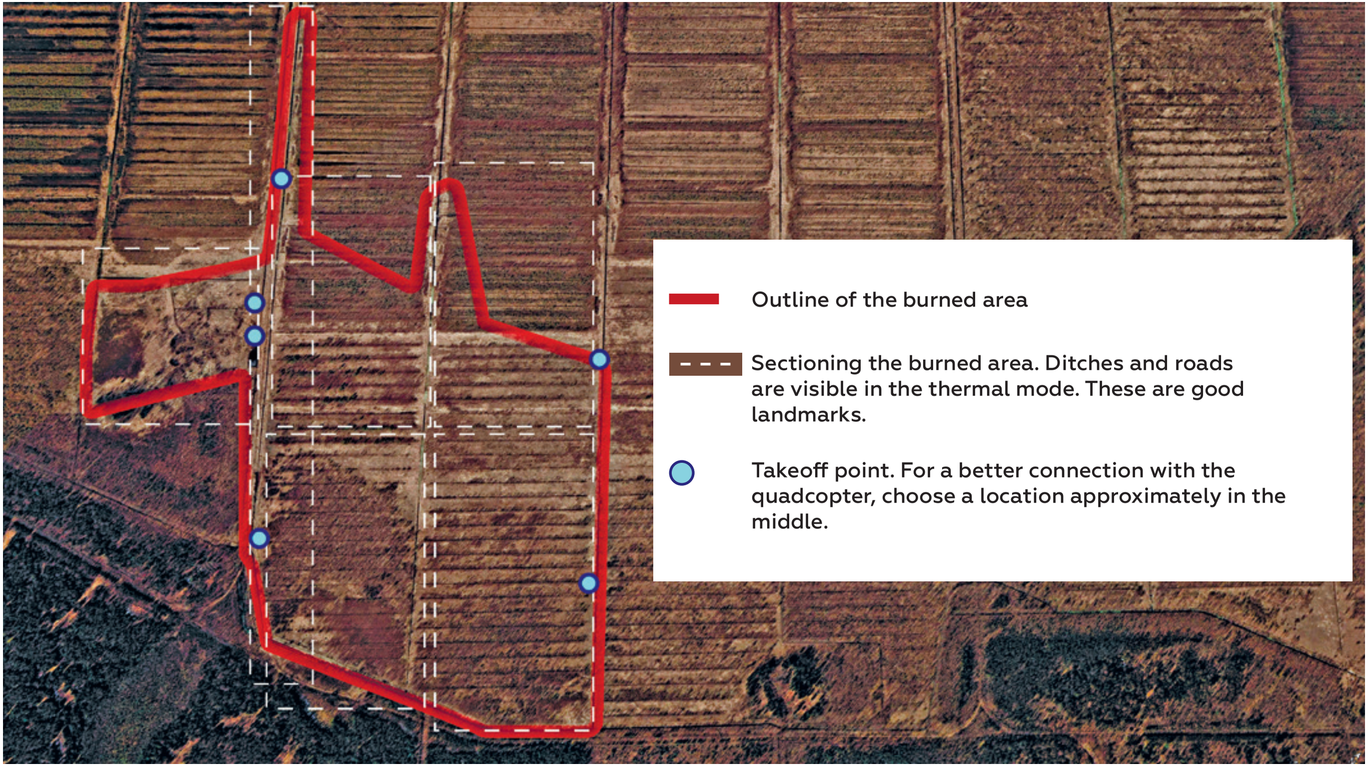
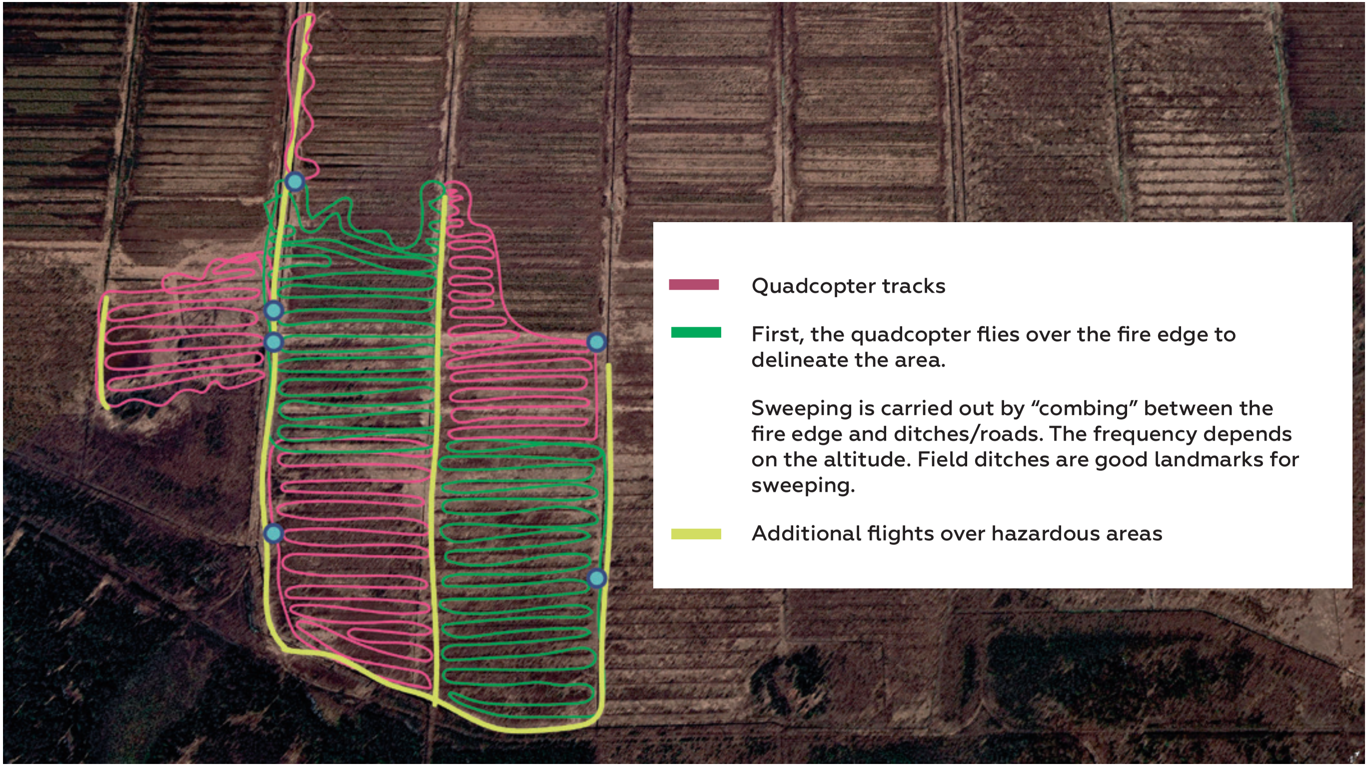


Fig. 43a. Peatland fire survey map



4.6.6. PROCESSING THE RESULTS OF RECONNAISSANCE

After the flights, we map the peat fire points and tracks obtained from the drone *(Fig. 44)*. This should be done before leaving the place — to be sure we have covered everything.

The drone logs its track in a text file, which must be converted into .kml format. This can be done using airdata.com. The coordinates of the photographs are recorded in the file properties.

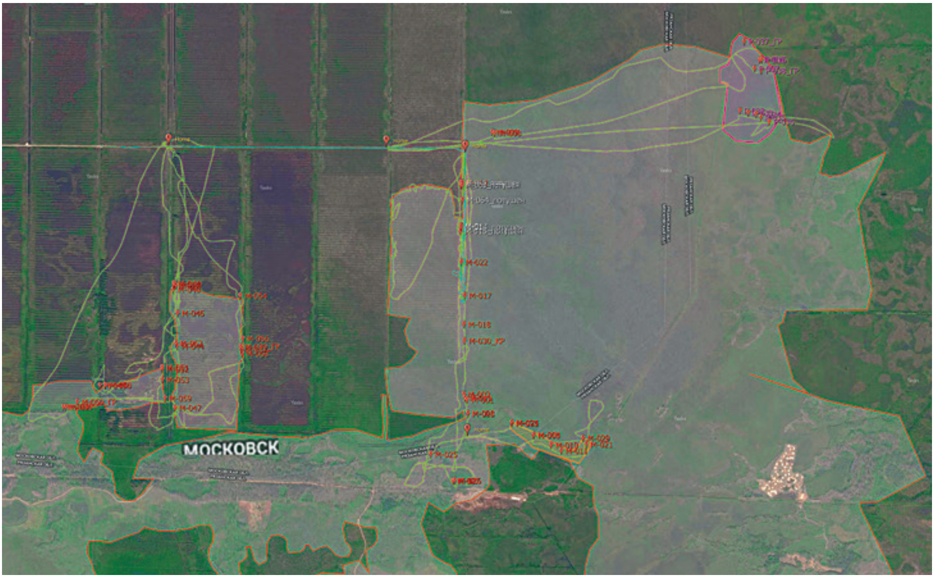


Fig. 44. A map of a large fire with quadcopter tracks and smoldering peat fire points are detected. Areas with large clusters of peat fire points are outlined

4.6.7. RECONNAISSANCE PROCEDURE

Before the field trip:

1. Prepare maps and make a preliminary plan for surveying the area.
2. Be sure it is legal to use the aircraft (register the flight according to applicable rules/regulations).
3. Be sure the weather conditions are suitable for flying.
4. Prepare the aircraft: charge the batteries, upload local maps into the remote control, and clear up the flash drives.

During the field trip:

1. Make the first flight in visual mode to survey the terrain and assess the situation: find out whether there is any smoke, extent of the burned area and the condition of the drainage network. If necessary, adjust the survey plan according to the new data. Determine which areas must be swept completely and which areas could be swept partially.
2. Set up the thermal imager. If possible, check the settings by using the nearest peat fire point.
3. Select the first area for sweeping. Use ditches, roads and the quadcopter's track over the fire edge as landmarks in manual mode, or select the automatic sweep mode.
4. Make additional flights over the areas in which fire points are most likely to occur.

5. Re-examine all suspicious points from a lower altitude, both in visual mode and by means of reconnaissance on foot.
6. Mark all fire points detected with their photographs. If necessary, transmit their coordinates immediately to the ground team.
7. Occasionally switch to the visual mode, searching the horizon for more smoke.
8. Sweep all planned areas.
9. Map the quadcopter tracks for quality control of the reconnaissance.
10. Be sure to double-check all questionable points with the ground team. If possible, double-check all peat fire points to verify the result.

After the trip:

1. Make a detailed map with peat fire points and drone tracks.
2. Write a report.

CHAPTER 5. EXTINGUISHING PEAT FIRES

5.1. DIRECTLY EXTINGUISHING PEAT FIRE POINTS

It is important to start extinguishing a fire in a drained peatland as soon as possible.

Smoldering peat fire points detected in their early stages can be extinguished quite easily within a day or two. The next step is to guard the area.

Long-lasting peat fire points may lead to the following problems: the fire may have already destroyed access roads; fallen trees may have caused extensive debris; and the local water may not be sufficient to extinguish an extensive area of burning peat.

When a single peat fire point is found, the first thing to do is understand its root cause. If there is evidence of a deliberate dry grass or a forest fire that took place a few days or even weeks earlier, inspect the entire fire-affected area and find all fire points. Only then should you start extinguishing individual fires.

Large peat fires often develop from small but improperly extinguished fires. It is therefore very important to follow the sequence of fire suppression stages and strictly control the quality of work at each stage *(Table 2)*.

Table 2. Stages of peat fire suppression

Stage	What should be done
Fire reconnaissance	1. Assess the number and location of smoldering peat fire points, identify safety zones. 2. Mark the areas that contain hazardous trees and concealed peat fire points. 3. Identify and assess the condition of water sources and decide on the need for water retention. Construct ditch blocks (dams).
Stopping fire propagation	1. Extinguish the most hazardous fire points to prevent dangerous consequences, including the destruction of roads, buildings, etc. 2. Stop open burning on the surface until the burning ceases completely and the fire cannot resume at the fire edge.
Containment	Contain all peat fire points and ensure the conditions to prevent fire propagation, including any identified or potential fire points.
Extinguishing fire points	Extinguish all peat fire points in the peat layer and control the quality. (The temperature in the peat fire point after extinguishment should not exceed 40°C.)

Stage	What should be done
Guarding	Conduct regular patrols along the perimeter of the contained fire edge and individual, extinguished fire points. The goal is to detect hidden sources of fire and extinguish any new peat fire points. The guarding period is at least seven days: the first patrol should take place three days after fire extinguishment, and the second one should be organized three or four days afterward.
Total suppression	1. If there are no fire points or signs (e.g., peat smoke and/or distinctive odor), withdraw the personnel and equipment. 2. Remove temporary dams if necessary (in case of imminent flooding or dangerous drainage of another area).

5.2. EXTINGUISHING SMALL FIRE POINTS IN THE EARLY STAGES

If the detected peat fire point is a single one (e.g., a campfire that has only begun to «sink» giving off a characteristic whitish smoke and acrid peat odor), it is possible to start extinguishing this fire immediately using one of the methods described below.

5.2.1. IF WATER AND EQUIPMENT ARE AVAILABLE

Small peat fire points are extinguished by mixing the burning peat with water until it has cooled completely. If there is enough water nearby, it should be poured into the fire point with a motor pump or buckets while mixing the peat with water until it forms a uniformly cold mass. See the details of motor pump operation in paragraph 5.4.

Water is first poured into the center of the fire point, hitting its bottom, the deepest parts are cooled and mixed, and then the edges of the fire point are washed off or cut off. Use a spade to cut off the areas of non-burning peat that contact the fire point (not less than 20 cm along the entire perimeter of the fire point) and mix them with water.

If the peatland is shallow, it is advisable to mix the entire layer of peat with water and the underlying noncombustible soil (sand and/or clay). If the peatland is deep, pour water and mix it with deeper layers of cold peat 20-30 cm below the bottom of the fire point. If a layer of crunchy charcoal (peat coke) or tree roots is felt with a spade at the bottom, such fire points should be dug out and extinguished until the next layer is reliably cold. Otherwise, hidden peat fire points may remain under the coke layer and roots, and smoldering may resume after a few hours or days.

5.2.2. IF NO EQUIPMENT IS AVAILABLE AND THERE IS NOT ENOUGH WATER

If there is insufficient water or no water-supply equipment is available, all burning peat should be dug out, placed in a fireproof container (bucket, trough), and taken to a water body, where it should be extinguished by mixing with water until a cold, homogeneous mass is formed. If there is no water body nearby, the burning material can be taken to an area with noncombustible soil (sand or clay) and mixed with a spade until the burning has ceased and the material has completely cooled.

If the peatland is shallow, all peat down to the underlying noncombustible substrate and all non-burning peat within 20 cm around the fire point should be dug out. If the peatland is deep and there is more distance to the underlying soil than can be dug out with a spade, extract all the burning peat plus 20-30 cm of the cold peat that is not burning.

5.3. EXTINGUISHING LARGE, LONG-LASTING PEAT FIRE POINTS AND THEIR CLUSTERS

It is not always possible to identify peat fire points at an early stage. The development of large peat fires often results from a lack of quality control over fire extinguishing and improper guarding of timely detected small fire points.

If deep peat fire points are found or the ones that are active over a large area cannot be extinguished within the first day, it is important to understand the following:

- How such a peat fire would evolve.
- Whether there is a risk of renewed open burning at the fire edge (which would lead to a sharp increase in the peat fire area).
- Where the water sources are located and whether water retention is necessary.
- Whether to ask for assistance and, if so, what kind of assistance.

Draw up a fire-extinguishment plan and make a list of equipment to be used. This will provide an overview of the situation to avoid confusion about the equipment and where to look for it so that nothing is missed in the effort to complete the fire suppression. An example of such a plan superimposed on a photograph of a peat fire point is shown in Figure 45.

Fig. 45. An extensive peat fire point in a drained fen. Preliminary fire-extinguishment plan

HOW TO EXTINGUISH A LARGE PEAT FIRE POINT

Use a spade and a probe thermometer to find the boundaries of the peat fire point. If hidden cavities (underground burned spots) extend beyond the visible boundaries of the peat fire point or if smoldering is detected in animal burrows, those areas should be marked on the ground with signposts and signal tape.

Begin extinguishing from the edges and move toward the center of the fire point, controlling the process by measurements *(Fig. 46)*. This method is safer for firefighters, and it decreases the risk that the hoses will be burned.

Occasionally, the central parts of peat fire points cool down without extinguishing, after burning down to the mineral soil or the groundwater table. In such cases, further advancement toward the central parts of the peat fire point is ineffective. If there are hidden parts of the peat fire point, they are opened either manually with spades or by compact water jets or with excavating equipment, and then extinguished as a regular peat fire point.

If water-supply equipment is available (a motor pump, a fire engine), water is supplied as a compact jet to wash off and mix the burning peat *(Fig. 47)*.

At the same time, the resulting mass is additionally mixed with the use of spades to break up the lumps and cinder. With this method of water supply, its average water consumption is up to 1 t per 1 m^3 of burning material.

When drainage ditch piles and former peat piles are burning, special deep nozzles are effective to preliminary saturate deep layers of smoldering peat with water *(Fig. 48)*. Subsequently, these areas are finally washed out by compact jets. When planning to extinguish former peat piles, large volumes of burning peat may need to be washed away or dug out *(Figs. 49–51)*.

When newly made piles of milled peat or extensive peat fire points with large quantities of hot peat ash are burning, the peat fire point should be moistened with a water spray to prevent the burning materials from being spread to new areas. One can then proceed with compact water jets, similar to extinguishing a peat fire point.

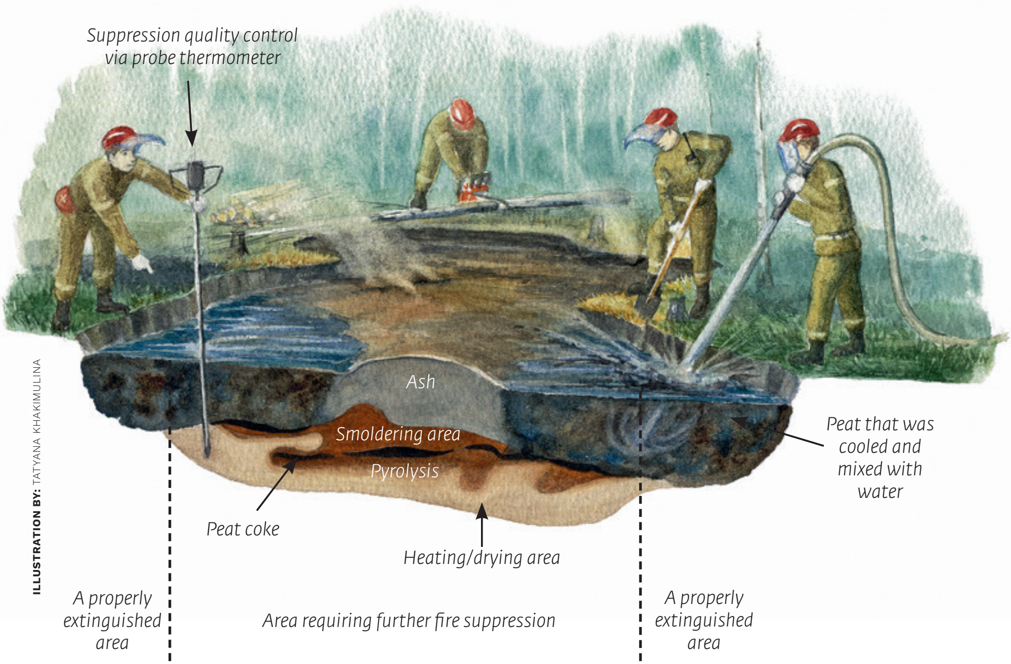


Fig. 46. Fire-extinguishment plan of a single, large peat fire (from edges toward the center)

Fig. 47. The initial stage of extinguishing a small peat fire with a manual fire hose nozzle RS-50. A compact water jet is poured into the central part of the peat fire point

Fig. 48. Using a deep nozzle at the initial stage of extinguishing a former peat pile. Subsequently, this area will be washed out by compact water jets from manual fire hose nozzles

Fig. 49. The beginning of extinguishing the deep peat fire point in a drainage ditch pile with manual fire hose nozzles RS-50

PHOTO BY: MARIA VASILIEVA/GP

Fig. 50. Extinguishing a peat fire point on a drainage ditch pile, which is the final stage of extinguishing a peat fire

PHOTO BY: MARIA VASILIEVA/GP

Fig. 51. Extinguishing an abandoned burning peat pile

5.4. EXTINGUISHING A PEAT FIRE USING MOTOR PUMPS AND FIRE ENGINES

If a peat fire is detected at an early stage, the primary means of water supply is a portable motor pump.

A motor pump is a water pump with an internal combustion engine powered by diesel or gasoline (two- or four-stroke). Motor pumps differ in terms of capacity and pressure, and they can be designed to handle clean or dirty water (Appendix 4).

Motor pumps are used in combination with suction and discharge fire hoses of various diameters, dividing breechings, adapters and manual fire hose nozzles.

5.4.1. PORTABLE MOTOR PUMP OPERATIONS

- Before using the motor pump, find out the specifics of the particular model, its fuel requirement, the maximum flow rate and pressure stated by the manufacturer, and the maximum particle size that is not hazardous for the pump.
- Install the motor pump on a level surface as close to the water body as possible. In theory, motor pumps can take water from heights of up to 7 m from the water's edge. In practice, it is better to install the

pump no higher than 1–2 m above the water level for a steady water intake. The pump must be secured to prevent it from slipping or toppling over due to vibration. The engine exhaust must not be aimed at combustible materials (e.g., dry grass, peat, bushes and fuel or oil canisters).

- Before starting the motor pump, fill it with water. Most motor pumps have inlets on top for this purpose. If there is no such inlet, water can be poured into the first discharge hose connected to the motor pump, and the pump can then be filled with water through this hose.
- If the pump does not take water from the water body when the engine is running steadily, check the gaskets and the tightness of the suction hose, the hose strainer deepening, and check for any dirt on the hose strainer. If there is an air leak, the pump will not be able to take water!
- If the suction hose is damaged, submerge the hole or wrap it with insulating tape. If the hose strainer is clogged with dirt, clean it and use one of the methods described below to install the motor pump at a muddy water body.
- If the pump does not start, check the ignition, gasoline valve, fuel, oil level (in a four-stroke engine), spark plugs and spark discharge. In four-stroke engines, a common cause of malfunction is that the oil level sensor is triggered when the motor pump is tilted or the sensor is defective. If the motor pump is level and the oil level and oil quality are normal, temporarily disconnect the sensor and restart the motor.
- When installing the motor pump on a shallow, clear water body, dig a small pit for the hose strainer. In a shallow water body with mud on the bottom, bury a bucket or a wicker basket in the bottom so that water flows to the hose strainer over the top edge *(Fig. 52)*.
- To prevent the hose strainer from lying on the bottom and clogging with mud in a deep water body with a silted bottom, tie it with a rope to a float made from an empty plastic bottle or a log. Adjust the rope length so that the hose strainer is in the cleanest layer of water but does not suck in air *(Fig. 53)*.
- If a shallow running water body (a stream, a ditch) does not have enough water for the pump, determine the direction of flow and build a temporary dam downstream. When constructing the dam, lay logs and branches across the streambed and reinforce with soil. Clear the ditch and its inflows upstream. If an

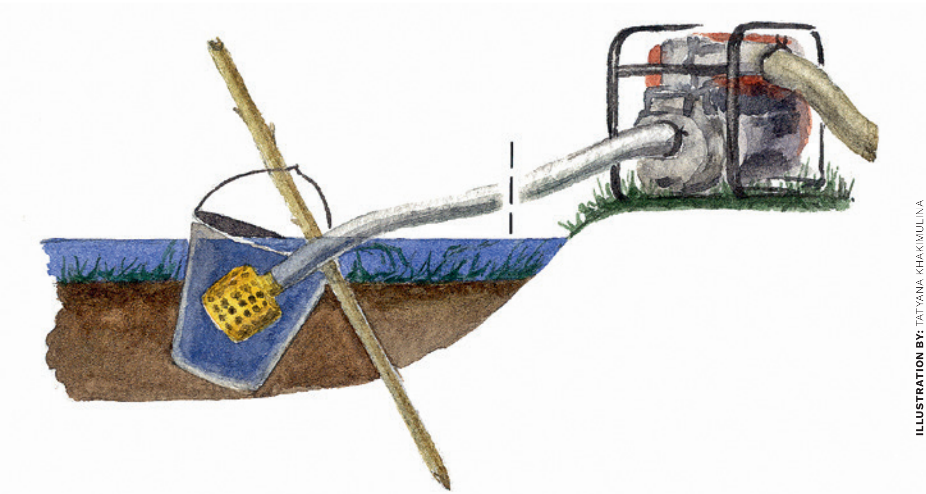


ILLUSTRATION BY: TATYANA KHAKIMULINA

Fig. 52. Taking water from a shallow water body

excavator is available, it may be useful to deepen the place of water intake. In case of excessive inflow of water, dig an overflow on the side of the dam opposite to the pump to prevent the place where pump is installed and access roads from flooding *(Fig. 54)*.

- If it is necessary to make a DIY hose strainer, the diameter of the holes must not exceed the permissible size of solid particles for this pump, and the total cross-sectional area of all holes is twice the cross-sectional area of the inlet connection.
- Route the hose line as straight as possible from the pump to the fire location, doing so without making any sharp bends (kinks) that would significantly reduce the pressure. Lay the excess hose in wide loops. If possible, use the hoses of the largest diameter available to limit pressure loss in the line. See Appendix 4 for a detailed calculation of the hose line length and diameters.

ILLUSTRATION BY: TATYANA KHAKIMULINA

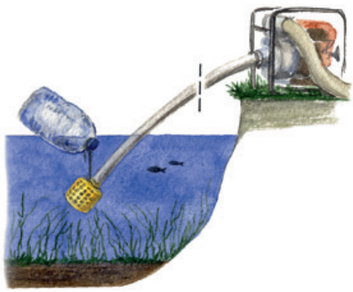


Fig. 53. Water intake from a water body with a silted bottom

ILLUSTRATION BY: TATYANA KHAKIMULINA

Fig. 54. Building a temporary dam to increase the amount of water in the water body

- Relaying water through intermediate containers creates less pressure but allows adding wetting agents to the water *(Fig. 55)*. An inline supply, where the discharge hose is connected directly to the inlet of the next pump, is slightly more complicated but produces much higher pressure and allows water to be supplied over a greater distance.
- For relaying water inline, it is preferable to use pumps of the same capacity. Check in advance whether it is possible to connect the discharge hose to the next pump's inlet (availability of adapters, etc.). Low-capacity pumps can be installed after a two- or three-way dividing breeching or further away from the water body in a very long (more than 1 km) line. It is common to install approximately the same number of hoses between the pumps in the line. A greater number of hoses can be used between the last pump and the fire hose nozzle, as long as there is sufficient pressure at the nozzle *(Fig. 56)*.
- The pressure at the inlet of the next pump in the line must not be less than 5 m of water column (abbreviated to mWC). The greater the height difference and the steeper the rise, the fewer hoses should be installed between the pumps. If the hose upstream of the pump is collapsing, move the pump a few hoses closer to the water body. If the hose downstream of the pump is inflating and is about to burst, move the pump a few hoses further away from the water body. One can check the line pressure and make a decision whether to rearrange the pumps only after the entire line has been filled with water, with fire hose nozzles fastened and at full throttle on all pumps.

ILLUSTRATION BY: OLESYA VOLKOVA

Fig. 55. Water relay through intermediate containers

ILLUSTRATION BY: OLESYA VOLKOVA

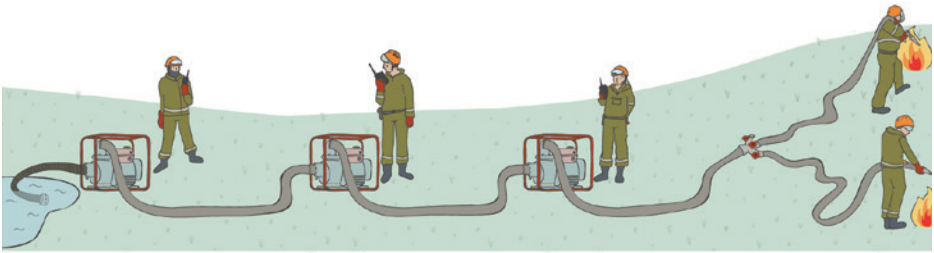


Fig. 56. Inline water relay

- The hose upstream of each pump should not lose its shape when squeezed by hand but can be squeezed with fingers when pressed hard, indicating that the maximum water supply range has been reached with minimum load on hoses and pumps.
- Inline water supply is usually applied for distances up to 3–5 km. The pump next to the water body is the first in the line to be started. The other pumps are started as the line fills with water. To obtain the highest possible pressure, design the pump/hose line beforehand (see Appendix 4).
- In case of long-distance water supply it is very important to be able to make simple calculations to assess which motor pumps in combination with which fire hoses will provide the most effective results (Appendix 4).
- To refuel all pumps in the line, they must be shut off at the same time. To relieve pressure, it is sufficient to reduce throttle on the pumps furthest from the water body. Use two-way radios to ensure that all members of the team can hear the nozzle operator's commands at the same time. Two adjacent pumps may be serviced by the same
- operator as long as they are located within sight of each other. The operator first shuts down the pump furthest from the water body, and then the one closest to it.
- When laying long hoselines with fittings called dividing breechings, draw a hose layout scheme to visualise exactly where and how many hoses to connect.
- Use hose spanners to connect hoses 38 mm in diameter and larger.
- When laying hose lines on steep slopes (when the hose filled with water is not supported on the slope and therefore slides down or when the hose is hanging off a rock), fasten the hoses to trees and rocks by attaching loops (fire-hose straps) to coupling heads (not to the hose body).

- If hose lines have to be laid across a roadway, hose crossing points must be made. To make them, use hose ramps, crossings made of logs and soil; on an unpaved road, a groove can be dug for the hose. If the hose gets under a vehicle's wheel, it may break or damage an impeller of the motor pump.
- There should always be a trained pump operator near the running pump who is able to stop it or start it, sometimes in an emergency.
- Establish reliable communication between the nozzle operator and the pump operator. The pump noise is louder than the human voice, so the operator needs to use radio communication or clearly visible, understandable hand signals.
- If possible, the nozzle operator should have an assistant who delivers additional hoses and helps move the hose line. It is safer to work in pairs. If the hoses need to be refastened, for example to increase the line length, the operator needs to be told to throttle down the pump. If a working line is being built from the dividing breeching, it is possible to shut it off at the dividing breeching only, without reducing throttle at the pump, after warning the other nozzle operators that pressure at their nozzles will increase.
- If grass or shrubs are burning or there is open burning on the forest floor, aim the jet at the base of the flame. When vertical surfaces are burning (dry trees, poles, steep
- slopes, walls), aim the jet from top to bottom in zigzags. When extinguishing a peat fire, aim the compact jet vertically downwards to break up sintered lumps and cut through the ground. Aim the jet downwards, constantly moving the fire hose nozzle while cutting and mixing the burning peat with water until it forms a uniformly cold mass. In cases of insufficient pressure, when the water fails to penetrate the bottom of the peat fire point or does not cut through the ground along the edges of the fire point, one or two people with spades must be sent to help the nozzle operator dig over, cut, and mix the peat with water.
- After the pump operations are finished, close the gasoline valve on the pump. Disconnect the hoses from the pump. If there are any loose spacers of hose nuts, tie them to the motor pump. Drain the water from the pump before it is transported.
- To avoid losing the hoses, roll the line in the direction from the hose nozzle to the pump. If the line is routed up the slope, open it from the hose nozzle to the pump to reduce the pressure. We do not recommend leaving rolled up hoses in a forest without reliable landmarks.
- Store fuel and lubricants in the shade, away from the operating pump. Sign all canisters (with drinking water, oil, clean gasoline or gasoline/oil mixture). Wait for the engine to cool down before refueling. Do not fill the tank to the top to avoid spillage.

5.4.2. FIRE HOSE OPERATION

- When transported to a fire location, hoses should be arranged in double donut rolls *(Fig. 57)* so that there is no difficulty in deploying them quickly. For long trips in the back of a car or on boats, tie each roll with a rope so the hoses do not become tangled.
- To roll a hose into a double donut roll, find its middle part, fold the hose in half, leaving the top half 20-40 cm shorter than the bottom half, and roll tightly from the middle to the half nuts.
- If a hose needs to be moved a short distance within one fire location without getting it mixed up with other hoses, the most convenient and fast way is to assemble it in a figure of eight while draining the residual water *(Fig. 58)*.
- A severely damaged hose requiring repair should be marked, for example by cutting off the half nut on the damaged side.

Fig. 57. Double donut roll

Fig. 58. A hose rolled in a figure of eight

- After returning from the fire scene, hoses should be washed and dried by hanging them by their middle part in a ventilated room or outdoors but not in the sun. At least once a year the hoses should be re-rolled to expose different seams, to avoid forming an easily worn longitudinal crease.
- If a hose is damaged and holes have appeared, which may lead to breakage, immediately close the hole with a hose clamp. It is a good idea to always have wire and clamps available for quick hose repairs. Sometimes a patch from an old hose of the same diameter, 20–30 cm long, is placed on the body of the new hose when tying the coupling heads. If the hose is damaged, depressurize the line and slide the patch in place of the new hole.

5.4.3. WATER SUPPLY BY FIRE ENGINES

It is also possible to use fire engines for water supply (water-tank trucks, fire pump trucks), adapted vehicles (sprinkler trucks, sewage trucks, etc.) as well as tractors with tank trailers or mounted pumps.

To deliver large volumes of water over long distances, fire pump trucks are used in combination with fire hose trucks.

Usually, a 150 mm diameter main line is laid from the fire pump truck installed at a water body with a four-way dividing breeching is installed on it, which enables further laying of second order main lines (usually 77 mm). Three-way dividing breechings are installed on the second order main lines, which are already as close as possible to the positions of nozzle operators, and from them, short working lines are laid to the fire hose nozzles. If the pressure generated by the fire pump truck is insufficient, additional booster motor pumps can be installed as relay pumps into the second order main lines or into the working lines. A fire pump truck can also be used to supply water to several relay water-tank trucks that supply water directly for extinguishing fires.

When using fire engines, it is important to position them at the water source so that the ground is not eroded or settled beneath them. If it is not possible to drive up to a water source to refill the tank, a motor pump or a vacuum ejector will be required. When using a vacuum ejector, lay hoses of suitable diameter (66 mm at the inlet, 77 mm at the outlet). It is very important to lay hoses without kinks and to position the hose strainer of the vacuum ejector so that it is not clogged with dirt.

A fire engine pump can rupture a hose line, particularly if the hose is pinched. When supplying water from a fire engine or a high-pressure motor pump, first supply water at a minimum pressure until the air comes out of the hose nozzle, then slowly increase the pressure.

Sometimes a fire pump truck is used to fill temporary water bodies (areas between dams, pits), from which water is taken by motor pumps and water-tank trucks. For example, a fire pump truck that operates uninterruptedly at night can fill a water body so water is taken by motor pumps throughout the next day in the immediate vicinity of active peat fire points.

The use of fire pump trucks for extinguishing peat fires only makes sense when a very large volume of water is required, and the water is available in accessible water sources. Usually before installing fire engines it is necessary to create piers for them, to deepen the place of water intake, and to build dams that retain large volumes of water. Fire pump trucks require large quantities of diesel. Laying and rolling down long main lines is time-consuming. It is more efficient to extinguish peat fire points in their early stages, when portable motor pumps or water-tank trucks are sufficient, and there is still plenty of water nearby.

5.5. FIRE EXTINGUISHING WITH THE USE OF HEAVY MACHINERY

Heavy crawler machinery can be used for extinguishing peatland fires as well as for debris removal, damming, and road construction.

Bulldozers

As part of peatland fire suppression, bulldozers are used for construction of roads, dams, and piers for fire engines. Bulldozers can be used to extinguish shallow peat fire points in shallow peatlands (with a thin peat layer).

Bulldozers can be used to extinguish peatland fires by mixing the burning peat with damp, non-burning soil or with the underlying non-flammable soil. Fire suppression begins from the edges of peat fire point, moving concentrically toward the center. Up to one-third of burning peat and two-thirds of non-burning peat is captured by a bulldozer blade. The resulting mass is additionally mixed with caterpillar tracks. In Russia this method of fire extinguishment is often called the Sretensky method. V. A. Sretensky, the author of the method, recommends using bulldozers in pairs, because itis faster and safer. This method can also be used with excavators.

The bulldozer mixing method is not appropriate when a peatland burns continuously and deeply because there is no overly moistened peat close to the surface. In such conditions, the risk of falling into burned spots is high, the machinery operation is hampered by debris, and large volumes of smoldering material heat the vehicle mechanisms when burning peat is mixed with the underlying soil.

Attempts to extinguish deep and extensive fires with bulldozers alone, without water, are ineffective and often result in renewed smoldering. Sometimes, after unsuccessful attempts at such extinguishing, the situation becomes worse because smoldering continues in the mixed, air-exposed piles of peat.

Excavators

Excavators at peat fire locations are used to contain individual peat fire points or their groups by excavating closed circular ditches to the groundwater level or to the mineral soil. Deep excavation will prevent fire spreading to new areas and allow time to lay hoses. A ditch is dug at least 1–2 m away from the visible edge of the peat fire point. In this case, the soil is piled outside the peat fire point, outside the circular ditch.

Excavators are useful in preparing water intake locations. They are used to deepen and clear silt and mud from suction hose locations, to build dams to retain water and to make overflows on dams, and to construct piers for fire engines from compacted peat or underlying soil *(Fig. 59)*.

If heavy machinery has been working at the peat fire points or removing debris and has been in contact with burning peat, its tracks or wheels must be sprayed with compact water jets to prevent the spread of burning particles of peat to new areas. Burning peat particles may cause machinery to catch fire.

PHOTO BY: MARIA VASILIEVA/GP

Fig. 59. Construction of a pier and deepening the water intake location for water-tank trucks

5.6. EXTINGUISHING LARGE PEAT FIRES IN CASES WHEN EXTINGUISHING INDIVIDUAL PEAT FIRE POINTS IS POINTLESS

Sometimes a fire that has not been extinguished at an early stage develops faster than it is being extinguished. In summer and fall, there may not be enough water in the drainage network to extinguish all peat fire points, in which case the only possible tactic is flooding the burning area by means of cascades of dams and new ditches redirecting water to the peat fire points.

If water is scarce, one option is to dig deep down to the underlying soil to create circular ditches around the peat fire points and their clusters. Ideally, firefighters will be able to fill the ditches with water. After containing f the peat fire points, efforts should be focused on preventing sparks and smoldering peat particles from spreading to the areas that are not yet burning. Ditches are made to encircle the clusters of peat fire points or the entire fire area with multiple peat fire points.

Important steps

- **Remove any hazardous trees that surround the ditch.** Rees are a hazard for firefighters and if they fall they become bridges for the fire.
- **Remove debris with chainsaws or spread the debris with bulldozers in the area surrounding the ditch on the side of the peat fire points.** In this way, we will minimize the number of sparks flying from the contained peat fire points when the debris is burning.
- **Create a protective ditch around the active peat fire point using an excavator.** A 1–2 m distance from the edges of the fire point must be observed to avoid digging out and spreading the burning peat into the pile. The pile is made on the protected side, outside the fire point *(Fig. 60)*, otherwise, the high pile may ignite from contact with the fire point, and the wind could throw sparks to the protected area. A passage about 4 m wide must be left between the pile and the edge of the ditch on the outer side of the fire point for ease of extinguishing and guarding.
- **Fill the ditch with water** (for example, by connecting it to the main outfall), consider options of retaining the water in case its level drops in the remaining part of the drainage network, such as by creating a cascade of temporary dams.

Fig. 60. Proper containment of a peat fire point by creating a ditch to the mineral soil (the pile goes outside). A passage is left between the pile and the ditch

- **Maintain an adequate number of people and equipment for guarding and extinguishing new peat fire points to prevent sparks from spreading beyond the containment line for the entire duration of peat burning.** Spark spreading occurs most often during daylight hours, when an open debris fire is burning and a strong wind carries burning materials. It is permissible to finally withdraw people from extinguishing such fires either in case the burning has completely ceased and the burned area has cooled or in case of stable fall or winter precipitation ruling out the ignition of peat and other combustible materials in the protected area.

5.7. QUALITY CONTROL OF FIRE SUPPRESSION

Each extinguished fire point must be carefully checked manually or instrumentally with a probe thermometer.

Manually

A small test pit is dug with a spade to feel the layers of peat by hand to the full depth of the extinguished fire point. Temperature is determined by hand *(Fig. 61)*. If the extinguished peat layers are warmer than the hand, keep extinguishing the fire point.

Instrumentally

Probe thermometers *(Fig. 62)* are submerged slowly into the peat to measure the temperature at different depths in the underlying soil *(Figs. 63, 63a, 63b)*. If the temperature exceeds 40°C, the peat fire point should be extinguished by digging out the warm area, pouring water over it, and mixing it; then the temperature should be measured again.

ILLUSTRATION BY: TATYANA KHAKIMULINA

Fig. 61. Manual quality control of fire suppression

Small, carefully extinguished peat fire points should be guarded for three days. Large peat fire points that were examined after extinguishing should be guarded for one week. Peat fire point guarding is most effective in the mornings and evenings when the smoke is easier to see, the odor of smoldering peat is easier to smell, and the difference in temperature between the smoldering surface and the extinguished surface is more reliably detected. Areas with renewed smoldering are flooded with water and mixed thoroughly. If the burning does not resume within a week, it is considered completely extinguished.

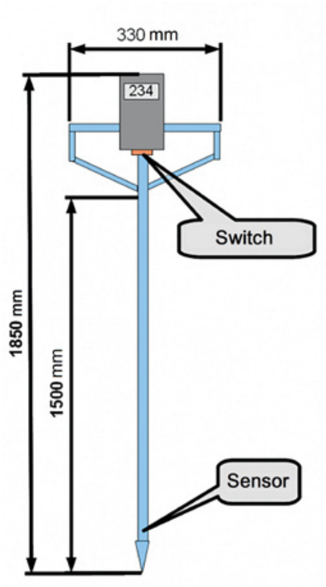


Fig. 62. A probe thermometer

PHOTO BY: MARIA VASILIEVA/GP

Fig. 63. Determining the depth of a peat fire point with a probe thermometer

PHOTO BY: MARIA VASILIEVA/GP

Fig. 63a. Temperature readings in the depth of a peat fire point on the probe thermometer

PHOTO BY: IVAN SEMENOV/GP

Fig. 63b. Tip of the probe with a heat sensor

5.8. COMMON MISTAKES MADE WHEN EXTINGUISHING PEAT FIRES

When extinguishing peat fires, it is very important to follow the correct sequence of stages, observe the procedure, and carry out quality control. Mistakes often result in renewed smoldering of the peat. We have compiled the most common mistakes to avoid.

Direct extinguishing by pouring water

Mistake 1. Extinguishing only the visible part of the fire point.

The result. Hidden smoldering fire points and areas where the heated peat is capable of further self-heating. Such areas usually remain under the overhanging sodden edges of peat fire points. This can lead to renewed smoldering of the fire point and a new fire.

The correct method. Detect the boundaries of the peat fire point using probe thermometers or manually. Dig test pits around the fire point and check the temperature. All areas detected with temperatures above 40°C must be totally suppressed.

Mistake 2. Extinguishing the peat fire point by simply filling it with water, without mixing the peat layers with a spade.

The result. Hidden smoldering fire points and areas with heated peat remain under the layers of dense, water-impermeable peat coke. This can lead to renewed smoldering of the fire point and a new fire.

The correct method. Open and shred the edges and lower point of the fire point with a spade, paying attention to where layers of peat coke may be present. Carefully monitor the temperature of the walls and the bottom of the peat fire point after extinguishing. If any areas with temperatures above 40°C are found, they must be totally suppressed.

Mistake 3. Extinguishing with a peat deep nozzle and not controlling the quality of fire suppression.

The result. Hidden smoldering peat fire points and areas of heated peat remain. This may lead to renewed smoldering of the peat in the fire point and a new fire.

The correct method. When using the peat deep nozzle, check the temperature with probe thermometers. If there is any doubt about the quality of water pouring or if areas with a temperature above 40°C are found, wash out all softened peat with a compact jet from the manual hose nozzle and mix it with a spade.

Mistake 4. Laying hose lines on unextinguished hot peat or hot peat ash *(Fig. 64)*.

The result. Damage or destruction of hoses.

The correct method. Lay the hose lines only over peat that did not burn or peat that has been fully extinguished. Regularly check to ensure the peat under the hoses has not ignited.

PHOTO BY: MARIA VASILIEVA/GP

Fig. 64. Laying the main line over burning peat, which is incorrect because the hoses will burn

Mistake 5. Extinguishing peat fires by plunging jets from manual hose nozzles or deluge guns *(Fig. 65)*. Extinguishing a peat fire by draining the water from main and working hoses without the use of hose nozzles.

The result. Inefficient use of water, poor quality of extinguishing, high probability of resumed smoldering.

The correct method. Extinguish with the use of compact jets to mix the burning, heated peat with water, and constantly monitor the quality of extinguishment.

Using heavy machinery

Mistake 1. In the burned area, a bulldozer rakes burning peat into heaps without fully extinguishing the fire.

The result. Heaps of burning peat smolder intensively for long periods. Sparks may scatter in windy weather, which may create new peat fire points.

The correct method. Disperse heaps of burning peat with a bulldozer and do not rake them manually.

Mistake 2. A bulldozer spreads burning peat with its caterpillar tracks after driving over an active peat fire point.

The result. New peat fire points are formed along the path of the bulldozer.

The correct method. Avoid driving over burning peat but if it is absolutely necessary, wash the caterpillar tracks and the entire undercarriage of the bulldozer with a water jet.

Mistake 3. A ditch around the peat fire point is made with an inside pile, on top of the burning peat *(Figs. 66-67)*.

The result. Such a pile of burning peat smolders intensively for a long time. Sparks are scattered in windy weather, which may create new peat fire points.

PHOTO BY: MARIA VASILIEVA/GP

Fig. 65. Extinguishing a fire from the water-tank truck. ***Wrong:* the plunging jet from a deluge gun does not ensure proper suppression of a peat fire**

The correct method. Keep a 1-2 m distance from the visible boundary of the peat fire point, and keep the pile outside it.

Mistake 4. Trees in and immediately around the contained peat fire point have not been removed *(Fig. 68)*.

The result. Trees in a peat fire point that has been contained but not extinguished will fall down because the roots are burned. Debris is formed, an open fire is reignited and sparks are scattered, potentially creating new peat fire points. The trees falling across the ditch at the edge of the peat fire point may also serve as bridges for an open fire to cross the containment line.

The correct method. Cut down and remove all hazardous trees near the edge of the peat fire point and the surrounding ditch.

PHOTO BY: MARIA VASILIEVA/GP

Fig. 66. Containment by means of a trench. ***Wrong:*** the outline is not closed and the pile is made inside not outside the trench, so the fire has not been stopped

PHOTO BY: MARIA VASILIEVA/GP

Fig. 67. Containment of a small peat fire point with a trench. ***Wrong:*** the pile is made on the side of peat fire point. Sparks spread across the ditch, which lead to new smoldering fire points along the perimeter

PHOTO BY: MARIA VASILIEVA/GP

Fig. 68. Containment by means of a wide bulldozer trench. ***Wrong:*** the burned trees have not been removed. As a result of debris burning, the fire has spread beyond the trench

5.9. PROTECTING BUILDINGS, STRUCTURES, AND INFRASTRUCTURE

The following facilities need to be protected when extinguishing peat fires: roads, former narrow-gauge railway embankments, transformer substations, detached houses and maintenance buildings built on peat *(Figs. 69, 70)*.

The main actions in protecting these facilities is to encircle them with ditches and trenches dug down to the groundwater level or to the underlying soil. It is crucial not to leave any combustible material that could allow an open fire to spread to the protected area. It is important to clear or disperse any debris from fallen trees in the vicinity of the protective ditch.

If it is suspected that the roadbed is burning, the section should be checked with probe thermometers or by digging test pits before any machinery passes over it. If machinery is not driven carefully on a burning road or embankment, the vehicle could fall into a burned spot. The embankments of narrow-gauge railways and earth roads built on top of peat often burn faster than other areas because they are elevated above the rest of the peatland and dry out more quickly. Signs of potentially dangerous burnout on a road include smoke on slopes and the formation of peat fire points of unknown depth on slopes and roadsides.

When creating a ditch to protect buildings constructed on peat, it is important to ensure that no smoldering peat spreads to the protected area through animal burrows or utility lines buried in the peat. It is desirable to maintain access roads to such facilities throughout the period of their protection. If it is not possible to dig protective ditches around access roads, patrols should be organized to detect peat smoldering areas at an early stage and to extinguish them using water.

5.10. USING AIRCRAFT TO EXTINGUISH PEAT FIRES

The main goals of using an aircraft, including unmanned aircraft, in peat fires are reconnaissance, visual detection of fire-exposed areas, and assistance in reconnaissance of large fires *(Figs. 71-73)*.

As a rule, there is no need to deliver people and equipment to drained peatlands by air because ground transport is usually much less expensive. In exceptional cases, water discharge from air tankers and heli-buckets may be possible to suppress open burning on a non-contained fire edge. Such discharges are carried out when there is intense open burning and the fire area is increasing or if ground teams cannot or do not have time to stop the spread of open fire.

The use of firefighting aircraft is acceptable in the areas where ground operations are impossible because of special hazards, such as high background radiation or contamination with hazardous substances. One of the possible tasks for aviation in such conditions consists of limiting the emission of smoke and hazardous combustion byproducts. Peat fires cannot be extinguished by water discharges from aircraft but such discharges can significantly reduce the amount of smoke and radioactive dust.

When making the decision to use aircraft to directly extinguish a peat fire, the incident commander should keep the following in mind:

- **Strong air currents from an aircraft flying at low altitude over a peat fire can cause trees with burned roots to fall down en masse.** This poses a lethal hazard to people working at the fire edge, and therefore all ground operations must be suspended for the duration of aircraft operations. Additionally, the workers must be taken to a safe zone at a distance of at least twice the height of the outermost damaged trees but not less than 50 m.

- **Any aircraft flying over and any water discharge can disturb local air currents carrying burning peat dust and thereby contribute to fanning an open fire from active peat fire points.** During peat fires, the negative impact of aircraft (fanning peat fire points and increasing the fire area) is often greater than the positive impact (partially extinguishing individual open fires at the edge). The benefits need to be weighed against the harms of exposure to air currents.
- **Water discharge in any quantity (up to one ton or more per square meter of burning peatland) cannot provide reliable fire suppression.** Such discharges can only temporarily dampen the surface layer, slow down the smoldering and reduce the amount of smoke produced. Regardless of how many discharges are made, the area cannot be considered extinguished until it is examined by ground teams.

Thus, one should refrain from the use of aircraft in the vast majority of peat fires. Light helicopters, light aircraft and drones used for reconnaissance can be exempted.

PHOTO BY: MARIA VASILIEVA/GP

Fig. 69. Summer houses (dachas) that have been partially destroyed in a peat fire

PHOTO BY: MARIA VASILIEVA/GP

Fig. 70. Burning embankment of a narrow-gauge railway

Fig. 71. A drained fen on fire. Reconnaissance of a peat fire point by unmanned, radio-controlled aircraft

Fig. 72. Searching for active smoldering peat fire points and water intake locations with an unmanned aircraft over a drained fen. Active peat fire points and a convenient site for installation of a water-tank truck or a fire pump truck at a river bend can be seen

Fig. 73. Survey of a burning drained fen from an unmanned aircraft. The image shows a characteristic location of smoldering peat fire points and burned tree debris

5.11. SPECIFICS OF EXTINGUISHING PEATLAND FIRES IN PROTECTED AREAS (PA) IN RUSSIA

When extinguishing peat fires in protected areas, we take into account their protection regimes as well as other legal and regulatory requirements applicable within their boundaries.

The regimes of protected areas often prohibit any clear-cutting, clearing, water drainage systems and disturbance of soil cover (hence the use of heavy machinery). Every time a decision has to be made on tactics and technology of fire suppression, one must compare the harm caused by fire with the harm caused by fire-suppression activities, and match this with the regime of the particular protected area. In Russia, the final decision on the choice of fire-extinguishing technology is made by the management of the protected area.

The sequence of peat fire point extinguishing is determined in consideration of the size, location and type or "zone" of the protected area as well as the locations of habitats and nesting sites of protected bird species, and areas of rare plants. In Russia nature reserves, national parks and other types of protected area are often divided into different zones. For example, a "zone of strict protection", "zone of limited land use", or a "buffer zone". Each zone has different rules in relation to nature protection and because of this, the prioritisations in a firefighting plan may be carried out differently depending on the type of protection and zone.

When extinguishing fires in protected areas, the use of wetting and foaming agents are avoided, additional access roads are not made and new water bodies are not created. Whenever possible, dams are constructed manually to limit any damage to the soil cover and trees. Direct suppression of peat fire points is preferred to minimize the burning areas. Motor pumps and hoses are often transported manually from the existing roads to the worksite *(Fig. 74)*.

Many protected areas with previously drained peatlands are now engaged in the gradual but consistent restoration of mires in those areas, accompanied by comprehensive scientific observations. This not only reduces the fire hazard but also provides valuable practical material for the development of rewetting projects in other areas.

PHOTO BY: MARIA VASILIEVA/GP

Fig. 74. Carrying light motor pumps and hose lines to extinguish a peat fire point in an area that is difficult to reach

CHAPTER 6. PREVENTION OF AND EXTINGUISHING PEAT FIRES BY RAISING THE WATER LEVEL

Raising the water level on a drained peatland allows us to either totally prevent peat fires or to create favorable conditions so they can be extinguished, such as by flooding some peat fire points and accumulating sufficient water. Water-filled ditches become obstacles to the spread of fire on the surface and underground *(Fig. 75)*.

It is important to remember that an incorrect estimation of water-level rise and the possible drop in the levels between the upstream and downstream pools of a dam can lead to its destruction, unwanted road flooding and other issues.

PHOTO BY: MARIA VASILIEVA/GP

Fig. 75. The result of successful fire extinguishment by water flooding

6.1. TERRAIN RELIEF MEASUREMENTS

Terrain relief measurement is the first step of water-retaining operations in drained peatlands. Measurements are the only means by which to understand the following: the level to which the water will rise and whether it is sufficient to extinguish peat fires; the boundaries of the flooded area; where the excess water that inflows through the ditch will be discharged, including during the spring flood; and what the difference between water levels on a single dam or a cascade dam will be. The overall inclination of the area can also be determined as well as the inclination of ditches and their profiles, and in turn the quantity of building materials required for the construction of the ditch block can be calculated.

Terrain relief measurements in a drained peatland are carried out by a geodetic optical levelling instrument or GNSS (Global Navigation Satellite System) equipment. All work is carried out in a custom coordinate system because it is important to determine how much higher one point of the terrain is than another as opposed to the altitude of the point in the height system used in your country. In geodesy, the height of a point on the terrain in reference to a certain base level is called the elevation.

6.1.1. MEASUREMENTS BY A GEODETIC OPTICAL LEVELLING INSTRUMENT

This method is suitable for measurements in a small area, within a radius of up to 150 m. For example, to determine which side of a ditch is higher, or to estimate whether the peat fire point is located above or below the level to which we want to raise the water in a ditch.

An optical levelling instrument is the simplest, most affordable geodetic device. It is always used with one or more levelling rods, and preferably with a tape measure 30 or 50 m long. It requires direct visibility between the instrument and the point whose elevation is being measured. A levelling rod (a levelling staff) is a sliding telescopic ruler with a scale that starts at its lower end (base of the rod). On one side, the rod has a scale with increments of 1 mm and on the other side it has an E-scale with increments of 1 cm. For working in peatlands, a 5 m rod is sufficient.

An optical levelling instrument is a field scope with magnification of 20x to 33x, with an axis of sight that must always be horizontal (if the instrument is operational and installed correctly). An optical levelling instrument enabless reading the levelling rod from a distance of several tens of meters with great accuracy, thus making it possible to identify the difference in elevations of interest. The recommended distance from the level to the levelling rod is not more than 50 to 75 m. The readings have an accuracy of up to 2 mm.

Because the range of optical level operations is limited, any large object is divided into sections by benchmarks, which are points tied to terrain with constant coordinates and elevations. They include: a nail hammered into a tree trunk at its base and protruding by 3 to 5 cm; a wooden stake or a metal rod 1.0 to 1.5 m long; a tree stump (one that is not rotten), with a measuring point marked by a hammered nail; or the top of the pipe at a pipe culvert under the road, with a measuring point is marked with paint. Any work at the facility or the area begins with the installation of a benchmark. In the following days, it can help ensure the accuracy of measurements — especially if the calculations show mistakes — because we will have a point on the ground with a known altitude.

It is extremely important to install a tripod with a levelling instrument at the measurement station and to bury the tips of the tripod supports in the ground. Peat soils are compressed under foot,

resulting in displacement of the levelling instrument, thereby rendering measurements inaccurate. We try to install the tripod on solid, mineral soils. If this is not possible, we do not step on the ground within a radius of 30 to 40 cm from the tips of tripod supports. If the soil surface is wavering too much, the tripod should be installed on poles that are inserted in the ground.

Places of installation of the levelling rod, i.e. the measurement points, are selected as follows:

- When measuring the total terrain relief in the area: on terrain discontinuities and its middle points but not on local elevations or in depressions.
- When measuring the profile of a ditch: on the transition from the surface of a bank to the slope of a ditch wall, at the bottom of a ditch, installing the rod base possibly on a hard bottom and, at the same time, reading the water level, if the bottom is under water.
- When determining the elevation of the crest of a dam: at the lowest point of the crest.
- When determining the spillway level: we are looking for the top point on the overflow path through which the excess water will be discharged.

When measuring, the readings on the scale are read through the central crosshair of the ocular grid. Two additional lines are for range finding, thus allowing us to measure the distance from the level to the rod. As a general rule, the optical levelling instrument has a rangefinder coefficient of 100, whereby the number of centimeters we see between the rangefinder lines is the number of meters from the level to the rod. The error of such measurement is approximately 1/300th of the measured distance.

The measurement results can be conveniently written and processed in the blank of level measurements *(Fig. 76)*.

What we enter into the table:

Back sight reading (BS) is the benchmark from which we start measuring in this area. If this is the first benchmark on the object, and this benchmark is not a point with a known absolute altitude, we assign its elevation (a relative height/altitude) ourselves. As a rule, it is a four-digit number that indicates the elevation of that point in millimeters. Experts recommend setting the height of the first benchmark in the range (relative height) of 5,000 to 9,000 mm to avoid negative numbers. We write the set height of the benchmark in the Height column and then record the staff readings in the same line in the Back sight column.

Intermediate sight is the number of the staff reading when measuring all the surface points and water levels taken in this area. They are written in subsequent columns.

Fore sight reading (FS) is the staff reading when measuring the next benchmark measurements in an area (if such a benchmark is available).

The heights of the measured points are calculated by means of the following formula:

H = Δh + Height of the benchmark = Back sight - Intermediate + Height of the benchmark.

All calculations are conducted without changing the plus/minus sign (algebraic calculations).

When the level is transferred to the next measurement area, its height in the log is transferred to the next line (purple and orange cells in *Fig.76*) but a new back sight reading is made for a new area.

Details about the operation of the optical level, methods of its calibration and configuration can be found in its manual and in textbooks on engineering geodesy.

	A	B	C	D	E	F	G
1	Date:						
2	Location:						
3	Executor:						
4	Measurement, mm			Δh, mm	Height, mm	Reference level point	
5	Backsight	Internediate	Foresight			Mark	Note
6	2355			-----	5000		
7		5455		-3100	1900		
8		3500		-1145	3855		
9		4500		-2145	2855		
10		5689		-3334	1666		
11			2375	-20	4980		
12	1595				4980		
13		4320			2255		
14		4310			2265		
15		5320			1255		
16			4331		2244		
17	2005				2244		
18		2500			1749		

Fig. 76. Blank of level measurements (with explanations)

6.1.2. MEASUREMENTS MADE WITH GLOBAL NAVIGATION SATELLITE SYSTEM EQUIPMENT

Global navigation satellite system (GNSS) equipment includes high-precision satellite receivers of the geodetic class. They allow measurements with centimeter accuracy. They do not require direct visibility on the ground but are demanding with respect to the open sky: branches and foliage should not block the satellite signal. These devices are expensive, but they can be rented.

A modern GNSS receiver is a waterproof, shockproof monoblock containing a satellite antenna, a data-processing microchip, batteries, receiving/transmitting equipment to communicate with other equipment, a power button and auxiliary indicators.

Below we provide a description of our work experience with GNSS equipment. The receiver is installed on a geodetic pole to be placed above the measurement point. The receiver is controlled from the controller, which is a protected, Android-based device with the GNSS receiver software installed. The receiver and the controller are connected using Bluetooth.

The points on the ground when measuring with the satellite receiver are taken in the same way as when measuring with the optical level. Additionally, it is recommended to install reference marks similar to benchmarks near the places where future work is planned as well as at the corners and along the perimeter of the work area. Later, this will allow us to conduct local measurements by means of a low-cost optical level or by transferring the base receiver to a new position. (See below for the specifics of operating with the team's own base.)

GNSS receivers always work in pairs because the change in the coordinates of the portable receiver (the rover) is measured in relation to the fixed receiver (the base). There are two modes of operation: (1) with the network of reference stations; and (2) with the team's own base.

When operating with the network of reference stations, the user may only have one rover (a portable receiver) for measurements on the ground. In this case, a satellite receiver permanently attached to a building will perform the role of the base receiver. The coordinates of this attached receiver are determined with high accuracy during the installation. A base receiver and the rover are connected using mobile Internet.

Operations in the network of reference stations are only possible in an area with a stable mobile Internet connection.

Access to the network of reference stations is fee-based. The organization that rents out the GNSS equipment usually also provides access to its stations.

This method of terrain relief measurement is possible at a distance of up to 50 km from the base station. The root mean square error (RMSE) of the measurement results is calculated by means of the following formula: 15 mm + 1 mm/km. But in practice, the RMSE can reach 12 to 15 cm when working at a distance of 50 km from the base station. This method can be used for preliminary estimated measurements at the object, where the accuracy of 15 cm is sufficient to understand whether the nearest road or village would be flooded. In this case, all

measurements will be performed in the height system in which the altitude of all receivers of the reference stations are determined in your country.

Working with one's own base is more convenient and accurate, but it is also expensive. Two identical receivers are needed, one of which is permanently attached to the point that we establish as the base point, and the second is a portable rover. The RMS error of the measurement results will be 2 to 4 cm, i.e., the elevations will be determined with accuracy of ± 2 to ± 4 cm.

In Russia, the base and rover receivers communicate through a license-free LPD433 band (433 MHz) with a transmitter of up to 2 W. This power is sufficient to communicate with receivers at a distance of up to 3.5 km in the conditions of overgrown peatland (dense shrub).

It is possible to install a remote radio transmitter of up to 35 W, but in Russia it is necessary to obtain permission from a local radio center.

To ensure a long range of radio communications and stable reception of the satellite signal without interference, the base receiver should be installed in a place with open sky at a height of at least 3 m above the ground. A geodetic pole is suitable for this purpose, in combination with a tripod or a geodetic tripod with an extension pole *(Fig. 77).*

It is important to install the base receiver reliably so that it will not be toppled by the wind. Before starting the work at the base location, we drive a reference stake into the ground and consider it as the base benchmark *(Fig. 78)*.

We install a pole tip on it with the base receiver, or we measure the height of the base on the tripod from the stake's top. We assign the elevation and the plane (horizontal) coordinates of this benchmark ourselves. For the sake of simplicity, the coordinates of the base benchmark can be used, as determined by the rover receiver, before the work begins.

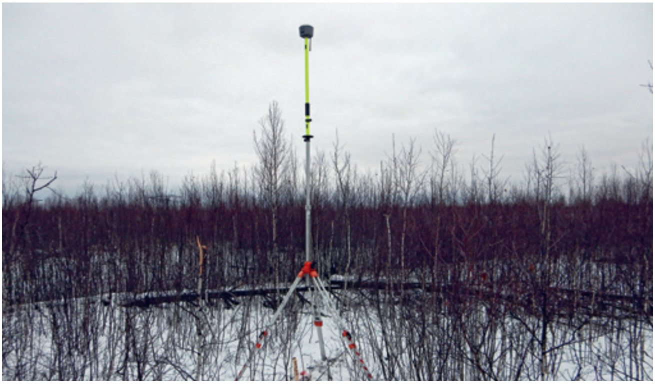


PHOTO BY: IVAN SEMENOV/GP

Fig. 77. Base global navigation satellite system receiver installed on a tripod

PHOTO BY: IVAN SEMENOV/GP

Fig. 78. Here, the benchmark is a length of rebar (a steel pole) measuring 1.5 m and driven into the ground. The wooden guard stake is used to record the designations and elevation

When working in Russia, we are not tied to the system of coordinates of the stations in the State Geodetic Network (GGS) in any way, as it is not necessary. To determine the inclination of ditches and the profile of a ditch, it is sufficient for us to know the difference in elevation between two points as opposed to their altitude in the national height system.

If we are planning to work from an object or area more than once (which is 99.9 % of all cases), it is necessary to make a “shift of the base”. When we turn on the base receiver, it determines its coordinates roughly, with accuracy to several meters. Consequently, the measurements made on different days will be shifted relative to each other by the size of that error, even if the receiver takes exactly the same position over the base benchmark. To avoid this, we need

to permanently appoint the coordinates of the base receiver on the ground and force the coordinates into it every time we turn on the base receiver (as a rule, at the start of the workday).

Actions after installing the base receiver over the base benchmark when it is turned on for the first time.

1. Measure the distance from the base benchmark to a special plate on the receiver, and record it in a notebook and on the stake of the base benchmark.
2. Turn on the base and the rover.
3. With the help of the rover, determine the plane coordinates and elevations of the base benchmark. The Base 1 point with roughly defined coordinates is automatically created in the controller's memory. On the following days of work, Base 2 and Base 3, and so on, will be created.
4. Add the height of the receiver over the base benchmark to the obtained elevation of the base benchmark. The result is the elevation of the base receiver's head, and for the sake of simplicity we appoint the plane coordinates of the base benchmark as the plane coordinates of the head.
5. Record the obtained plane coordinates and the elevation of the base receiver's head in several places (such as, a notepad, the measurement log, a map, a spare tourist satellite navigator). These will be its permanent coordinates.
6. In the controller, go to the Point Database section (or similar) and create a point with the assigned coordinates, calling it, for example, Base_1_Measure. Type in the coordinates manually from the keyboard. This will be the so-called catalog point.
7. Go to the Base Shift section, where we need to specify the GNSS point and the catalog point. Specify the GNSS point as Base 1 (on the following days, Base 2 and Base 3, respectively), and the catalog point is our assigned point Base_1_Measure every time. Press the OK button, and the program will calculate the base shifts for each measurement day.

To make sure that the shifts are applied correctly and to ensure that we work on the same coordinates every day, it is useful to put two reference benchmarks at a distance of 10 to 20 m from the base.

Their coordinates, determined after the very first shift of the base, will become the reference coordinates. In the following days, at the beginning of the measurements after the base shift procedure, we check the reference benchmarks. It is important that the coordinates measured every work day (first of all, the elevation) coincide with the coordinates of the first measurement on the first day with a maximum error of 4 cm.

The results of the GNSS survey can be obtained from the controller as files of the following format:

- **.kml** to upload to Google Earth or similar software. The points have plane coordinates but no elevations. On the satellite image one can clearly see the exact location where the measurements are taken, but the error of georeferencing of the image must be taken into account.
- **.csv** — an Excel table with full information about each point (coordinates, elevation, survey date, database);
- **.dxf** to upload to special software for building a digital model of terrain relief.

During the survey, points can be quickly marked on a paper map or an outline (schematic drawing) of the terrain. An intermediate option is possible: A .kml file is uploaded into the software, and the points of interest are edited by entering the elevations instead of their names. This method is convenient for making electronic schematic maps to be viewed and printed.

6.2. CALCULATIONS AND MEASUREMENTS DURING WATER RETENTION

Recommendations for measurements and calculations that may be needed during water-retention operations.

All calculations are in the International System of Units (SI) system. Dimensions are in meters (m), speed is in meters per second (m/s), time is in seconds (s), and discharge is in cubic meters per second (m^3/s).

6.2.1. MEASUREMENTS OF THE DEPTH AND CROSS SECTIONAL AREA OF A DITCH

With the ditch width up to 20 m, we make depth measurements every 0.5 m. It is important to identify any changes of bottom gradient. If we measure the depth (to determine how much building material is required), we measure down to a solid bottom. If we need to calculate the cross-sectional area of the ditch for calculating the discharge in the ditch, we measure down to the silt and bottom sediments. There is no water flowing in them *(Fig. 79)*.

The tool for measuring depth is a hydrometric staff gauge (a piece of hydrometeorological equipment) or a levelling rod. To detect the surface of silt and bottom sediment, there should be a support washer (a circle with a diameter of 150 to 200 mm or a square 200 × 200 with beveled corners) at the end of the staff gauge. The washer is stopped by bottom sediments so that the staff gauge does not sink into them.

Horizontal distances across the ditch are measured from the permanent starting point, which is a stake driven into the bank. It is used to hook up a measuring tape or to press a geodetic levelling rod laid across the ditch against it.

The cross-sectional area A of the ditch is the sum of the areas of the sections between the measurement points (verticals):

$$A = A_1 + A_2 + \ldots$$

We present each section in the form of a rectangular trapezium *(Fig. 80)*, the area of which is calculated by means of the following formula:

$$A_2 = 0{,}5 \times (h_1 + h_2) \times d_2$$

Bank sections are presented in the form of triangles whose area is calculated as:

$$A_1 = 0{,}5 \times h_1 \times d_1$$

$$A_4 = 0{,}5 \times h_3 \times d_4$$

6.2.2. MEASUREMENTS OF FLOW VELOCITY AND DISCHARGE IN A DITCH

The water flow velocity can be measured by means of a hydrometric current meter or a float. Measurements with a current meter are more accurate, but it is an expensive piece of professional hydrometeorological equipment. A float can be a DIY device.

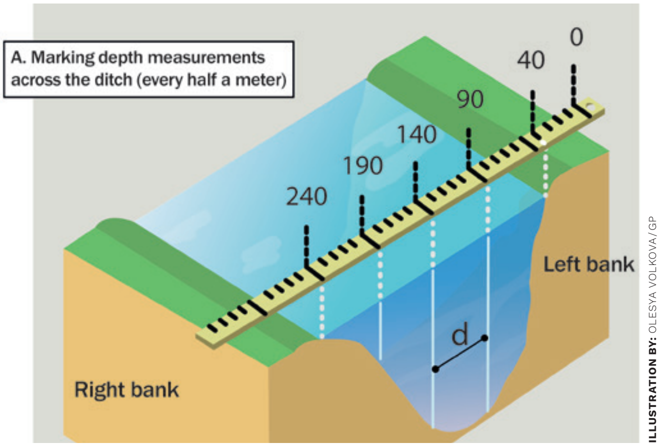


Fig. 79. Dividing the width of the stream bed into 0.5 m sections

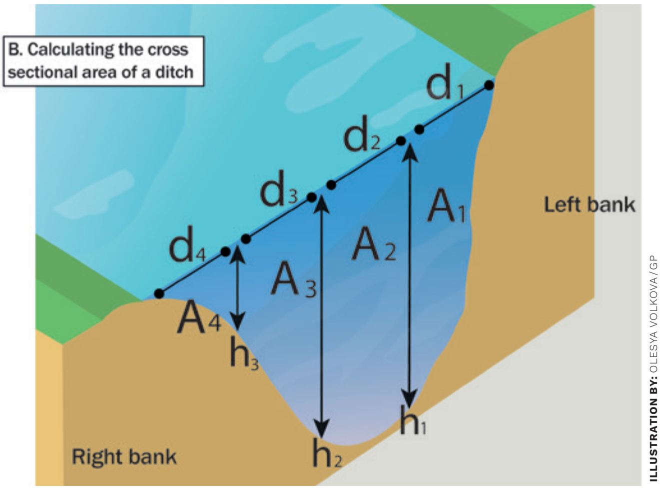


Fig. 80. Dividing the cross section of a ditch into sections to calculate its area

IMPORTANT!

All measurements are carried out in a straight section of the stream bed, with a uniform transit flow of water so there will be no impact from obstacles or bends in the stream.

Measurements of the flow velocity V by a hydrometric current meter are carried out on the same velocity (measurement) verticals as the measurements of the channel profile depths. At depths exceeding 50 cm, the flow velocity measurement at each velocity vertical is performed at two points: at 0.2 and 0.8 of the ditch depth from the water surface at the given vertical *(Fig. 81)*.

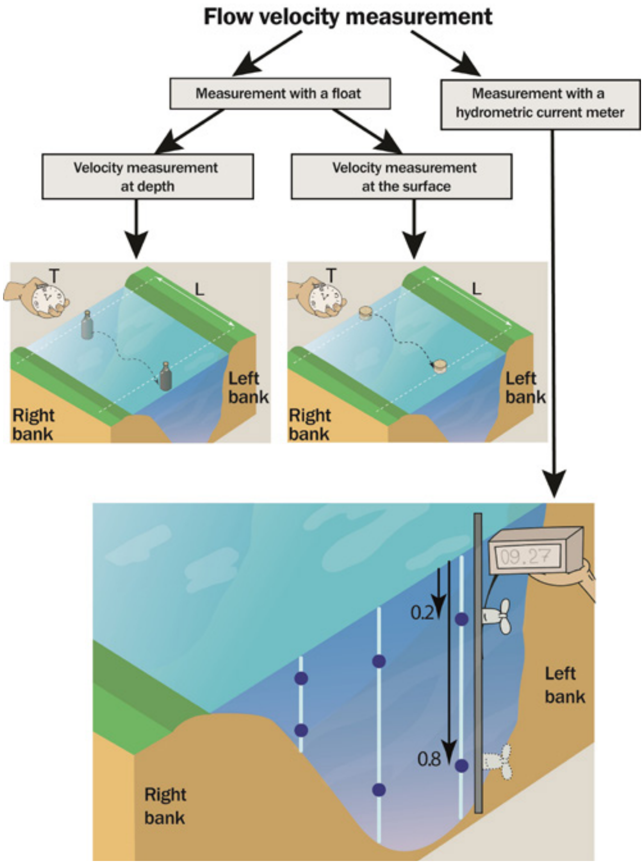


Fig. 81. Different ways of measuring water flow velocity

ILLUSTRATION BY: OLESYA VOLKOVA/GP

Subsequently, the average flow velocity at this measuring vertical is calculated:

$$V_{AVG} = (V_{0,2} + V_{0,8}) / 2$$

At depths of less than 50 cm, the flow velocity measurement is performed at a 0.6 of the depth from the water surface.

Subsequently, the discharge is calculated for each trapezoidal stream bed section (sections A_2 and A_3 — *Fig. 80*) and each triangular bank section (sections A_1 и A_4 — *Fig. 80*).

For the stream bed section A_2, the discharge through it will be equal to:

$$Q_2 = A_2 \times (V_{1\ AVG} + V_{2\ AVG}) \div 2\ (m^3/s)$$

A_2 is the cross-sectional area A_2 (m^2);
$V_{1\ AVG}$ and $V_{2\ AVG}$ are average flow velocities at the measurement verticals h_1 and h_2 (m^3/s).

Similarly:

$$Q_3 = A_3 \times (V_{2\ AVG} + V_{3\ AVG}) \div 2\ (m^3/s)$$

For bank sections A_1 and A_4, the discharge is calculated by formulas:

$$Q_1 = A_1 \times V_{1\,AVG} \times K \text{ (m}^3\text{/s)}$$

$$Q_4 = A_4 \times V_{3\,AVG} \times K \text{ (m}^3\text{/s)}$$

K is the bank coefficient, taking into account the influence of the type and nature of the bank on the flow velocity:

K = 0.9: a concrete wall;
K = 0.8: a natural vertical bank;
K = 0.7: a natural gently sloping bank; or
K = 0.5: if the water flow borders a "dead space" with no flow in the direction of the main stream (whirlpools near banks, a swampy bank).

Measurements of the flow velocity by a float can be carried out with DIY devices. We will need a measuring tape, a stopwatch and a float. Measurements are more accurate when conducted in the calm or mild wind (up to 2 m/s) so that it will not affect the speed of the float.

A float can be a wooden disk 5 to 15 cm in diameter and 2 to 5 cm thick, sawn from a suitable log, or it can be a similar object such as a spruce cone. When flowing downstream, this float will have the speed of the water surface layer, meaning it will be a surface float.

For measurements in a straight section that is not overgrown, two measuring lines are made. They can be thin sticks or levelling rods thrown from one bank to the other, or ropes stretched across the stream bed in the air. The measuring line is necessary to accurately record when the float crosses. The section above the upstream measuring line should be a straight section of the course bed with a calm stream so that the float picks up the flow velocity before entering the first line. The distance L is measured with a measuring tape between the lines and is thus recorded.

The float is launched 5 to 10 times. Three measurements are selected where the time of passing the distance between the lines does not differ by more than 10%. The average time T_{AVG} of the float passing the distance L is calculated, and the float's average speed is as follows:

$$V_{AVG} = L \div T_{AVG} \text{ (m/s)}$$

The actual discharge is calculated by means of the following formula:

$$Q = V_{AVG} \times K \times A \text{ (m}^3\text{/s)}$$

A is the average cross-sectional area between the measuring lines (m^2);

K = 0.8…0.85 is the coefficient of transition from the surface stream velocity to the average depth velocity.

Measuring the velocity by a submerged float made from a submerged bottle makes it possible to obtain the flow velocity averaged over the depth. But this method is complicated and requires selecting the float's depth depending on the stream bed depth. The method is given here for information only.

6.2.3. CALCULATION OF DISCHARGE IN A DITCH IF THE WATER SURFACE ELEVATIONS ARE KNOWN

The discharge can be calculated if the cross-sectional area of the ditch and the water surface inclination are known, for example, by knowing the elevations of water level at the beginning and the end of the measurement section, the water depth, and the surface roughness factor of the ditch bottom (the Gauckler–Manning coefficient can be found in reference books or on the Internet).

First, measure the elevations of the water surface using a geodetic optical level in a straight measurement segment with steady movement of water. And calculate the water level difference:

$$\Delta Z = Z_2 - Z_1 \text{ (m)}$$

Here, Z_2 and Z_1 are the water surface elevations at the beginning and end of the measurement segment.

Next, determine the length of the measurement segment L (m) and the cross-sectional profile of the ditch, calculate the cross-sectional area of the ditch A (m^2), determine the average water depth h (m) = A ÷ B, where B is the ditch width over the water surface.

Using the Manning formula below, we calculate the Chézy coefficient:

$$C = (h^{1/6}) \div n$$

Here, n is the coefficient of ditch wall roughness (the Gauckler–Manning coefficient), it can be found in the reference tables.

For typical surfaces, the Gauckler–Manning coefficient is as follows:

- Concrete poured into a formwork: 0.015
- A clean earthen ditch: 0.022
- An earthen ditch with gravel banks: 0.025
- A ditch of rough wooden boards: 0.013

We calculate the discharge by means of the following formula:

$$Q = A \times C \times (h \times \Delta Z \div L)^{0,5}\ (m^3/s)$$

6.2.4. CALCULATION OF DISCHARGE IN A PIPE

It is possible to approximately determine the discharge in the pipe culvert. To do this, calculate the cross-sectional area S of the stream flow and determine the flow velocity in the pipe *(Fig. 82)*. The flow velocity V is determined by the float as described above.

How to calculate the cross-sectional area of water flow.

1. Measure the inner diameter d of the pipe and the depth f of water in the pipe using a measuring tape. For accuracy, measure at the pipe outlet or in the middle section of the water flow to make sure there is no entrance funnel on the water surface.
2. Calculate the pipe radius R = d ÷ 2.
3. Calculate the cross-sectional area S of the water flow.

To do this, draw a circumference of the pipe internal diameter on paper in scale, then draw a line of the water level, and use a protractor to determine the angle α.

Or, we can calculate the angle α according to the following formula:

$$\alpha = 2 \times \arccos(1 - f \div R)$$

Next, we calculate the cross-sectional area of the water flow:

$$S = (3{,}14 \times R^2 \times \alpha) \div 360 - (R^2 \times \sin\alpha) \div 2$$

Calculate the discharge:

$$Q = S \times V\ (m^3/s)$$

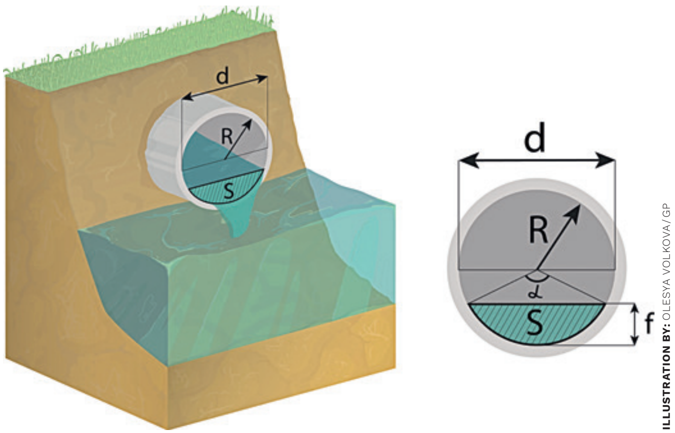


Fig. 82. schematic showing how to calculatie the discharge in the pipe

6.3. TOOLS AND EARTH-MOVING MACHINERY

6.3.1. TOOLS

The following is an approximate list of tools and equipment required for rewetting operations:

- A spade, which must be sharpened.
- An axe.
- A large geodetic 2 kg hammer with a 30 cm handle (for installation of benchmarks).
- A large 5 kg hammer to drive in stakes or sheet piles.
- A pruner for branches*.
- A gasoline-powered chainsaw.
- A single-wheel barrow for carrying soil and building materials*.
- Optical level with a 32x to 33x magnification. When working within a radius of 15 m, the optical level can be replaced by a household laser level.
- An aluminum tripod for the level.
- A 5 m levelling rod.
- 100 mm construction nails.
- An oil-based paint or an industrial marker with coloring paste to sign reference benchmarks.
- A cord 4 to 6 mm in diameter for marking the places of ditch blocks construction.
- A signal tape for marking the places of ditch blocks construction and reference benchmarks on location.
- A set of GNSS equipment to work with the team's own base (2 receivers with built-in VHF modems, a 3.6 m pole, a telescopic tripod with extension poles to install a base receiver at a height of at least 3 m) to cover large areas where an optical level is not sufficient*.
- An 80 kg vibrating plate for sand compaction*.

** Preferable but not absolutely necessary.*

Earth-moving machinery, heavy or small, can make the work easier and faster than by hand when constructing ditches and delivering building materials and tools to the work location. However, it is important to remember that the time and resources required for transportation of machinery on public roads and in off-road locations to the work site can outweigh the advantages. Small machinery can make the work easier, but one should not expect it to perform as well as heavy machinery does.

The use of any machinery is limited by the soil carrying capacity. Trees, which may not always be removed, can also become obstacles. As a rule, volunteer organizations do not own earth-moving machinery, but equipment can be rented or provided by the state organizations partnering in water-retention efforts.

6.3.2. EARTH-MOVING MACHINERY AND ITS SPECIFICS

A track dumper with a self-loading device:

- The most inexpensive type of rented machinery (in Russia).
- The width is 8085 cm, so it can drive between trees *(Fig. 83)*. This type of vehicle has a relatively high center of gravity when carrying a load, which increases the risk that it will tip over.
- Does not require a tractor driver license (in Russia).
- The weight is approximately 500 kg, so it can be transported by pickup truck or in a passenger car trailer.
- The self-loading device makes it possible to get sandy soil from ditch piles, but it cannot handle dense turf or roots, so they need to be cut off with a spade.

A mini-excavator weighing up to 1 t:

- Most imported models have a width of 8085 cm and a high center of gravity. This makes it possible to pass between trees, but creates a risk of tipping over on slopes.

- Its speed is 2 km/h. To prevent the machine from overheating, it is not advised to run it for more than 2 km per day.
- There are Russian models with greater width (up to 1.45 m), speed of up to 5 km/h and no restriction on daily mileage. They allow the development of quarries with a depth of up to 2 m to get the soil to build ditch blocks where no piles are available, and to move the soil into ditches *(Fig. 84)*.

PHOTO BY: FRANK EDOM

Fig. 83. Building a sand dam with a track dumper

PHOTO BY: MARIA VASILIEVA/GP

Fig. 84. A reduced tail-swing mini-excavator, 1.45 m wide, working to block a ditch

A remote-controlled bulldozer loader weighing 1,200 kg:

- It facilitates working with soil in piles or quarries so that it can be transported to the ditch block construction location.
- It can be used to bring construction materials, drag logs to the construction location *(Fig. 85)*.

PHOTO BY: MARIA VASILIEVA/GP

Fig. 85. Construction of an earthen dam using a remote-controlled tractor

PHOTO BY: YULIA PETRENKO/GP

Fig. 86. Digging around peat fire points using a wheeled excavator

Heavy earth-moving machinery (excavator, front loader):

- Its use depends on the soil carrying capacity.
- It facilitates digging around peat fire points (an excavator), digging light soils in a quarry, and transporting them to the ditch block construction location *(Fig. 86)*.

Heavy earth-moving crawler machinery, including amphibious machinery *(Fig. 87)*:

- Can work on weak soils.
- Facilitates all the soil digging work and laying into the ditch block.
- Effective with large volumes of work on wide ditches (main channels and main outfalls).
- Expensive can be owned by state partners.

PHOTO BY: YULIA PETRENKO/GP

Fig. 87. The use of a floating excavator to build temporary blocks on main channels

6.4. GEOLOGICAL SURVEY OF A PEATLAND

The geological survey of peatland helps us to understand whether a ditch block should be built in a particular location and which type of ditch blocks can be built on such soils.

If we build a ditch block on soil with a high filtration coefficient, also called "saturated hydraulic conductivity", such as sand, it will slow the water infiltrate during spring snowmelt. The water will drain beneath the permeable soil, so the ditch block will not work at its full capacity.

Impermeable and poorly permeable soils are those with the filtration coefficient of 0.3 m/day or less. These are clay, loam and highly decomposed peat with the degree of decomposition not lower than 45 % (not lower than H7 on the von Post scale) (Appendix 3).

There are methods to determine the degree of peat decomposition in the laboratory. However, in the field the "fist compression method" can be used. The "fist compression method" is described in different literature in different scales and for different countries [17, 19: pp. 58.. 60, 35, 46, 48, 49, 54, 56, see appendix 3 in this book]. The most common scales are the Procent-scale in Russia and other post-Soviet countries and the Scandinavian von-POST-scale in most European countries.

The following descriptions with recommendations for building with peat are from [19, pp. 58..60]:

- If the peat freely passes between the fingers when compressed in the fist, no water flows at all and the hand remains brown, dark brown or black, this is a well-decomposed peat, 60–95 % decomposed [by Soviet/Russian scale]. Such peat is suitable for the construction of ditch blocks *(Fig. 88)*.
- If brown or dark water is squeezed out from the fist as the peat is squeezed between the fingers but a fibrous mass up to half of the sample volume is left in the fist, the degree of decomposition is 40–60 %. It is also suitable for ditch blocks but requires mixing to obtain a homogenous mass.
- If residues of peat-forming plants are clearly distinguishable in the sample, some brown water is squeezed out and up to half the sample remains in the fist, the degree of decomposition is 25–40 %. Such peat can be used to build the body of a dam, but a well-decomposed peat must be used for the slope of the upstream embankment.

To build ditch blocks, choose locations with impermeable underlying soils or with banks of well-decomposed peat, at least 0.5 to 0.7 m thick.

Soil sampling from the ditch bottom is an option to make it easier to determine the underlying soil type and to select the appropriate dam type. For example, in a ditch with a sandy bottom it is highly undesirable to build a sheet-pile dam (paragraph 6.5.3).

The best way to take soil samples and determine the structure of the deposit is to use a peat borer (Appendix 2). Soil samplers that have not been designed for peat will be unsuitable for taking peat samples.

Therefore, for survey purposes, a small test pit is dug with a spade, from which peat samples are taken at a known depth. As a rule, a test pit is dug down to the underlying soil or groundwater but not deeper than 1.5 m, for safety reasons. This method does not allow reaching the underlying soil in large unexploited peatlands.

Conventional garden borers are suitable for taking peat samples, but they are difficult to use in deposits with lots of roots in the peat mass. Conventional borers mix the layers from different depths when taking a sample, which can lead to an inaccurate assessment of peat decomposition degree.

PHOTO BY: IVAN SEMENOV/GP

Fig. 88. Determining the degree of peat decomposition in the field using the "fist compression method"

6.5. TYPES OF DITCH BLOCKS AND BUILDING METHODS

Before building a temporary water-retaining ditch block, first determine the geometric dimensions (elevation of the crest, width and length, height from the ditch bottom). This requires the measurement of terrain relief (paragraph 6.1). Second, a decision must be made on the type of ditch block and the material for its construction. The choice of construction materials will be determined by the type of underlying soil under the peat layer, the thickness of the peat deposit, the materials and technical resources available for construction.

6.5.1. EARTHEN DAM

This dam is the simplest, most affordable and reliable. It can be built on any ditch using any type of underlying soil as long as the stream does not carry away the filled soil.

Before starting the work at the place of dam construction, it is desirable to remove the top layer of soil (about 20 cm) and any plant roots because they can contribute to high water filtration.

The material for an earthen dam may be a highly decomposed peat (the degree not lower than 45 %), clay or loam, that is, the soils with a low filtration rate. Sand can be used, but one should remember that it has a high filtration rate, so a dam constructed with sand will slow down the water flow, but water will still pass through it. Soil must be filled with layers no more than 15 cm thick that are tamped with any available tools (manually, using wheelbarrows filled with soil, by using heavy or small earth-moving machinery). If the dam is being made of sand, it can be tamped by a vibrating plate.

An earthen dam can be built either manually, with a spade and wheelbarrows to bring soil, or using earth-moving machinery. It is advisable to work manually if soil piles are available along the ditch banks or if the distance from the soil source is not more than 10 to 15 m. Use earth- moving machinery if a quarry needs to be dug to obtain soil or if soil needs to be transported over a distance greater than 20 m.

If a quarry is opposite the dam, it should be located no closer than twice the maximum depth of water from the ditch bank so that the water does not flow through it bypassing the dam. The soil used for the dam should not contain large wood residues through which water may seep.

Recommended dimensions of earthen dams:

- The crest of the dam is 0.5 m higher than the maximum water level in the ditch, or 0.75 to 1.0 m above the spillway height. One needs to take into account the settlement of dam soil and of its base, increasing the effective height of the dam by 10 to 20 %.
- The width of the crest should not be less than 1.0 m.
- Slopes (Fig. 89, marked “m”) of the peat dam: the upper slope is 1:2.5 to 1:3, the lower slope is 1:2 to 1:2.5.
- Slopes (Fig. 89, marked “m”) of the sand dam: the upper slope is 1:2 to 1:2.5, the lower slope is 1:2 *(Fig. 89)*.

In practice, especially if there is water in the ditch, it is difficult to keep the desired slope angles. In this case, it is necessary to calculate the design width b of the dam *(Fig. 89)* as the sum of the angles of the upper and lower slopes m and the width b_n of the crest, and fill the soil up to the construction elevation throughout this entire width. Subsequently, it will slide down under gravity to the desired slope angle, but due to the excess material, the dam will not collapse *(Fig. 90)*. However, it is labor-intensive and involves high soil consumption.

To reduce filtration through the body of the dam and the ditch bottom, one can cover the upstream pool slope and a section of the ditch bottom in front of it with soil that have a low filtration rate (clay, highly decomposed peat) or make the so-called upstream apron, which is an anti-filtration screen of polyethylene film at the bottom of the stream bed before the upper slope.

6.5.2. TEMPORARY DAM OF PEAT BAGS

Dams made of soil bags are often built during floods to quickly create an obstacle for water. Sand is used to fill the bags. It is free-flowing, does not form lumps, and it can be poured into bags quickly and easily.

However, the construction of a dam of peat bags has a number of shortcomings:

- Filling bags with peat is a time-consuming process. The peat needs to be dug out, broken into big lumps, and poured into bags. Roots of grass and shrubs create additional difficulties and the process becomes highly labor intensive.
- Water seeps through the body of temporary dams, through the joints between the bags.
- To avoid this, the filled bags need to be tamped very thoroughly and the slope of the upstream pool needs to be covered with crushed peat to fill the joints between bags.

ILLUSTRATION BY: OLESYA VOLKOVA

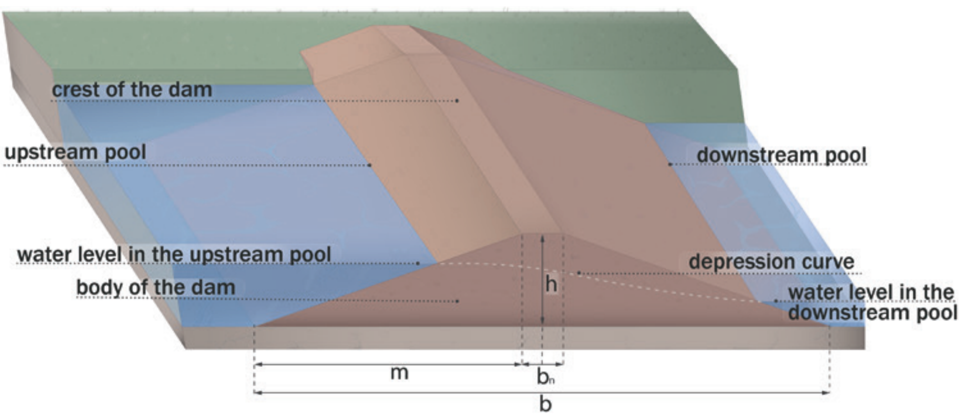


Fig. 89. Scheme of the earthen dam with its elements

PHOTO BY: IVAN SEMENOV/GP

Fig. 90. Sand dam at the main outfall

- Separate bags are not connected so they can be carried away by the water stream. No reliable method of connecting the bags has been devised.

The most rational use of bags with peat is to close the local leakage in a dam when there is a strong water stream carrying away the filled soil.

6.5.3. PLASTIC LARSSEN SHEET-PILE DAM

This is a quick dam, but it requires additional building materials and is highly demanding with respect to the underlying soils under the peat layer.

Plastic (PVC) Larssen sheet piles have a U-shape profile with locks that link individual sheet piles into a solid baffle. This makes it possible to quickly block the ditch bed by driving separate sheet piles in the bottom using a large 8 kg hammer.

The sheet piles are driven until they stop into the mineral soil but not less than 40 to 50 cm down. For a rational construction of the dams, sheet piles PVC G-300 type150 mm wide, weighing approximately 2 kg per linear meter, should be used. For a sheet-pile dam, an additional, reliably fixed support beam on the upper edge of the baffle is required so that it does not get uprooted from the bottom. Also, during the work this beam will be a bridge from which one can drive the sheet piles down conveniently.

To approximately evaluate the force P_B the water exerts on the support beam and its bank fasteners, let us find the force P acting on one meter across the dam:

$$P = 0{,}5 \times \Delta h^2 \times \rho \times g = 4905 \times \Delta h^2$$

P is the force of hydrostatic pressure (measured in Newtons).
Δh is the difference in the depths of water in the upstream and downstream pools (meters).

As an example, let us consider the case when the water level in the ditch upstream of the dam reaches its top and there is no water downstream of the dam, that is, the case of its maximum loading. Then:

$$P = 4905 \times h2$$

P is the force of hydrostatic pressure (measured in newtons).
h is the height of the dam (meters).

The distance from the crest of the dam to the point of the force P application is equal to h × 2/3. Thus, the following force will be acting on the upper beam:

$$P_B = P \div 3 = 1635 \times h$$

Now, let us divide the width of the ditch into 1 m sections. In the middle of each section, determine the height of the dam from the bottom; for each section, we determine P and P_B. Next, we will sum up the obtained P_B values and obtain the total force acting on the support beam. Half the total load will act on each of its bank fastenings.

A Larsson sheet pile dam requires a mandatory peat embankment on both sides to the full height of the dam immediately after its construction. If an embankment is not made, the rising water will wash through the mineral soil at the bottom of the ditch and under the sheet piles and the dam will be destroyed. Washing is very quick in sandy soil in the absence of a peat layer at the bottom of the ditch *(Fig. 91)*. The embankment slope angles are recommended to be made as with the earthen dam but not less than 1:1.

The remains of tree roots inside the peat deposit can cause problems when driving in Larsson sheet piles. If roots are present, a 70 cm (maximum) deep trench is made and any roots are removed with a chainsaw. The chainsaw will not wear down because there are no minerals or abrasive particles in the peat.

6.5.4. SINGLE-WALL TIMBER DAM WITH EARTH EMBANKMENT

These are inexpensive dams that can be built quickly. The wood is carrier frame, supporting the soil embankment that retains water. The frame makes it possible to reduce the soil volume in the dam.

There are several options of single-wall timber dams with an earth embankment.

A wattle dam is built using local building materials. Wooden stakes with a diameter of 50 mm are driven in the ditch to be blocked, with an interval of 0.5 to 0.6 m, and intertwined with long birch branches with a butt end diameter of 15 to 20 mm. Subsequently, the dam is covered by peat on one or both sides, and sealed by tamping, by hands or by feet. To strengthen the dam, additional stakes can be driven in to support the sheet pile from the downstream pool side. A dam up to 20 cm high can serve as material for beavers, which if present will build a dam that will support and strengthen the structure. Stakes are preferably made of dry wood because raw, recently sawn wood will split when driven into the ground *(Fig. 92)*.

A solid dam made of vertically driven planks, covered by soil or without soil. This dam is less expensive than a Larssen sheet pile dam. Peatland scientists from Germany recommend building dams of this type on a ditch with a peat layer with a thickness at least twice the ditch depth. To reduce filtration through the baffle, it can be additionally covered with geotextile or a waterproofing material at the side of the upstream pool.

A solid dam made of horizontal branches or planks fastened to separate stakes. This dam is made with a soil embankment from one or two sides. German peatland

PHOTO BY: IVAN SEMENOV/GP

Fig. 91. A washout under the dam of Larssen sheet pile. The outgoing water can be seen bubbling out to the right of the dam

PHOTO BY: YULIA PETRENKO/GP

Fig. 92. A wattle dam with a one-sided peat embankment

specialists recommend building such a dam in ditches with any type of soil base, including mineral soil.

More information on wooden and single-wall timber dams with an earth embankment can be found in the book by Sobol' et al. [30]

If water goes over the crest of the dam, the dam will be destroyed. Overflow dams need to be strengthened from above by a layer of rock riprap or rubble. Volunteers are not usually able to deliver sufficient heavy and expensive building material to the construction location.

If water goes through the joint between the dam and the bank, this is a pre-emergency situation. Washing the joint between the dam and the bank is one of the most frequent causes of destruction of the water-retaining structures constructed by volunteers in peatlands.

Excess water should always be discharged at the dedicated location, such as a bypass channel or a low terrain area, bypassing the dam.

6.6. EMERGENCY WATER RETENTION WHEN EXTINGUISHING PEAT FIRES

Creating ditch blocks helps to prevent fires and to extinguish peat fire points. Active peat fire points can often be flooded, especially in the spring *(Fig. 75)*. To create a ditch block, temporary dams are created on drainage ditches slightly below the burning peat fire point or the existing water drainage systems are used.

Building a dam and raising the water level ensures a supply of water to extinguish the fire and limit its potential spread.

For a temporary dam, choose an area where minimum resources will be required, and where the subsequent dam deconstruction will not involve a lot of work. Good places for building temporary dams are pipe culverts, which are ditch crossings built on top of reinforced concrete pipes *(Fig. 93)*.

It is occasionally possible to use the hydroseals that have been preserved on such crossings (devices for blocking the flow: metal gateways with a mechanism for their opening and closing), and stoplogs (hydrotechnical constructions regulating the water level by blocking the stream with a shield made of individual beams laid in grooves of guiding structures). Even if the hydrotechnical construction itself is not operational, it is usually easier to make a temporary dam.

Wooden shields can be selected by shape and size and inserted in the pipes of pipe culverts. Temporary baffles can be easily dismantled.

If there is no pipe culvert nearby, or it is impossible to install a wooden baffle a dam can be built.

For emergency water retention in a fire, any of the ditch blocks described in paragraph 6.5 can be built. The particular type of dam is selected based on the available machinery, materials and personnel. The quickest ones are an earthen dam and a single-wall timber dam with earth embankment.

When building any dam, determine the following in advance:

- How much the water level will rise.
- Whether the soil carrying capacity will allow the firefighting machinery to move on it.
- Whether it will be possible to make piers in convenient locations to install fire engines (including fire pump trucks).
- Whether water shortages will be created as a result of water retention in areas of high water consumption.

It should still be possible to deconstruct the temporary dams that may later affect the optimal water regime in a swamp, mire or peatland and the areas around them.

PHOTO BY: MARIA VASILIEVA/GP

Fig. 93. Building a temporary earthen dam at a pipe culvert (rewetting, creating a water intake location for firefighting machinery)

6.7. BEAVERS AND THEIR IMPACT ON FIRE RISK IN SWAMPS, MIRES AND PEATLANDS

Beavers significantly affect the fire hazard in swamps, mires and peatlands. On one hand, beavers help to reduce the risk of peat fires because their dams retain water and increase the level of groundwater in the surrounding areas. And on the other hand, beavers dig channels that redistribute water and significantly reduce access for people and machinery. The beaver burrows drain the banks of ditches, thus increasing the risk of peat fire points if open fire passes through the area.

Beaver settlements are not always permanent. The animals can relocate to other areas for reasons that include the depletion of food reserves are depleted around their settlements, the number of parasites increase, or someone of the adult beaver couple bringing offspring dies. When the animals move to another area, the old dams rapidly deteriorate, resulting in a drop of water level and an increased fire hazard. In dry periods, the so-called beaver meadows, which are extensive deforested spaces with tall grass, are at high risk of fire.

How can beavers be encouraged to remain in a specific swamp or peatland?

- **Try to reduce the pressure on animals from local hunters.** It is worth explaining to hunters how beavers reduce the fire risk of a swamp or mire.
- **In the years that are difficult for wildlife, support their settlements through biotechnical measures.** Remove any ice close to beaver lodges and burrows (especially in the cold winters, when the layer of ice can be too thick) and feed beavers with young aspen trees by immersing branches into the water (if fires have destroyed the entire stock of solid vegetable feed around). For feeding, branches or young trunks are suitable, 4–6 cm in diameter, two branches per animal per day. If an extreme flood is anticipated, rafts can be made (sustainable floating wooden platforms), tied to large trees and filled with feed.
- **If the beavers have left their area, support and strengthen the beaver dams so that the water level does not fall.** Determine whether beavers have left by looking for the presence of fresh bites, traces and scent marks. Most likely, after a few years, these or other beavers will populate the area again. Dams can be reinforced by soil or by driving in extra stakes. To avoid washouts in the central part of the dam, reinforce it with branches and create a mild slope for the water so that no hole is washed out under the downstream slope of the dam.
- **Support beavers in their dam construction,** especially in the areas where constructing dams is difficult and the animals are attempting to retain water. For example, in the areas with a clear shortage of building materials where beavers build a dam with soil, grass, and leaves that become washed out by water, we can bring in some branches, drive in some stakes, or make a wattle sheet of sticks, so the beavers can strengthen the dam (paragraph 6.5).

  We can try stimulating the beavers' construction activity, e.g., by laying a log across the ditch and driving stakes at an angle to the stream. There is evidence that if there are small grooves on the banks leading to the initial dam (similar to ruts in a road when crossing a river), and the depth of water near the experimental dam is more than 40 cm for the animals to feel safe during the construction, the probability of beavers' arrival is increased.

  Stimulating construction activity makes sense near the center of beaver settlements such as next to the lodges or inhabited burrows, feed reserves, or beaver feeding tables. Creating such dams at the borders of two beaver settlements does not give results because beavers are territorial animals and will not build anything on the border with neighbors, avoiding a conflict.

If a beaver settlement is affected by a peat fire, extinguish the fire with extreme caution because of high injury hazard. It is very easy to fall down into the burning burrows, and it is difficult to predict the development of a fire in extended and branched burrow systems.

6.8. WATER LEVEL MONITORING

Monitoring water levels in the ditch before and after the construction of ditch blocks, and photographing and filming the building process are necessary to assess the effectiveness of water-retaining activities, keep track of the errors, and produce visual reports about the work.

To monitor the water level, one can make a simple hydrological gauging site as a section of a telescopic levelling rod fastened on a base made of a wooden stake driven in the bottom of the ditch, or a bar with a cross section of 50 × 50 mm *(Fig. 94)*. The base should be driven down in the bottom at a depth of 50 to 70 cm so that it is held strong and motionless. Instead of a wooden bar, which will rot, a steel L-shape piece with a size of 40 × 40 mm can be driven in, and then the gauging site will be operable for several years.

After the water staff gauge is installed, we use an optical level or GNSS to record the elevation of its top. During subsequent visits to the object, we will be able to calculate the water elevation on the scale without using any geodetic equipment.

In winter, a hydrological gauging site can be damaged by moving ice. To track the site and repair the water staff gauge, install a reference benchmark at a distance of 30 m on land and use it as a reference to control the elevation of the water staff gauge.

A relatively inexpensive way of monitoring the water level with a water staff gauge is to use a camera trap in timelapse mode to produce photographs at specified intervals on schedule but not by a motion sensor. The optimal interval between shots is 15–30 minutes. Select the maximum photo resolution so that the centimeter scale on the staff gauge can be read when the photo is magnified. A 32 GB memory card allows 1–2 months of daily photography, depending on the size of the image file.

The camera trap, if possible, should be fastened to a sturdy tree so that it is not shaken intensively by the wind *(Fig. 95)*. In the future, this will allow making a video from the images, showing how the water level changes in the ditch.

You can power the camera trap from an external battery. 1.2 Ah AGM batteries have proven useful, providing up to 2 months of operation of the camera trap in the warm season. It is not necessary to buy a sealed container for the battery. It can be hidden in an old canister, so the terminals are protected from rain and snow.

PHOTO BY: IVAN SEMENOV/GP

Fig. 94. A hydrological gauging site

PHOTO BY: IVAN SEMENOV/GP

Fig. 95. A camera trap tracks water level changes in a ditch

6.9. TYPICAL MISTAKES DURING PEATLAND REWETTING

6.9.1. COMMON FALLACIES

"That will do!" A ditch block built in a hurry without proper design and ways of discharging excess water will last from several tens of minutes to 1 year in 90 % of cases. Two to three times more resources will be spent on subsequent repairs and remakes of a poorly constructed ditch block so it is worth spending time planning and constructing a structure that will last a long time.

"We live in a country of great mental achievements and small production deficiencies." Do not be tempted to miss any stage that appears insignificant compared to the rest of the work. Neglecting to make a bypass ditch can mean that water will wash out from the join between the dam and the bank. Neglecting to remove turf from the bottom of the ditch can cause water to wash out the soil under the dam. If a quarry is made too close to the ditch for the extraction of soil for the dam, water will begin flowing around the dam through the quarry.

6.9.2. FALLACIES AT THE MEASUREMENT STAGE

"I'll remember this one." Do not trust your memory, especially with multiple ditch blocks. That is why we take notes, write down and mark everything. If the site is a benchmark, write down not only its name on the stake but also its elevation. Take a photo and record the coordinates in an ordinary satellite navigator, and enter the elevation in the notes relating to the point. If you need to take a photograph of something important and know the coordinates of this place in the future, take a photo of the object and a photo of the navigator screen with coordinates visible. If you install a benchmark near a noticeable tree, you will not remember it after one year. Therefore, make a bright mark on the tree, which will not burn out in the sun (a signal tape tied to a white birch tree can become white and unnoticeable after one year).

"I have written that down." We need to keep paper logs of measurements filled out with a pencil or a permanent marker. But documents have a way of getting lost or being forgotten in the office when traveling to the object. Therefore, carefully fill out and store all paper logs during the trip. And after returning from the field, scan or photograph them to make sure they are kept in digital form. Additionally, they can be uploaded to the cloud to be downloaded on the way to the object in case they are left in the office.

"The other bank is just like this one in every way." This mistake can be made in the second half of summer, when there is tall grass hiding the ground surface on the other bank of a wide, deep ditch. For example, thickets of reeds can conceal a local depression or a beaver burrow, through which the water that you are trying to retain in the ditch will be drained. Therefore, take time and effort to explore both banks in the area of planned rewetting, build a bridge or cross to the other bank of the ditch on a boat.

We do not think about the ones who come after us. Another person can continue the measurements at the same object without you. The benchmarks by which they can tie their measurements to yours should be unique and be marked on location by paint or something noticeable. A birch tree stump used as a benchmark can be very similar to other stumps within a radius of 5 meters.

Incorrect conversion of measurement units. This is a common error in many calculations. During GNSS measurements, the elevations of points are determined in meters and recorded in the software of a controller with an accuracy of 3–5 decimal places. For example, a benchmark has an elevation of 80.38436. But when copying this to paper, this value is often rounded up to two decimal places, i.e., to centimeters. In our example, this would be 80.38. But the measurements with an optical level are carried out with an accuracy of millimeters, i.e., up to three decimal places. And when entering into the level log, the elevation of our level mark should be recorded as 80380, i.e., a zero that appears pointless has to be added. If this is not done and the elevation of the benchmark is recorded as 8038, the subsequent elevations will be calculated with an error.

CHAPTER 7. SAFETY

This chapter presents general safety rules that guide us at peat fires in Russia, including with the participation of volunteers. These rules comply with official state regulations. Please note that other standards or instructions can be applied in your region.

7.1. ENSURING SAFETY WHEN EXTINGUISHING FIRES AND CONSTRUCTING CAMPS

Peat fires are dangerous. First, firefighters usually stay much longer at a peat fire than at other types of fires. Fatigue accumulates, and attention is reduced. Second, the smoke from peat fires can be more toxic than smoke produced by other wildland fires. Prolonged smoke exposure can be a health hazard. Third, it is necessary to consider additional hazards when extinguishing peat fire points, such as falling trees and burned spots in peat.

7.1.1. SAFETY AT ANY WILDLAND FIRE

The priority task in any fire area is to establish a permanent observation of the fire and separate hazards, maintain a steady constant communication between the team members, and have escape routes to prepared safe zones, known to all firefighters. LCES (Lookouts, Communications, Escape routes, Safe zones).

General rules

- All firefighters should have appropriate clothing, footwear, and personal protective equipment required for the corresponding fire category.
- Never work alone at any wildland fire. All movement of people, including from the camp to the work location, should be in groups of at least two people.
- Fires should be extinguished by groups of no less than two people, one of whom is appointed a responsible person. The personnel under the responsible person in a forest fire team should be as many as this person can control when working on a fire, but no more than seven people (three or four people on average).
- If any firefighter, a team or and team members disappear from visibility or communication, the responsible person should be contacted immediately. The responsible person must suspend work in the area partially or completely and start a search. If resources are insufficient, request the help of other teams.
- The responsible person establishes the procedure of radio communication during the search and the procedure of phone communication with the missing persons, who attempts to reach them, at which intervals, who talks to them if connection is successful. If necessary, the responsible person calls for help.
- While a fire is being extinguished, observe any dry or burned trees. They must be removed in a timely manner so that they do not fall and cause an injury.
- During the work, observe the places of possible reignition, such as trees or dry grass on the edges of peat fire points. To prevent reignition, spray vegetation with water once every 15–30 minutes.
- In conditions of high temperatures and smoke, fire suppression is carried out in shifts. A normal shift consists of one hour of work and a 15-minute break and a one-hour lunch break. The total duration of a shift is no more than 8 hours.
- Alcohol, narcotic and psychotropic substances are strictly prohibited during

firefighting operations. Any person who is in a state of alcoholic or narcotic intoxication, or anyone who is not feeling well, shall not be allowed to extinguish fires.

- Upon arrival at the fire location, immediately position the vehicles so that they face in the direction of exit or evacuation in the advent of an emergency. The vehicles should not block access.

Work rules at the fire edge

- Stay within visibility of others, taking into account the safe zone between firefighters. A recommended distance when working with entrenching tools is 2–3 meters.
- Never lose sight of the firefighters nearby, visually control their movement all the time, and inform the responsible person in case of their disappearance.
- If you as a firefighter think you may be at risk of being surrounded by fire (the fire edge encircles you), immediately move away in a safe direction, inform the supervisor about the hazardous situation, and warn others nearby about the danger.
- How to avoid getting surrounded by fire:
  - When working from an area not yet exposed to fire, try to avoid working when the fire edge ends up on both sides from the firefighter.
  - Never work in "pockets" or in spot-shaped fire zones.
  - When working on a slope, avoid staying above the fire; when working on a slope below the fire, keep an eye on any rolling burning materials capable of creating a fire point below the firefighter.
- The firefighters at the edge do not have the right to leave the work location without the permission of the responsible person except in emergencies such as injuries, burns or carbon monoxide poisoning. In an emergency, notify the nearest volunteer and the responsible person about the departure so that he/she allocates one or two accompanying persons.

7.1.2. SAFETY DURING PEAT FIRE SUPPRESSION

Hazards of a peat fire:
— Thick toxic smoke reduces visibility and can cause poisoning with fatal results.
— Trees with burned roots can fall suddenly and silently.
— Temperatures of up to 600°C can occur in peat fire points.

- All firefighting activities in peatlands should only be carried out in daylight.
- Before starting to extinguish a peat fire, carry out a reconnaissance to determine the boundaries of the peat fire point. Mark the identified boundaries by signal tape. Use a thermometer to find the boundaries of peat fire points and) to detect any hidden fire points.
- Never stay within the marked boundaries of hazardous fire areas.
- The firefighters should closely monitor any hazardous trees such as those that are leaning, have burned roots or are dry or rotten, and warn others of any dangers. If possible, the hazardous trees should be removed. Also, any debris that interferes with the work or evacuation from the work area needs to be removed.
- If a bulldozer or an excavator is used for fire extinguishing, people should be no closer than 50 meters.
- When felling trees, other firefighters should be in a safe area at a distance of twice the tree height but not closer than 50 meters from the work location.

- The work of a bulldozer operator must be coordinated by a supervisor showing the direction of movement, observing the spread of fire, and warning of any danger.

7.1.3. SAFETY DURING FIELD CAMP CONSTRUCTION

The location of the camp is determined by the incident commander. If possible, choose dry places for the camp. Take into account the conditions of water supply, the convenience for vehicles and water transportation. Consider the potential for smoke pollution if the humidity or wind direction change.

The camp must not be organized in the following areas:

- In lowlands filled with smoke from peat fires at night.
- In dry streams, at the bottom of creeks or hollows.
- Near power lines, on routes of gas or oil pipelines.
- On flooded islands, sand bars and low shores.
- In a zone of an active forest fire edge.
- In young coniferous forests because they are extremely fire prone.

When making the camp, we take the following into account:

- The camp must be located in a safe zone.
- All dry, inclined and rotten trees should be cut down at a distance of 50 m from the boundary of the camp.
- Never make campfires on peat soil. Cook on a gas stove (burner) only.
- If there is a risk that the open burning of the peat fire point can resume, the places for rest and sleep should not be closer than 100 m to the edge of a contained side of the fire, and they should be surrounded by a fire line (dug to mineral soil) no less than 2 m wide; in case of fire breakthrough, provide an opportunity to create new barrier lines.
- For the period of rest, the responsible person appoints another person to be on duty.
- During the extinguishing of large or fast-growing fires, a permanent watch is established in the camp. The direction and strength of the wind are monitored.

7.1.4. SAFETY IN AN AREA CONTAMINATED WITH RADIONUCLIDES

Only those who have passed the medical examination and received instructions on how to work in a high hazard environment can be sent to extinguish fires in the areas contaminated with radionuclides.

- All firefighters should have closed workwear, footwear, respirators or insulating gas masks, individual dosimeters, and cumulative dosimeters. Coveralls with dust cuffs can be used; to protect against biological hazards, costumes, headwear (berets, underhelmet caps), closed footwear (rubber heat-resistant tall boots), mittens can be used *(Fig. 96)*.
- In the zone of soil contamination with Cesium–137 from 1 to 5 Ci/km^2 (37–185 kBq/m^2) and Strontium–90 from 0.15 to 1 Ci/km^2 (5.55–37 kBq/m^2) the work may only be carried out with extra protection from the harmful effects of dust and combustion products that include respirators, closed rubber shoes and appropriate workwear.
- In a zone with a high level of contamination, work on the ground in Russia is only carried out in accordance with the requirements of special regulatory legal acts, and in accordance with the requirements of regional fire extinguishing plans for the areas contaminated by radiation. All workers should receive full and objective information about the radiation situation in the work area *(Fig. 97)*.

- When extinguishing with water or chemical solutions, stay on the windward side of the fire edge, where the combustion and extinguishing products cannot enter the respiratory tract.
- Every day, at the end of fire extinguishing, workers must take a shower and change workwear, footwear and other personal protective equipment.
- Food and drinking water are kept strictly in closed containers. Meals are organized after treating clothes and hands, away from the fire, on the windward side.
- Sleeping at night in the area of fire extinguishing is prohibited.
- When the additional radiation dose is accumulated over 0.5 rem (5 mSv), the worker is taken out of the radioactive contamination zone for one year.

7.1.5. WORK SAFETY DURING A THUNDERSTORM

- Fire extinguishing is stopped during a thunderstorm. Turn off radio stations, turn off and ground antennas, and stay away from metal objects, machinery, and mechanisms.
- People should stay in a safe place in a glade, a young forest, in a small fold in the terrain, on a hillside or among the trees growing no more than 20–25 m from each other.
- Never hide from a thunderstorm under separate trees, triangulation or observation towers, near the supports of overhead power lines, poles and wires of communication lines, antennas or counterweights, and do not touch them. If possible, people should be located indoors, and mechanisms should be at a distance of at least 10 m from people.

PHOTO BY: VLAD ZALEVSKY/GP

Fig. 96. Measuring the radiation level in a peat fire point in a contaminated zone

PHOTO BY: VLAD ZALEVSKY/GP

Fig. 97. Using a portable dosimeter in a peat fire

7.2. REQUIREMENTS FOR WORKWEAR AND PROPERTY

Most importantly, clothing should be durable but should not constrain movements. It should protect the body from heat radiation, sparks and damage, and it should be sufficiently warm for staying in the forest at night.

Each firefighter must be provided with appropriate clothes and equipment.

- Workwear should be made of cotton or non-combustible fabrics with reflective elements with an area of at least 10 dm^2, of a color scheme that ensures clear identification of the person's silhouette against the background of natural vegetation at a distance of at least 50 m. Never use clothes made from combustible synthetic materials such as sportswear].
- Boots should have solid soles. Never use footwear made from flammable materials.
- Use a forest firefighter helmet or a hard hat for head protection from falling objects, impacts of equipment and mechanism parts. The hard hat should have a fastening that immobilizes it reliably and prevents it from falling from the head during intense and regular flexion of the body and gusts of wind.
- Protective goggles should be worn. They are needed to protect the eyes from small mechanical particles (stones, sawdust, chips, branches, sand) and liquid particles of fire extinguishing solutions. The goggles must be stationary on the head and not fall down during intense, regular flexion of the body.
- A respirator to protect the respiratory tract from dust and smoke hazards (soot and burning particles).
- Gloves (mittens) of durable material.
- Individual first-aid kit.
- Compass, knife, portable flashlight.
- An individual flask or containers with drinking water.
- The volume of water depends on the mode of operation and weather conditions but not less than 0.8 l.
- A whistle.

The organization that sends workers to extinguish fires should provide necessary equipment such as clothing, personal protective equipment, equipment/gear, field inventory, insect repellents, firefighting equipment and tools, and individual and group medical aid kits, taking into account the conditions of fire extinguishing.

7.3. ORIENTATION IN A FIRE

Anyone going to extinguish fires needs to be able to orient oneself in the terrain, use a map and a compass, and know how to communicate location details such as map coordinates.

7.3.1. TOOLS

Map

The supervisor familiarizes all firefighters with the map *(Fig. 98)* and assigns tasks, highlighting reliable landmarks, such as clearings, roads, overhead power lines, water sources, and uplands. It helps to have the map uploaded to everyone's smartphone or satellite navigator.

All firefighters should have clear instructions on how to respond and where to go in an emergency: loss of orientation, malfunctioning equipment, loss of communication, strong wind or a change in its direction, the fire becoming a crown fire, or if they are not feeling well. Everyone should know and remember how to return to the safe zone.

PHOTO BY: MARIA VASILIEVA/GP

Fig. 98. Orientation on the map

Compass

Everyone must have a compass. The sun can be blocked by smoke or clouds. One cannot use the wind direction and the elements of fire edge to orient oneself because they can change quickly.

When orienting oneself by the sun, one needs to find out and remember the exact time of sunrise and sunset in the region at different times of the year.

Coordinates and azimuth

During the orientation and transfer of geographic information, the position is transmitted as the coordinates (latitude and longitude), and directions are transmitted as azimuths.

Latitude is the distance from the equator to the north or south.

Longitude is the distance from the zero meridian to the east or west. Latitude and longitude are measured in degrees, minutes (60 minutes in one degree), and seconds (DDD° MM' SS.S"), or in degrees and minutes with thousandth parts of minutes (DDD° MM.MMM'). It is important that all firefighters (including the team in headquarters and other organizations) record and transfer the coordinates in the same format. The format with thousandths of minutes is universally accepted.

The azimuth of an object is the direction in degrees from the observer to the object, measured clockwise from the north direction. If an object is exactly in the west, then its azimuth is 270°.

The azimuth is measured from true north (maps are oriented toward true north, but a compass shows magnetic north). The deviation of magnetic north from true north is magnetic declination, which is different in different regions. In magnetic anomalies, declination can change very quickly (up to 30° at a distance of 2 km).

Magnetic declination is considered positive to the east and negative to the west. To obtain true azimuth, add magnetic declination to the magnetic azimuth (add if eastern, subtract if western). Declination for each region can be found on the Internet.

One should not forget about the compass deviation, which is the arrow deviation under the influence of the magnetic field of objects (an axe on the belt, a car, a boat, overhead power lines). Never use a compass next to a car or under an overhead power line because the arrow will always point to a heavy iron object or across the power line.

Navigator

We highly recommend that you have not just one compass in each team but also NAVSTAR (GPS)/GLONASS satellite navigators *(Fig. 99)*. It lets you do the following:

- Determine the location.
- Automatically record the traveled path on the map as well as the detected peat fire points for subsequent inspection.
- Automatically calculate the area of the fire and draw its borders with an accuracy to several meters.
- Determine the speed.
- Accurately determine azimuths.

A map uploaded to the navigator makes it possible to receive detailed information about the local area and accurately calculate the distance to the water sources and natural barriers. The format of coordinates (DDD° MM.MMM') is set in the navigator's settings. To determine an azimuth, quickly walk to the object in a straight line holding the navigator, (i.e., toward the fire edge of a fire seen at a distance) several tens of meters. The navigator will automatically determine the azimuth and show the direction of movement.

There are advantages and disadvantages in using a navigator. A navigator, unlike a compass, is not affected by magnetic interference such as from magnetic anomalies or overhead power lines, but in a dense forest or a deep ravine it may lose contact with satellites. Moreover, determining an azimuth requires a quick movement in a straight line. An electronic compass built into some navigators is an ordinary magnetic compass, which is not protected from deviation.

7.3.2. METHODS TO DETERMINE THE LOCATION OF A FIRE USING GROUND RECONNAISSANCE

Sometimes it is important to accurately determine the location of a fire by observing smoke from a distance. How can this be done?

Determine the fire location from several locations.

If we see signs of fire (pillars of smoke in the afternoon, a glow in the night), it is very important to determine its location accurately and quickly. If signs of fire are visible from several points (observation towers, stations) with known positions, the fire location can be found by drawing true azimuths on the map from these locations and marking the point of their intersection. When sending and receiving messages with the azimuth data, specify which azimuth it is, that is, true or magnetic.

Determine the fire location using a mobile ground team.

If the goal is to find the fire location through the efforts of one team with a car or a boat, two azimuths must be taken alternately from different locations.

In this case, the fire location on the map is determined by the intersection of two true azimuths, which are drawn on the map. The distance between the locations in which the azimuths are taken should be at least one-third of the expected distance to the fire location. The location points can be placed on the map using the coordinates from the navigator and the coordinates on the map.

PHOTO BY: MARIA VASILIEVA/GP

Fig. 99. Training volunteers to use a satellite navigator

If this is not possible (no navigator available or the map does not have a coordinate grid), one can determine the fire azimuths by selecting the characteristic points that can be unmistakably tied to the map (these could be road intersections, bridges, fords, road turns), and then taking azimuths from them.

Remember that azimuths next to an overhead power line can be taken only by a navigator (by moving with it toward the object and recording this direction) because an ordinary compass (and the magnetic compass in navigators) will not work correctly.

If there is no good compass or navigator but there is a detailed map and one can accurately determine our own location, we can determine the fire location with sufficient accuracy. To do this, move on the same line with the visible smoke and another object whose location is known (for example, a water tower, a geodetic sign, a cellular tower). By drawing lines passing through the point of our location, a known landmark and the visible smoke on the map, we can determine the fire location by the intersection of the two lines with sufficient accuracy.

On the way to the fire location, it is useful to determine additional azimuths to visible elements of the fire edge, specifying its size and location while tracking its development. An accurate azimuth to a large fire can be usually taken only to the windward part of the fire edge (its rear or flank) because the leeward part of the fire edge is not visible due to smoke.

7.4. RADIO AND MOBILE COMMUNICATION IN A FIRE

A reliable communication channel in a fire provides basic safety *(Fig. 100)*. Agree on the mode and time of communication with the firefighters, and ensure that all groups have operational means of communication, and spare batteries. It is advisable to discuss in advance the possibility of switching to another frequency if the connection is unstable or the channel is busy, and to agree on backup channels and the procedure for switching to them.

The optimal solution is to have both cell phones and radio stations. Advantages of cellular communication are availability of remote users with light, compact devices. Advantages of radio communication are no restrictions on the distance from the cellular towers, all commands are immediately audible to all firefighters, and communicating a short message is rapid.

7.4.1. RULES OF RADIO COMMUNICATION

- **Leave the two-way radio turned on at full volume** so you don;t miss the beginning of a conversation.

PHOTO BY: YULIA PETRENKO/GP

Fig. 100. Using two-way radios for communication between firefighters

CHAPTER 7. SAFETY

- **Each group is assigned a call sign.**

  Call signs are chosen so that they cannot be misheard due to a poor connection. If there are several teams of the same type, a number is added to the call sign.

  For example, Russian volunteer teams searching for missing persons or victims usually have a call sign, such as Lisa-1 or Lisa-2. Mobile teams often get names for their vehicles.

- **Before starting a radio conversation, listen on the frequency.**
- **Before pressing the radio button to start a conversation, think through the message you are about to give.**

  After pressing the radio button, take a one-second pause and then speak toward the microphone.

- **When making a call, first state the name of the person you are calling (the unit, the specialist) and then state your name.**

  Example: "Lisa-1, this is the base." At the end of the message, say "Over."

- **Upon completion of the conversation, speak to end the conversation.**

  Example: "Lisa-1, over and out."

- **Speak clearly, calmly but not quickly.** High emotions and shouting are unacceptable.
- **Speech should be simple and understandable, and your messages should be brief and laconic.** Try to refrain from the use of codes or abbreviations unless absolutely necessary.
- **Cursing is forbidden.**
- **If you are transmitting coordinates, remember that latitude is a two-digit number and longitude is a three-digit number. Minutes should include two or three decimal places, by agreement.** The second decimal place gives an accuracy of up to 20 m, and the third decimal place gives an accuracy of up to 2 m. When working in limited areas (up to 100 kilometers wide), degrees are usually not transmitted because minutes can unambiguously identify the team's position.
- **In conditions of strong interference and poor audibility, the message should be repeated** by asking to "give a receipt" (i.e., to repeat back the last sentence) to make sure the information is complete and undistorted.

  For example, the base transmits information to Lisa when the message is poorly audible:

  Lisa: "Lisa to the base, in one hour a strong increase of wind speed is expected, be careful, do you copy, over."

  The base: "the base to Lisa, we copy, in one hour a strong increase of wind speed is expected, we will be careful, over."

- **The most important information is always repeated, even in conditions of good audibility**, to rule out any errors.
- **If it is difficult to understand a word or a name, use the international phonetic alphabet** to transmit messages or their most important parts by letters. In this case, numbers are better transmitted digit by digit.
- **The use of radio should be minimal.** Remember that there is only one frequency but there are many units.

When working on large fires with intensive radio exchange, appoint a person at headquarters to maintain radio communication and a radio log.

Examples of fields in the communication log are: communication time; call sign; summary of the message (enter the coordinates, azimuths and other numerical information in the same field); and the signature of the person responsible for the log (if maintained by several people). When working in highly hazardous conditions, also enter the time of the next scheduled connection with this person. If a team does not communicate on time, search-and-rescue operations begin.

An example of radio exchange between the station (Base call sign) and the operational group (Lisa call sign) in conditions of poor audibility (the coordinates of the operational group: N55°41.567’ E037°52.002’):

Lisa: “Base, this is Lisa, come in, over.”

The Base: “Lisa, this is Base, go ahead, over.” Lisa: “We see smoke, take the coordinates, over.” The Base: “Writing down, over.”

Lisa: “Four — one point five — six, five — two point zero — zero. Do you copy? Over.”

The Base: “Your coordinates are four — one point five — six, five — two point zero — zero. Over.”

Lisa: “All correct. Magnetic azimuth to the smoke six — five, over.”

The Base: “From you, azimuth to the smoke is six — five, we are going to check the map to see what's there, and contact the spotters. Meanwhile, move toward the smoke.”

Lisa: “Copy, moving toward the smoke, waiting for additional information. Over and out.”

The Base: “Good luck. Over and out.”

7.4.2. FEATURES THAT AFFECT THE QUALITY OF COMMUNICATION

The terrain relief affects the quality of communication. Hills are impenetrable by radio waves. There is usually no connection in ravines.

To obtain a maximum range of communication, stand in an elevated open area with your back to the other person (your body will focus the radio waves) and keep the radio in front of your face in an outstretched hand with the antenna pointing straight up. Speak loudly, clearly and slowly, using simple words and commands. Remember that in the fog, during the rain or a thunderstorm, the radio communication range drops significantly.

In a car, it is always better to use an external antenna that must be set up. For communication over large distances, use a repeater.

7.4.3. CAPABILITIES OF EQUIPMENT

When using radio communication, observe local standards and permissions. In Russia, radios of civilian ranges: 27 MHz (CB), 433 MHz (LPD), and 460 MHz (PMR) are commercially available. Citizens band (CB) radios are more powerful, have a slightly longer range in the forest, on the crossed terrain and when installed on cars. LPD and PMR radios are better as portable two-way radios because they are light and compact, and their connection is not dependent on the weather.

A typical range of communication in the forest is 5–8 km for CB radios, 2–7 km for LPD/PMR radios. At the same time, two cars with CB radios and properly set up antennas can communicate at a distance of 20–30 km, and with a base station with a large antenna they can communicate at a distance of 50–70 km. For communication within 1 km, it is often enough to have basic LPD radios. The range and quality of communication must be checked on arrival at the location. Overhead power lines, energy-intensive enterprises and radio centers may interfere with radio communication.

The main reasons for the failure of radios are: low battery charge or an obstacle between callers.

If a radio that is not waterproof has been dropped into water, pick it up as quickly as possible, remove the batteries, leave the radio out to dry and inform the supervisor about the loss of communication (via a partner, another team, or via cell phone).

7.5. FIRST AID

All firefighters should be able to provide first aid. It is desirable that anyone who is going to extinguish fires receives first aid training *(Fig. 101)*. If there is no such possibility, each working team should have at least one person trained in the first-aid program. It is recommended to include a doctor in a team working on a fire for more

PHOTO BY: YULIA PETRENKO/GP

Fig. 101. Practical first-aid training for volunteer firefighters

than one day, especially if the evacuation time to the nearest healthcare institution is longer than two hours.

We highly recommend making a medical plan before going to extinguish a fire. Compile a list of healthcare institutions in the area near to the fire, with their contacts, working hours and specifics of their healthcare services.

Before departure, the supervisor of the firefighter team must make sure a first-aid kit for the team is packed and ready. Each firefighter should have an individual first-aid kit.

If the team has a doctor (which is always preferable), he/she can pack a first-aid kit for the team on the basis of his/her knowledge and qualifications. If there is no doctor or paramedic, the first-aid kit is packed on the basis of the knowledge of possible exposures that are typical for this area and require the use of medicines and dressing materials. A first-aid kit that can be used by non-medical personnel may only have the medicines of such types and forms that anyone without special medical education can use.

The team's responsible person appoints someone to be responsible for storing and replenishing the first-aid kit and keeping track of the shelf life and condition of its contents. A convenient form of storage of the first-aid kit for volunteer firefighters and forest firefighters is a dedicated backpack or a tactical vest with labeled compartments or pockets. The first-aid kit also includes a list of its contents with brief instructions on their correct use.

7.5.1. LIST OF MEDICINES IN THE FIRST-AID KIT FOR A VOLUNTEER FOREST FIREFIGHTERS TEAM

This first-aid kit *(Table 3)* includes medicines to provide first aid to a team of up to 12 volunteer firefighters working autonomously for up to one week, with means of communication available and the ability to call for qualified assistance to arrive within one day.

7.5.2. LIST OF MEDICINES FOR THE INDIVIDUAL FIRST-AID KIT OF A VOLUNTEER FOREST FIREFIGHTER

Volunteer forest firefighters should always have their individual first-aid kits with them *(Table 4)*. To provide first aid to a victim, the victim's first-aid kit should be used.

Table 3. List of medicines for a team first-aid kit

No.	Item/Replacement	Quantity
1	Analgesic or another painkiller	2 packs
2	Sterile gauze bandage 5 × 10 cm	15 ea.
3	Sterile gauze bandage 5 × 5 cm	10 ea.
4	An immobilizing brace or ready-to-use alternative means made of cardboard or polyurethane foam	1 pack
5	Sterile napkin 16 × 14 cm	4 packs
6	Burn bandage 10 × 15 cm	5 ea.
7	Hypothermic (cooling) package	5 ea.
8	Tourniquet	1 ea.
9	Ketoprofen gel for bruises and strains	1 pack
10	Adhesive plaster 1 × 250 cm in a roll	1 ea.
11	Bactericidal adhesive plaster, 20 per pack	3 packs
12	Levomekol ointment	1 ea.
13	Nitroglycerin (Nitrokor) 20 ea.	1 pack
14	Hydrogen peroxide 3% 40 ml	2 bottles
15	Chlorhexidine 0.5% 40 ml	2 bottles
16	Suprastin pills	2 packs
17	Lubricating eyedrops (artificial tears)	1 pack
18	Blunt-tip scissors	1 ea.
19	Acetylcysteine ACC or an analog (for mitigation of smoke exposure)	2 packs
20	Paracetamol or another anti-cold medicine based on paracetamol	4 packs

No.	Item/Replacement	Quantity
21	Enterosgel adsorbent or activated carbon	2 packs/20 packs
22	Antiseptic gel	2 packs
23	Device for mouth-to-mouth artificial respiration with check valve	1 ea.
24	Tweezers	1 ea.
25	Medical gloves to protect the rescuer's hands from the victim's blood when providing first aid	4 pairs
26	A list with instructions	1 ea.
27	Case	1 ea.

Table 4. List of medicines for an individual first-aid kit

No.	Item/Replacement	Quantity
1	Sterile bandage 5 × 10 cm in water-proof packaging	1 ea.
2	Sterile bandage 5 × 5 cm in water-proof packaging	1 ea.
3	Gel burn bandage 10 × 10 cm	1 ea.
4	Chlorhexidine 0.5%	40 ml
5	Bactericidal adhesive plaster	20 per pack
6	Analgesic or another painkiller	0.5 pack/4 pills
7	Suprastin or another allergy medicine	0.5 pack/4 pills
8	Medical gloves to protect the rescuer's hands from the victim's blood when providing first aid	2 pairs
9	Individual medicines (for known chronic diseases, allergies)	in the required quantities

7.6. PREVENTION OF OCCUPATIONAL DISEASES

Prevention of chronic occupational diseases caused by prolonged smoke exposure is very important. What can be done to preserve the health of volunteer firefighters?

- Ensure that those who are in the area with the heaviest smoke swap with those who are working in less dangerous conditions at least once per hour.
- If it is impossible to organize rest outside the smoke zone, give the firefighters an opportunity to regularly breathe purified air from cylinders.

Benzopyrene, which is emitted in large quantities in peat fires, has strong carcinogenic and mutagenic action. The high content of fine dust in smoke leads to increased likelihood of oncological and chronic respiratory diseases.

Thus, the people who have been working in a smoke zone for a long time need to have medical examinations regularly over the next few years to identify any of respiratory and cardiovascular problems and to help with early detection of oncological diseases.

CHAPTER 8. PROMOTION OF PUBLIC AWARENESS

Promotion of public awareness, both among adults and schoolchildren, is of great importance. In Russia, people often become involuntary perpetrators of peat fires. At the same time, they do not associate burning dry grass in spring with peat fire points, and they may even believe in the spontaneous combustion of peat.

In the natural environment peat is never self-ignited, whether from heat or from wind. Peat fires are always man-made, and the main causes are deliberately burning dry grass, campfires on top of peat or forest fires that have reached a peatland.

In Russia, state and public organizations are conducting a large-scale information campaign "Stop the Fire!" using video and audio materials, outdoor advertising, cartoons and games for children. The goal of the campaign is to change public opinion about the root causes of fires and instill behavioral change to foster safety and to encourage people to think carefully before starting a fire, remember the phone number of fire services and report any fires they see.

Before the campaign, a large-scale sociological survey took place to understand the public's attitude to the problem of wildland fires. The survey results showed that almost half the respondents considered spontaneous combustion as the cause of fires, resulting from sunny and windy weather. Of the respondents, 47 % named spontaneous combustion as the cause of forest fires, and 58 % named spontaneous combustion as the cause of peat fires.

Spontaneous combustion does not occur in the natural environment. Natural causes of fires include volcanic eruptions, meteorite falls and dry thunderstorms. In Russia, 9 out of 10 wildland fires occur due to human activity. The number of peat fires can be reduced by changing public opinion, involving the population in fire prevention and affecting the behavior of citizens in how they handle fire in natural areas.

Examples of materials of the public awareness campaign "Stop the Fire!" in Russia can be viewed at https://dlpinfo.ru/ostanovi_ogon/.

It is important to install information boards to remind people that peatland is at high risk of fire *(Fig. 102)*. Phone numbers to report peat fires should be shown on such boards. The installation of information boards must be coordinated with the local administration.

A unique number can be included on every information board, and a map with these numbers can be given to the firefighters and the heads of local administrations. By stating the number of the nearest board, you can quickly explain to the firefighters in which part of the peatland you discovered the peat fire point.

PHOTO BY: MARIA VASILIEVA/GP

Fig. 102. An information board on a drained peatland was made and installed by children

CHAPTER 9. LEGAL BASES OF FIRE SUPPRESSION

In this chapter, we have collected some basic legal issues, the answers to which will help you organize firefighting operations on a voluntary basis and/or participate in them. We strongly recommend studying the legal framework of fire extinguishment and regulatory legal acts on wildland fire suppression relevant to your region as well as the local acts governing the peatland rewetting activities.

- Do I have the legal right to extinguish wildland fires?
- Who do I report to while extinguishing the fire?
- What documents do I need to have on me?
- To whom are volunteers obligated to present their documents?
- Our team of volunteer firefighters has decided to extinguish fires. Who should we notify and what documents should we obtain?
- Do we have the right to go out and extinguish a wildland fire without the necessary experience?
- Can we organize our own volunteer fire team to protect our settlement from fires?
- What service is obligated to extinguish a wildland fire in a particular area?
- What should I do first when I see a fire?
- My friend wants to dam a drainage ditch in an abandoned peatland so that it does not dry up and burn. Can we do this? What approvals should we obtain?

APPENDICES

APPENDIX 1. MIRE AND PEAT CLASSIFICATION. HYDROGENETIC MIRE TYPES AND HYDROSTRUCTURE

Table 5 shows the terms widely used by wetland and peatland specialists, describing natural or drained swamps, mires and peatlands with or without peat. This terminology is based on the classification by Joosten & Clarke [43], Kessler et al. [45], it includes definitions according to Kats [9], P'yavchenko [21], Boch & Mazing [2], Succow [52], Succow & Joosten [54], Succow & Stegmann [55], AG Boden [39], Edom & Wendel [41], Wendel [57], Sirin et al. [50].

The blue highlight shows the terms that belong to the generalized definition of the Russian term "boloto" according to Boch and Mazing [2] and the German term "Moor" according to Succow & Joosten [54].

Table 5. Terms widely used by peatland and wetland specialists in English, German and Russian (transliterated)

<table>
<tr><td>No peat
Kein Torf
Torf otsutstvuet</td><td>Peat thickness ≤ 30 cm
Torf ≤ 30 cm
Moshchnost' torfa ≤ 30 sm</td><td>Peat thickness > 30 cm, ≤ 50 cm
Torf > 30 cm, Torf ≤ 50 cm
Moshchnost' torfa > 30 sm, ≤ 50 sm</td><td>Peat thickness > 50 cm
Torf > 50 cm
Moshchnost' torfa > 50 sm</td><td>Peat thickness > 70-120 cm
Peat suitable for mining
Abbauwürdiger Torf (oft Torf > 70-120 cm)
Moshchnost' torfa > 70 – 120 sm Torf prigodnyi dlya dobychi</td></tr>
<tr><td rowspan="3"></td><td>Paludificated soils with a thin peat cover (peaty soils) and thin floating mats.
Versumpfungs- und Verlandungsböden mit Torf (Anmoor) und Antorf
Zabolochennye pochvy s malym torfyanym pokrovom (torfyanistye pochvy) i malomoshchnye splaviny</td><td colspan="2">A peatland
Torfmoor bodenkundlich
Torfyanoe boloto</td><td>A peatland, peat deposit, peat deposit site, peatland body[1]
Torfmoor sowie Torflagerstätte
Torfyanoe boloto, torfyanoe mestorozhdenie, torfyanaya zalezh', torfyanik</td></tr>
<tr><td colspan="2">Paludificated lands
Versumpfende Ländereien
Zabolochennye zemli</td><td colspan="2">A moist peatland
Torfkörper im nassen Zustand
Torfyanoe boloto uvlazhnennoe</td></tr>
<tr><td>Drained paludificated lands with peat (drained peaty soils)
Entwässerte versumpfte Ländereien mit Torf
Osushennye zabolochennye zemli s torfom (osushennye torfyanistye pochvy)</td><td colspan="3">A drained peatland
Torfkörper im entwässerten Zustand
Torfyanik v osushennom sostoyanii</td></tr>
</table>

[1] *In the framework of this manual we use a "peat deposit" to translate the Russian term "torfyanaya zalezh'", which is defined by Tyuremnov [35, p.8] as "natural stratification / layering of different peat varieties from the surface down to the mineral soil or bottom lake deposits (gyttja)." The Russian term "torfyanoe mestorozhdenie" also can be translated as a "peat deposit", but in this manual it is translated as a "peat deposit site" meaning a geological formation consisting of layers of one or more types of peat, characterized in its natural boundaries by excessive moisture and a specific vegetation cover. It can be an object of industrial or agricultural use, depending on its size and peat reserves. Another use case of the "peat deposit" term can be found in the peat substrate key "Portraits of peatland deposits" [49]. In this case we would use the Russian term "otlozhenie" and the English analogue "peatland substrates" to avoid misunderstanding.*

Table 5. Continued

Other types of ecosystems and landscapes Andere Ökosystem- und Landschaftstypen Drugie tipy ekosistem i landshaftov	A naturally or anthropogenically drained peatland (Natürlich oder anthropogen) entwässertes degradierendes Torfmoor Osushennoe (estestvennym ili antropogennym obrazom) torfyanoe boloto
Wetlands without peat Feuchtgebiet ohne Torf Vodno-bolotnye ugod'ya bez torfa	Wetlands with peat, where peat degrades due to hydrochemical causes, or a completely flooded peatland Feuchtgebiet mit aus hydrochemischen Gründen degradierenden Torfschichten (mit Pseudo-akrotelm) oder von Wasser überstautes Torfmoor Vodno-bolotnye ugod'ya na torfe, gde torf degradiruet iz-za gidrokhimicheskikh prichin, ili polnost'yu zatoplennoe vodoi boloto
A swamp or over-moistened lands without peat yet, hydrophilic vegetation (noch) nicht torfbildener Sumpf ohne Torfschichten Boloto ili pereuvlazhnennye zemli, poka bez torfa, vlagolyubivaya rastitel'nost'	A wet peatland or a swamp without peat formation, but with peat, e.g., a drained peatland in the process of regeneration (noch) nicht torfbildener Sumpf über Torf (z.B. regenerierendes Moor) Mokroe boloto s otsutstviem torfoobrazovaniya, no s torfom. Naprimer, boloto v osushennom sostoyanii v protsesse regeneratsii
	A mire (with peat formation, a growing mire) Wachsendes Torfmoor Boloto s torfoobrazovaniem (rastushchee boloto)

Specific parent vegetation results from different types of water supply and nutrition. Vegetation forms different types of peat, and the latter reflect the water supply conditions in which they were formed.

The following becomes clear from this statement:

- The vegetation and the upper layers of peat only reflect the water supply conditions of the upper parts of the peat deposit but not the water supply of the entire peat deposit (neither horizontally nor vertically).
- During peat mining, the types of peat that reflect past water supply conditions will appear on the surface of the peatland.

TYPES AND VARIETIES OF PEAT

Peat is divided into bog, transitional and fen types, based on chemical analysis; then its subtypes, groups and types of botanical composition are determined *(Table 6)*.

Table 6. Chemical characteristics of fen, transitional and bog types of peat, and their main groups [22]

Type	Salt pH	Exchange Al, mg-eq / 100 g of peat	Peat group	Degree of decomposition	Total N	CaO	Degree of base saturation
				%			
Fen	4.8–5.8	0–3	Mossy	10–25	1.8–2.5	1.5–3.0	65
			Herbaceous and grassy	20–40	2.0–3.2	2.0–3.5	
			Woody	35–60	2.4–3.8	2.5–5.0	
Transitional	3.6–4.8	3–6	Mossy	10–25	1.4–1.8	0.5–1.0	45
			Herbaceous and grassy	20–40	1.6–2.0	0.7–1.2	
			Woody	35–60	1.8–2.4	0.9–1.5	
Bog	2.8–3.6	6–10	Mossy	5–20	0.6–1.0	0.1–0.6	25
			Herbaceous and grassy	20–40	0.8–1.8	0.1–0.6	
			Woody	35–60	1.2–1.8	0.1–0.6	

This kind of approach is useful to understand how to use different types and varieties of peat after peat mining, and choose places for agricultural and forest amelioration. For fire suppression and water retention (peatland rewetting), such classification (fen, transitional, bog mires and peatlands) helps to understand the peat exploration reports and to have an approximate idea about the type of hydrochemical nutrition of mire in the past.

If fen, transitional and bog plant communities are interpreted as a nutrition type of the mire, this should be understood as the type of water chemical composition but not necessarily the type of water source. The type of water chemical composition also changes during the flow through the mire vegetation and the upper layers of peat. Vegetation filtration, dilution with precipitation and an increase in the concentration of substances in water during evaporation contribute as well.

Ecological classification of mires with basic types of peat-forming vegetation is presented in Figure 103. The terminology here reflects the actual chemical composition of the peat, and does not take into account water supply, but the actual nutrition.

The Soviet (Russian) peat classification identifies the three main types of fen, transitional and bog peat in terms of chemical indicators, and each type is subdivided in terms of plant residues (by botanical analysis under a microscope in a laboratory) into subtypes, groups and varieties of peat *(Fig. 104)*.

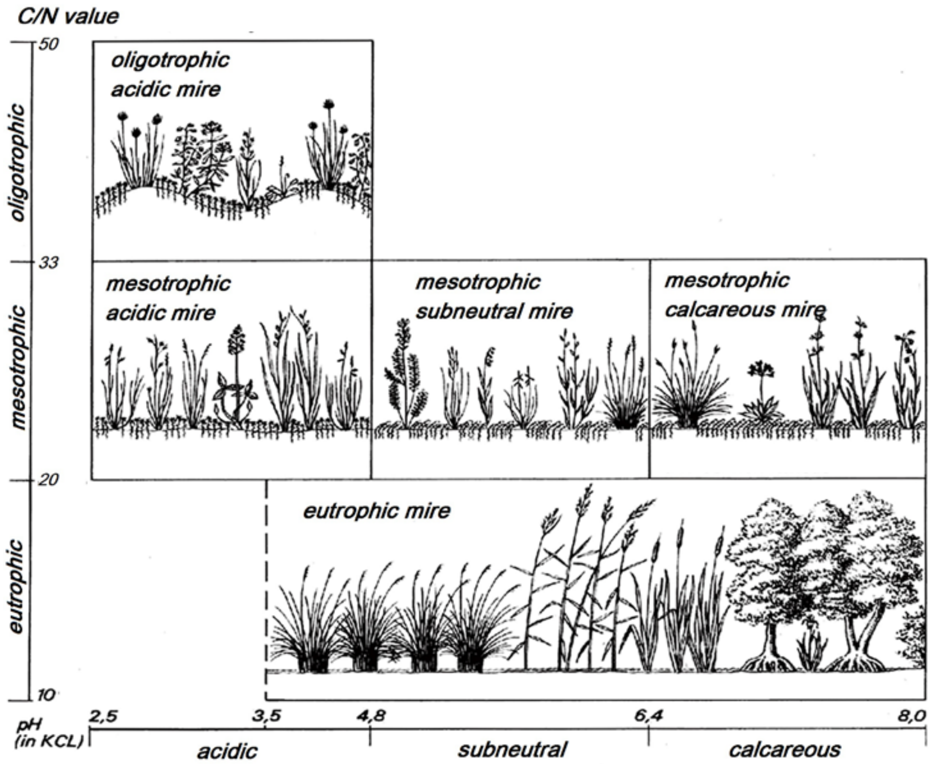


Fig. 103. Ecological classification of mires and the main types of peat-forming vegetation [53]

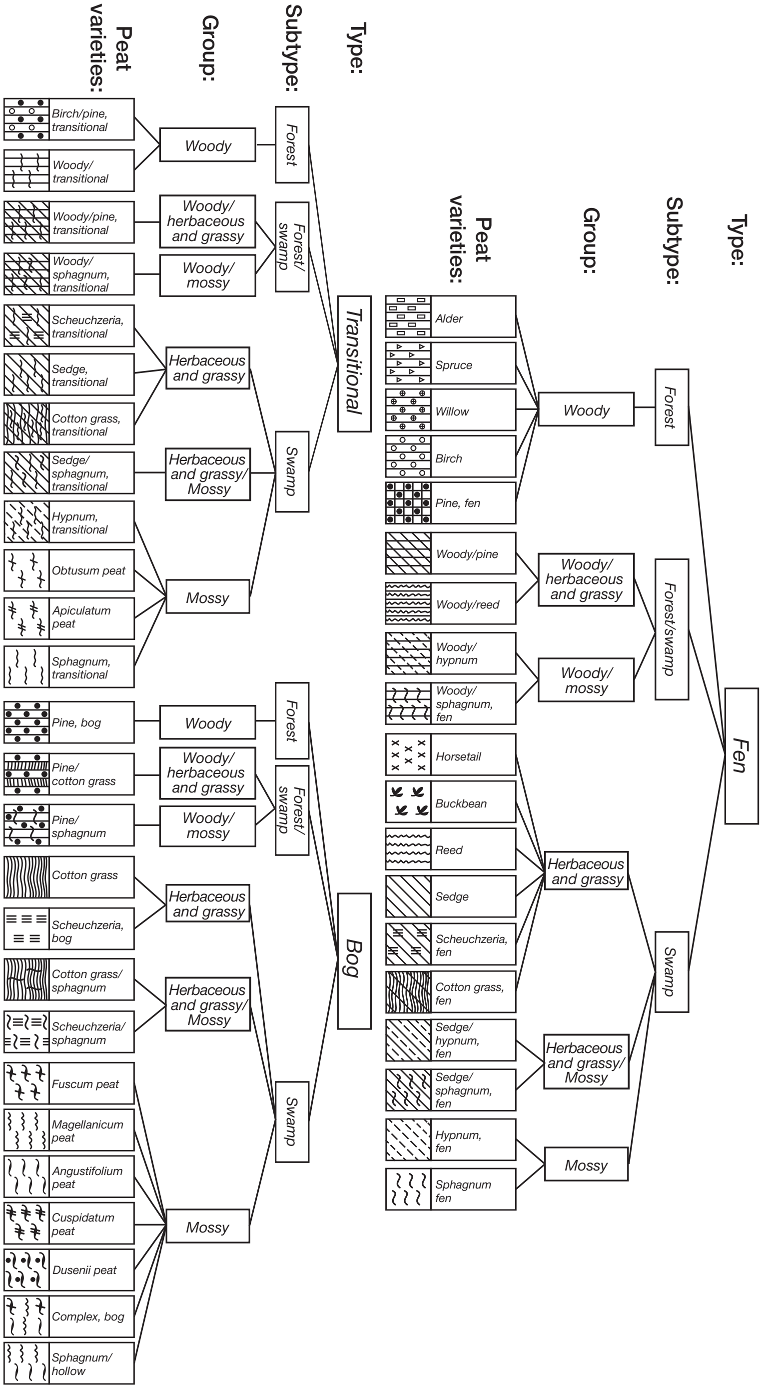


Fig. 104. Classification of peat varieties [25]

Based on the classifications accepted in Russia, it can be concluded that peat exploration in Russia and the USSR classified peat in most regions not according to their water supply but according to the chemical properties of peat and its botanical composition. The type of water supply can be identified if hydrogeological and hydrological surveys are carried out, including detailed water balance calculations.

PHASES OF PEAT DEVELOPMENT

One of the most hydrologically proven patterns of peat deposit development for the northwestern regions of Russia distinguishes three phases of mire development. The first one takes place in a concave terrain, the third one takes place in a convex terrain [8], i.e., the development of peat progresses from nutrient-rich to nutrient-poor.

Exceptions are as follows:

- Two separate bogs become connected. Then a transitional (in terms of peat) mire is formed between them, also partially covering the peripheral parts of two bogs. After the connection, the development again progresses up to bog peat with oligotrophic nutrition *(Fig. 105)*.
- The mire development and growth at the groundwater source from one aquifer eventually leads to a partial

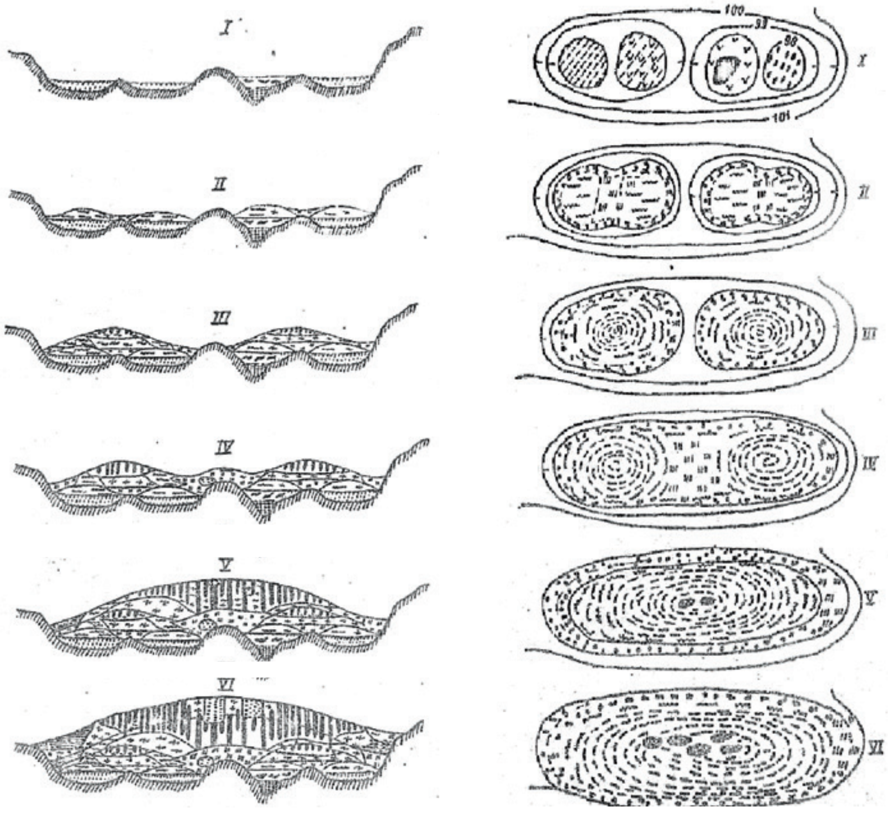


Fig. 105. Bog connection scheme. Based on peat exploration data in northwestern Russia [10]

hydraulic blocking of this aquifer. Then the groundwater next to the mire rises to a higher aquifer, where a more minerotrophic water comes out. Thus the formation of fen peat begins in the mire again, although transitional peat has been forming previously.

- As part of historical climate change processes, the ratio between the precipitation and the components of minerotrophic water supply changes. Thus, more and less minerotrophic types of peat will alternate in depth.

HYDROGENETIC MIRE TYPES

An important element of mire classification is the types of mires in terms of their hydrology and development history, i.e., **hydrogenetic mire types** [52, 53, 54]. They take into account the types of water supply, the specifics of water flow in the peat layers or above them and the type of peat formation. Primary, secondary and tertiary phases of mire development, and mires hydrogenetic properties (the current ones or before the drainage) are also identified.

Middle European scientists have identified 10 hydrogenetic mire types that are relevant also in Russia and all of Europe, with the exception of Arctic and Northern Aapa mires (Succow [52], Steiner [51], Succow and Joosten [54]). All of the relevant types describe mire-forming vegetation or, in case of drainage, types of surface peat layers *(Table 7)*.

Botanical types of peat and abiotic features make it possible to indirectly define the current or former type of water supply. On that basis, conclusions can be made on water retention for the purposes of fire suppression or rewetting.

Table 7. Hydrogenetic types of mires in the European temperate zone, their water supply; types of peat in the Russian classification and botanical types of peat in the German classification (Succow [52] and Steiner [51]; taking into account TGL 24 300/04 [56], Succow & Joosten [54], and based on personal experience of F. Edom in inventory of mires and peatlands)

Main type of water supply	Main sources of water supply	Hydrogenetic type (original name in German)	Main types of peat (in the upper layers of deposit) in the Russian classification	Main botanical types of peat (in the upper layers of deposit) in the German classification
Ombrogenic (with atmospheric water supply) (Bogs in terms of water supply)	Condensation of moisture	Condensation mire (Kondenswassermoor)	Bog, transitional	Sphagnum, sphagnum-shrub
	Liquid and solid atmospheric precipitation (rain, snow, hail)	Rain mire (bog with the subtypes raised bog, mountain bog, blanked bog, percolation bog) (Regenmoor (Hochmoor), ombrogenes Deckenmoor)	Bog	Sphagnum/cotton grass, sphagnum-shrub
Minerogenic (mineral) (Fen and transitional mires in terms of water supply)	Soil water	Blanked mixed mire (soligenes Deckenmoor)	Bog, sometimes transitional	Sphagnum-cotton gras, Sphagnum-sedge
	Lake water	Terrestrialisation mire (Verlandungsmoor)	Depending on the hydrochemical nature of the water body: fen, transitional, bog peat	Different types of peat, mainly above the gyttja (often sphagnum oligotrophic floating mats), or reed, alder, hypnum, coarse sedge (eutrophic) peat
	Soil water (including surface water), groundwater, precipitation	Paludification mire as well as groundwater rise mire (Versumpfungsmoor)	Depending on the geochemical nature of soil and the value of atmospheric water balance: fen, transitional, bog peat	With soil water supply: often sphagnum, cotton grass, sedge forest peat. With groundwater supply: often reed, coarse sedge, alder peat
	River or marine water, partially groundwater	Flood mires (floodplains with peat accumulation, sea shores with peat accumulation) Überflütungsmoor (Auen-, Küsten-)	Fen, rarely transitional	Riverine: reed, alder, sometimes sedge peat Marine: reed, sedge, other grassy or eutrophic forest peat Abiotic signs: silt or sand admixtures in peat

Table 7. Continued

Main type of water supply	Main sources of water supply	Hydrogenetic type (original name in German)	Main types of peat (in the upper layers of deposit) in the Russian classification	Main botanical types of peat (in the upper layers of deposit) in the German classification
Minerogenic (mineral) (Fen and transitional mires in terms of water supply)	Groundwater (often confined or artesian, as well as non-confined groundwater, such as slope springs)	Spring mire (Quellmoor)	Fen, rarely transitional	Coarse sedge, reed, alder, rarely small sedge, hypnum-sphagnum peat Abiotic signs: ferruginous or carbonate water, (white, ochre brown or gray) carbonates (limestone deposits, siderite), black iron sulphides, silt or fine sand mixtures in peat; in case of carbonates: hills of carbonate peat sediments are formed on locations of groundwater outlets
	Sloping soil and surface water	Sloping mire (Hangmoor)	Fen, transitional, sometimes bog peat	Sphagnum, sphagnum/cotton grass, sphagnum-sedge, sedge, spruce, birch peat Frequent abiotic signs: silt or sand admixtures in peat
	Slope soil and surface water, groundwater	A kettle hole mire (Kesselmoor)	Transitional, fen, sometimes bog	Sphagnum, sphagnum-sedge, sedge, hypnum-sedge, hypnum, sphagnum-forest, sedge-forest peat
	Groundwater	Catotelm percolation mire (Durchströmungsmoor)	Fen, sometimes transitional	Hypnum, sedge, hypnum-sedge

HYDROSTRUCTURE

What is important to know about the external hydrostructure of a mire?

- It determines the system boundaries of the framework, within which we will review the projects of peatland rewetting. It is better to learn about these boundaries at the beginning of a project to avoid any errors leading to the instability of the hydrological regime.
- Most mires and peatlands have groundwater and surface **hydrological catchments,** i.e., the areas from where groundwater or (semi-) surface water is inflowing. This also includes the so-called bogs because many of them are hydraulically connected with the underlying or adjacent fen peat. Surface catchments are determined by the terrain relief; underground water catchments are determined by the regional groundwater isohypses (contour lines of groundwater).
- The **water level of the water bodies downstream** of the mires and peatlands (rivers, lakes, seas) fluctuates. Groundwater flows from mires and peatlands to rivers, lakes and seas, therefore the water level in them determines how much water leaves the mire or peatland underground. If they are deepened during the regulation of rivers or re-created (as ameliorative channels), more water flows out of the peatland than it would in natural conditions. Besides, temporary flooding may originate in some such water bodies (during the spring floods or during sea tides), which is also important for the mire and peatland.
- If **groundwater is used in the surroundings** of a mire or peatland, less water will come to the peatland or more water can leave the peatland. In other words, the level of groundwater in some areas of the peatland will drop. Such groundwater uses may be a withdrawal of groundwater for drinking and household needs, quarries where minerals (sand, gravel) are mined below the groundwater level, construction of settlements or summer houses (dachas) with many water wells or drainage channels. As a result, a part of the peatland will be drier than it would be in natural conditions, little water remains for fire suppression and it is harder to retain such water. This should be taken into account.
- When rewetting or retaining water with ditch blocks, the groundwater level can rise in the areas around the peatland. If it is detrimental for the land use in these areas, e.g., basements in houses, fields or forests are flooded, then this zone is called **the impact zone.** In the course of natural growth of a mire, the adjacent areas can also become paludificated (an area in which peat accumulation begins); new mires and paludificated forests are formed. In this case, this is a natural zone of the mire impact.
- **The climatic surroundings** and their condition affect the magnitude of evaporation from the mire or peatland. The forest around the mire helps lower evaporation by reducing the wind speed. The water bodies with a large evaporation surface are also helpful, thus increasing the air humidity in the wind path toward the mire.
- **The hydraulic connection between the peatland and groundwater horizons** is important to determine because groundwater can inflow from there or the water can flow out of the mire under the ground. **The layers and dimensions** (depth, distribution, existence of underground barriers) of these aquifers affect the volume and water exchange between the peatland and its surroundings. There are also so-called **hydrogeological windows**, i.e., spots of high water permeability in low-permeable layers, where the groundwater can flow in or out more rapidly. Hydrogeological windows can be created artificially, such as if the drainage ditch is dug down to the sand layer. It is at these places that the groundwater flows in or out.

Table 8. External and internal elements of the hydrostructure of a mire or peatland

	Internal hydrostructure	**External hydrostructure** (+hydrogeology)
Horizontal elements	– Hydromorphology (relief) – Water bodies and drainage network – Vegetation zoning – Internal layout map of groundwater isohypes (Groundwater contours)	– Location of surface and underground hydrological catchments – Regional layout map of groundwater isohypes (groundwater contours) – The lower water bodies as hydraulic boundary conditions or sources of (temporary, potential) flooding – Adjacent zones of groundwater use (water intakes, quarries, etc.) affecting the underground inflow or outflow of water to or from the peatland – Zones of water impact during rewetting or development of peatlands – Climatic surroundings impacting peatland evaporation
Vertical elements	– Layers of peat and gyttja (sapropel) – Soil horizons	– Connection between a peatland and groundwater horizons (hydrogeological windows), their layers and dimensions

APPENDIX 2. PEAT BORER AND ITS OPERATION

A peat borer is required to study the structure of peat deposits, determine their depth and types of underlying soils. It facilitates the extraction of soil samples with an intact structure, i.e., the peat borer takes the sample without mixing up the soil elements taken from different depths.

It distinguishes this particular borer from other types of geological boring samplers, which sample highly decomposed or very wet peat poorly.

Peat borers are no longer produced in Russia, so we give instructions here on how to make a borer or to order a custom one. The borer design is presented in the drawing *(Fig. 101)*. In Germany and in the Netherlands are produced some other types of peat borers.

The borer consists of a T-shaped turning handle and an extension rod with 1 m sections, which are connected by spring-loaded pins, cotter pins or a thread. A sharp edged half-pipe (a pipe is sawn along), with a diameter of 45–55 mm and a length of 0.5 m, is attached to the rod. The sharp edge is inserted into a core tube made of a pipe similarly sawn along, whose inner diameter is 0.5–1.5 mm greater than the outer diameter of the sharp edged pipe. Additionally, the core tube pipe has two blades bent to the side, so the core tube does not turn in the ground when working with the borer. At the bottom end of the core tube, the bottom point is fastened to the lower axis of rotation of the sharp edge, and on the top end, there is a stop sleeve, through which the rod passes, being rigidly connected to the sharp edged pipe.

Before the work, the sharp edge is rotated in the core tube to open up the cavity for the sample. Next, the borer is pressed into the ground without rotation for the entire length of the core tube, and the handle is rotated 180°. At this point, the sharp edge comes out of the core tube, cuts out a sample from the soil and closes it inside the core tube *(Fig. 106, section A-A in the drawing)*. Subsequently, the borer is raised to the surface without rotation, the core tube is carefully opened, and the sample is studied *(Fig. 107)*. To take the next sample, the borer is cleaned of any residue from the previous sample, the cavity is reopened and the borer is pressed into the ground for the next step of sampling, equal to the length of the core tube.

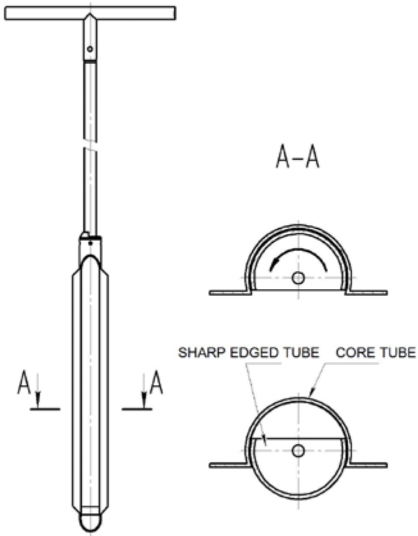


Fig. 106. Drawing of the peat borer

PHOTO BY: IVAN SEMENOV/GP

Fig. 107. Studying a core (soil sample) in the peat borer

Degree of peat decomposition/ humification (Scale by von POST 1926)	% (Soviet/ Russian scale)	Wet peat			Dry peat	
		Peat description and the structure of plant residues	When compressed in a fist, the following comes out between the fingers:	Residue after squeezing in a fist	Volume of distinguishable (structured) plant residues in peat	Color of peat (only for bog peats)[1]
H1	5–10	Completely undecomposed peat. Plants remain easily recognizable	Colorless, almost clear water	No amorphous (pasty) material	Consists completely of distinguishable plant residues	From light gray to yellow
H2	15	Almost undecomposed peat. Plant residues are still easily identifiable	Clear or yellowish water	No amorphous (pasty) material	Consists completely of distinguishable plant residues	Light brown
H3	20–25	Very slightly decomposed peat. Plant residues can still be identified; no amorphous material	Brown, turbid water	No amorphous (pasty) material	Consists completely of distinguishable plant residues	From light brown to brown
H4	30	Slightly decomposed peat. Plant residues are slightly pasty, some of their distinguishing features have been lost	Dark, very turbid water	No amorphous (pasty) material	Consists completely of distinguishable plant residues	From dark brown to black
H5	35	Moderately decomposed peat. The structure of plant residues is somewhat vague, although some signs can still be recognized	Very turbid water with a small amount of amorphous granulated peat	Pasty residue	Consists almost entirely of distinguishable plant residues	From dark brown to black

[1] *This column applies only to the bog peat (sphagnum, cotton grass, scheuchzeria). In fens, low-decomposed peat may have a dark color.*

Degree of peat decomposition/ humification (Scale by von POST 1926)	% (Soviet/ Russian scale)	Wet peat			Dry peat	
		Peat description and the structure of plant residues	When compressed in a fist, the following comes out between the fingers:	Residue after squeezing in a fist	Volume of distinguishable (structured) plant residues in peat	Color of peat (only for bog peats)[1]
H6	40	Moderately highly decomposed peat with a very vague plant structure	Up to a third of the peat comes out between the fingers	Pasty residue	More than two thirds of the sample volume	From dark brown to black
H7	45	Highly decomposed peat. Contains a lot of amorphous material with a very poorly recognizable plant structure	Approximately half of the peat comes out between the fingers. Water, if any, is very dark and very pasty	The residue is pasty, but the plant structure is visible more clearly than before squeezing	Approximately half of the sample volume	From dark brown to black
H8	50	Very highly decomposed peat with a large amount of amorphous material and a very vague plant structure	Approximately two thirds of the peat comes out between the fingers. A small amount of water may come out	Roots and fibers, poorly decomposable	About 1/3 of the sample volume	From dark brown to black
H9	55	Almost completely decomposed peat, having almost no recognizable plant structure	A homogeneous paste with almost all of it coming out between the fingers	Roots and fibers, poorly decomposable	Very little of distinguishable plant residue	From dark brown to black
H10	60	Fully decomposed peat without any visible plant structure	Entire wet peat is squeezed out between the fingers	No residue	No distinguishable residues	From dark brown to black

See the original table in: Succow [52], Succow & Joosten [54, p.554], TGL 24300/04 [56], Luthardt, Schulz and Meier-Uhlher [46].
The columns for dry peat (columns 6–7) are originally from Grosse-Brauckmann (1996)..

A note from Luthardt, Schulz and Meier-Uhlher [46]:

The table does not apply to peat of secondary decomposition resulting from anthropogenic drainage (earthified and murshified peat). It is necessary to determine the type of degraded horizons for it.

For peats with wood residues, it is necessary to determine the degree of decomposition of the main substance without taking into account wood residues in the sample.

APPENDIX 4. SELECTING A MOTOR PUMP & DESIGNING HOSE LINES

ALL PHOTOS ON THE STRIP BY: YULIA PETRENKO/GP

Figs. 108, 109. Extinguishing a peat fire point

Motor pumps are pumps for water supply equipped with an internal combustion engine. Motor pumps are used in combination with suction and discharge fire hoses of various diameters, dividing breechings, fire hose coupling heads and manual fire hose nozzles. All of them make up a hose line.

A preliminary calculation of the hose line is required:

- When purchasing equipment, make sure the purchased motor pumps, hoses, and fire hose nozzles are suitable for the water supply in your conditions.
- When going out to a fire, be certain of which fire hose nozzles, adapters, hoses, and pumps to take.
- When deploying a hose line on a fire, select the best combination of equipment.

Practice shows that motor pumps are often ineffective precisely because of gross mistakes when choosing and deploying a hose line. To act quickly and confidently in a fire, one should practice in advance and estimate calculations for possible fire scenarios typical for your locality.

A motor pump has the following characteristics specified by the manufacturer:

- The head, i.e., the maximum height of water lifting (m).
- Flow rate, i.e., the amount of water that is pumped over per unit of time (L/min).
- Permissible size of solid particles.
- Weight.
- Engine type.
- Size.

A table with the characteristics of frequently used motor pumps is given in Appendix 5.

A motor pump is most effective with medium values of the head and water flow rate. Pumps for clean water are lighter and more efficient than mud pumps, but mud motor pumps can work from almost any water source, including those filled with peat hydromass. Four-stroke motor pumps are more cost effective but heavier than two-stroke ones. The weight and size are important in terms of logistics.

Fire hoses are flexible pipelines for supplying water to a fire, and they are equipped with coupling heads.

Hoses differ in terms of the following:

- Materials (made of natural or synthetic fibers, with an internal waterproofing layer or double-sided coating).
- Purpose (for mobile fire extinguishing machinery, such as fire trucks or motor pumps, or for fire hydrants in buildings and structures).
- Nominal internal orifice (corresponds to the actual internal diameter in the following order: 40–38 mm; 50–51 mm; 65–66 mm; 80–77 mm; 90–88 mm).
- Pressure.
- Resistance to external impact (wear-resistant, oil-resistant, heat-resistant). Important: All hoses, except percolating types, burn easily.
- Climatic category (from -40 to +50°C, from -50 to +50°C, from -60 to +50°C).

Table 9. Types of hoses (used in Russia) by purpose, diameter and possible line pressure

Type	Diameter (mm)	Pressure P, MPa (kg/cm^2) but not less than
For fire hydrants in buildings and structures	25, 40, 50, 65	1.0 (10.0)
For mobile fire equipment	150	1.2 (12.0)
	25, 40, 50, 65, 80, 90	1.6 (16.0)
	25, 40, 50, 65, 80	3.0 (30.0)

When choosing hoses, pay attention to labelling. The standard hose length for mobile fire equipment is 20 meters. The hoses that have been used may be shorter due to their repair (removal of a damaged part of the hose), so when calculating the length of the line, take into account not only the terrain relief but also the inaccurate length of hoses, and always add 10 % to the required number of hoses.

For example, the distance from water to the fire edge is 200 m, the standard length of a single hose is 20 m. Therefore, we need to take 200 m ÷ 20 m + 10% = 11 hoses (always round up to integers).

The hoses differ in volume and capacity depending on their diameters. The greater the hose diameter is, the smaller the resistance to water movement will be inside. (In a larger-diameter hose the flow rate is significantly lower. Thus, the pressure loss due to friction with the hose material is much lower too.) But more water is needed to fill such a hose. The smaller the hose diameter is, the greater the resistance to water movement in it will be. However, a smaller volume of water is needed to fill the hose. The hose volume is important when laying a line from limited water sources, e.g., from water tank trucks. The 350 m distance from a fire engine with a 1.6 t reservoir to the fire edge is enough for all the water to only fill the line with a diameter of 77 mm.

Table 10. Water volume in a 20 m fire hose

Hose diameter, mm	25	38	51	66	77	125	150
Water volume, L	9	22	40	70	90	190	350

Resistance to water movement is one of the most important factors that must be taken into account when laying the hose line. Typically, largediameter hoses are used in the main line, but a smaller diameter working line is laid directly to the fire hose nozzle operator to facilitate the nozzle operation (hoses of large diameters are heavy and uncomfortable when maneuvering due to the volume of water in them and their materials).

The fire hose nozzle forms a water jet and practically turns the pressure in the line into the speed of a jet. The distance of the jet and the way it washes out the ground will depend on its speed. If the hose lines are properly equipped with fire hose nozzles, the water consumption can be minimized and the efficiency of fire extinguishment increased. The nozzles can be equipped with special elements to make a compact jet, form a veil, and supply both water and foam. The models of fire hose nozzles used in different countries differ from each other by their characteristics, but in any case it is important to know the flow rates at different pressures. We present the values for the nozzle models used in Russia *(Table 11)*.

Table 11. Flow rates of fire hose nozzles with small pressure values (the lowest possible for operation)

	Q, L/min		
Pressure P, mWC	**RS-25 model**	**RS-50 model**	**RS-70 model**
Less than 5	—	—	—
5 м	**14.4**	**78**	**138**
8 м	**18**	**96**	**168**
10 м	**20.4**	**114**	**186**

In Russian markings of manual fire hose nozzles, the following notation is used: 50 or 70 is a nominal orifice equal to the diameters of 51 mm and 66 mm, respectively.

For example, RS-70 is a manual fire hose nozzle that only makes a compact jet, having an inlet diameter of 66 mm. The diameters of the outlet hole may differ in different modifications of nozzles. RS-50 with a nozzle diameter of 13 mm and RS-70 with 19 mm are the most popular models. If it is necessary to supply a large amount of water, 51 mm to 25 mm coupling heads (GP 51–25) are often used instead of conventional nozzles.

The line from the water source to the peat fire point consists of motor pumps, hoses and fire hose nozzles, and it is laid on the ground. When calculating, the following points are taken into account:

- The pressure the motor pump can provide at a certain flow rate (PMP).
- The height (h) to which water should be raised from the source level.
- Pressure loss in the hose line (LHL).
- Pressure required for the effective operation of the fire hose nozzle (PHN).

For a desired output, the values in the calculations must be greater than zero. A formula for designing the pump hose line can be written as follows:

$$PMP - h - LHL - PHN > 0$$

To get data for calculations, refer to Table 12 "Data for designing hose lines for some motor pumps."

In this table, values are highlighted in color for different types of operations: green is to work at peat fires (pressure and flow rate are high); yellow is to work at crawling fires and grass fires (low pressure, average flow rate); and red is for refilling the reservoirs (pressure and flow rate are low).

Determine the zone that suits your type of operation. Find the pressure value at the motor pump outlet according to the required flow rate in the table. Find the pressure loss in the hoses with the same flow rate and multiply them by the number of hoses.Take the pressure value at the nozzle inlet with the same flow rate from the table.

Define the height to which water will be raised, taking into account the height of the nozzle operator.

Important: All calculations are made including low pressure values and, accordingly, low flow rates in fire hose nozzles.

Note: Typically, the pressure and flow rate are calculated by the following formula:

$$Pmp = Nh \times S \times Q^2 \pm Zt \pm Zn + Pn,$$

where Pmp is the pressure at the motor pump outlet, mWC (meter of water column).
Nh is the number of hoses in the main line, meters.

Table 12. Data for designing hose lines for some motor pumps

Flow rate, L/min	GP 51-25 coupling head model	RS 70 nozzle model	RS 50 nozzle model	RS 25 nozzle model	Hoses (diameters in mm)					Honda WB30	Koshin SEM 50V	Koshin SERM 50V	Honda WB20	Honda WX15	Robin-Subaru PTG 110	Flow rate, L/min
					77	66	51	38	25							
	Pressure at the nozzle inlet, mWC				Pressure loss in one hose, mWC					Pressure at the motor pump outlet, mWC						
10				3	0.00	0.00	0.00	0.01	0.11	25	46	79	28	36	37	10
15				6	0.00	0.00	0.01	0.03	0.25	25	46	78	28	36	37	15
20				10	0.00	0.00	0.01	0.06	0.44	25	45	78	28	36	37	20
30				23	0.00	0.01	0.03	0.13	1.0	25	45	76	28	36	37	30
40			1	40	0.01	0.02	0.06	0.22	1.8	25	44	74	27	36	35	40
45			2	51	0.01	0.02	0.07	0.28	2.3	25	43	73	27	36	34	45
60		1	3	90	0.02	0.04	0.13	0.50	4.0	24	42	71	26	36	31	60
80	2	2	5	160	0.03	0.07	0.23	0.89	7.1	24	41	67	26	35	23	80
100	2	3	8		0.04	0.11	0.36	1.4	11.1	23	39	64	25	33	13	100
120	3	4	12		0.06	0.16	0.52	2.0	16.0	23	37	60	24	31		120
130	4	5	14		0.07	0.18	0.61	2.3		23	36	58	24	29		130
160	6	8	21		0.11	0.28	0.92	3.6		22	34	53	22	24		160
180	8	10	27		0.14	0.35	1.2	4.5		22	32	50	21	20		180
200	9	12	33		0.17	0.43	1.4	5.6		22	31	46	21	16		200
240	14	18	48		0.24	0.62	2.1	8.0		21	28	40	19	5		240
260	16	21	56		0.28	0.73	2.4			20	26	36	18			260
300	21	28	75		0.38	0.98	3.3			20	23	29	15			300
320	24	31	85		0.43	1.1	3.7			19	21	26	14			320
350	29	37	102		0.51	1.3	4.4			18	19	21	12			350
390	36	46			0.63	1.6	5.5			18	15	14	10			390
420	42	54			0.74	1.9	6.4			17	13	9	8			420
480	54	70			1.0	2.5	8.3			16	8					480
540	69	89			1.2	3.2				14						540
600	85				1.5	3.9				13						600
660					1.8	4.7				11						660

S is the coefficient of resistance in the hose (usually can be found in reference tables).
Q is the flow rate, L/sec; therefore, $S \times Q^2$ is the pressure loss in one hose of the main line.
Zt is the geometric height of the uplift (+) or the descent of terrain (-), m.
Zn is the biggest height of uplift (+) or the depth (-) of nozzles operations, m.
Pn is the pressure at the extinguishing devices (nozzles), mWC.

When using dividing breechings, instead of Pn, the pressure at dividing breechings is taken as 10 m higher than at the nozzles (Pdb = Pn + 10).

For a better understanding and greater clarity, we propose a simpler method similar to the above using Table 12. It is created specifically for field calculations and is based on the diagrams of pressure/flow rate characteristics of motor pumps, the coefficients of hose resistance and the characteristics of fire hose nozzles. Because motor pumps are not generally equipped with pressure gauges to determine the actual outlet pressure, Table 12 also includes ready-to-use calculations for some motor pumps models.

Let us analyze several tasks on that basis.

Task 1.

20 hoses with a diameter of 51 mm, RS-50 nozzle, and Honda WX15 motor pump were brought to a peat fire with an area of 10 m^2. The distance from the water source to the fire is approximately 200 m, and the height of the terrain uplift (h) is 5 m.

How much time will it take to supply the required amount of water to extinguish the peat fire point, if 1 m^2 of peat requires at least 1 t of water?

Solution.

For this fire, a scheme can be drawn *(Fig. 110)*.

First, we calculate whether it is possible to supply water to the desired distance and height using the existing equipment.

Because the standard hose length is 20 m, we would need 11 hoses to lay a line to the peat fire point.

Let us review the values in the green area of the table. For RS-50, the value for peat operations begins with a flow rate of 100 L/min. Let us see whether it is possible with the available equipment to provide the minimum necessary pressure for efficient operations with this fire hose nozzle. All values in this calculation are taken for a precise flow rate of 100 L/min: Honda WX15-33 motor pump provides 33 mWC pressure; the pressure loss in one hose with a diameter of 51 mm is 0.36 mWC; and the required pressure at the fire hose nozzle is 8 mWC.

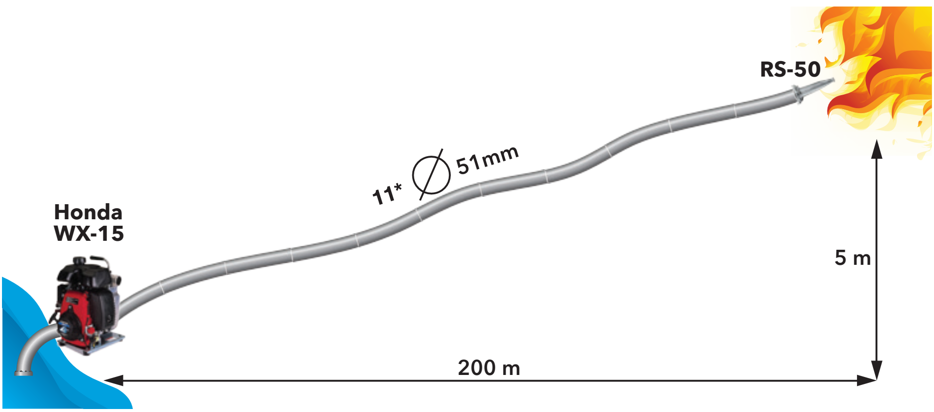


Fig. 110. Scheme of a hose line

Flow rate, L/min	GP 51-25 coupling head model	RS 70 nozzle model	RS 50 nozzle model	RS 25 nozzle model	Hoses (diameters in mm)					Honda WB30	Koshin SEM 50V	Koshin SERM 50V	Honda WB20	Honda WX15	Robin-Subaru PTG 110	Flow rate, L/min
					77	66	51	38	25							
	Pressure at the nozzle inlet, mWC				Pressure loss in one hose, mWC					Pressure at the motor pump outlet, mWC						
100	2	3	8		0,04	0,11	0,36	1,4	11,1	23	39	64	25	33		100

Let us calculate by the following formula: PMP – h – LHL – PHN = 33 – 5 – 0.36 × 11 – 8 = 16.04 > 0. A value much greater than zero indicates that the actual flow rate will be more than 100 L/min, but such a line will work in any case.

2. Now, let us calculate the actual flow rate of such a line. The next flow rate value in the table is 120 L/min.

Flow rate, L/min	GP 51-25 coupling head model	RS 70 nozzle model	RS 50 nozzle model	RS 25 nozzle model	Hoses (diameters in mm)					Honda WB30	Koshin SEM 50V	Koshin SERM 50V	Honda WB20	Honda WX15	Robin-Subaru PTG 110	Flow rate, L/min
					77	66	51	38	25							
	Pressure at the nozzle inlet, mWC				Pressure loss in one hose, mWC					Pressure at the motor pump outlet, mWC						
120	3	4	12		0,06	0,16	0,52	2,0	16	33	37	60	24	31		120

Let us calculate by the following formula: PMP – h – LHL – PHN = 31 – 5 – 0.52 × 11 – 12 = 8.28 > 0.

The next flow rate value in the table is 130 L/min.

Flow rate, L/min	GP 51-25 coupling head model	RS 70 nozzle model	RS 50 nozzle model	RS 25 nozzle model	Hoses (diameters in mm)					Honda WB30	Koshin SEM 50V	Koshin SERM 50V	Honda WB20	Honda WX15	Robin-Subaru PTG 110	Flow rate, L/min
					77	66	51	38	25							
	Pressure at the nozzle inlet, mWC				Pressure loss in one hose, mWC					Pressure at the motor pump outlet, mWC						
130	4	5	14		0,07	0,18	0,61	2,3		23	37	58	24	29		130

PMP – h – LHL – PHN = 29 – 5 – 0.61 × 11 – 14 = 3.29 > 0

The next flow rate value in the table is 160 L/min.

PMP – h – LHL – PHN = 24 – 5 – 0.92 × 11 – 21 = -12.12 < 0

A negative number indicates that the line will not provide a flow rate equivalent to 160 L/min.

Flow rate, L/min	GP 51-25 coupling head model	RS 70 nozzle model	RS 50 nozzle model	RS 25 nozzle model	Hoses (diameters in mm)					Honda WB30	Koshin SEM 50V	Koshin SERM 50V	Honda WB20	Honda WX15	Robin-Subaru PTG 110	Flow rate, L/min
					77	66	51	38	25							
	Pressure at the nozzle inlet, mWC				Pressure loss in one hose, mWC					Pressure at the motor pump outlet, mWC						
160	6	8	21		0,11	0,28	0,92	3,6		23	34	53	22	24		160

According to previous calculations, we can see that the value closest to zero was at a flow rate of 130 L/min, i.e., the line drawn in the scheme will provide approximately 130 L/min.

If the peat fire point is 10 m^2 and not less than 1 t of water is required for 1 m^2, then at least 10 t of water or 10 000 liters will be needed for the fire point. With the flow rate of 130 L/min, 10 000 liters can be supplied in approximately 77 minutes.

Result. It will take approximately 77 minutes to supply the required amount of water to extinguish a peat fire point without taking into account the time for deploying and removing the hose line.

Task 2.

Ten 77 mm hoses, ten 51 mm hoses, two RS-50 nozzles, two RS-70 nozzles, one GP 51-66 coupling head, RT-80 three-way dividing breeching, and Honda WB30 motor pump has been brought to a fire location. The distance from the water source to the fire edge is approximately 220 m with a terrain uplift of 2-3 m.

Is it possible to use two nozzles simultaneously with a pressure suitable for operations at the peat fire? What type would these nozzles be?

Let us draw one of the options of the hose line scheme *(Fig. 111)*, which could be laid under specified conditions. To reduce pressure loss in a hose line, it is recommended to lay the main line as close as possible to the peat fire point and put the hoses of smaller diameter only for the working lines that are immediately next to the nozzle operator.

Solution.

To design a line with a dividing breeching, take into account the number of fire hose nozzles to be used in the line. The setting indicates that it is necessary to supply water to two RS-50 nozzles. The minimum operational value in the green zone of table 12 is provided by RS-50 at the flow rate of 100 L/min. Because we have two RS-50 nozzles, the motor pump should provide such pressure so that at least 200 L/min (100 L/min per nozzle) pass through the hoses to the dividing breeching.

First, we make a calculation upstream of the dividing breeching. The RT-80 is a three-way dividing breeching, with an 80 mm nominal internal diameter of the inlet and three outlets, two of which are 50 mm and one is 80 mm. The RT-80 is equipped with valves that allow blocking the lines. Upstream of the RT-80, we have a line of ten 77 mm hoses and a

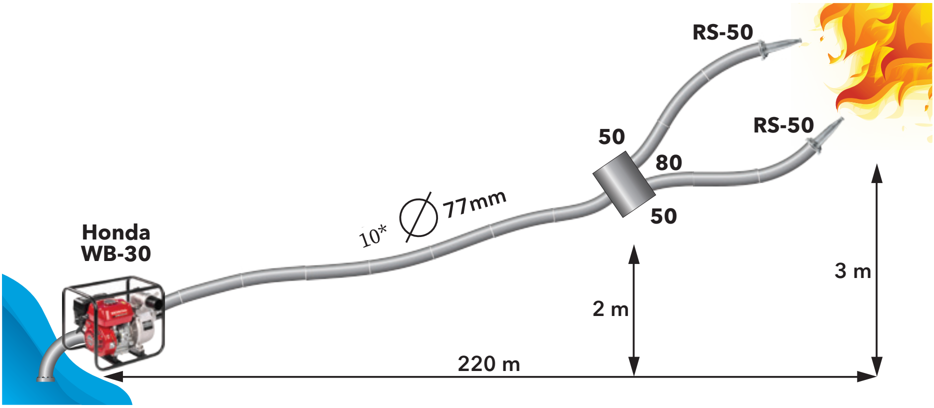


Fig. 111. Schematic of a hose line

Honda WB30 pump. The pressure values for the motor pump and pressure loss in the hose are taken from Table 12 according to the minimum required flow rate of 200 L/min.

PMP – h – LHL = 22 – 2 – 0.17 × 10 = 18.3 is the pressure that will be at the inlet of RT-80, and this pressure will be the same for each line downstream of the dividing breeching.

We will now calculate the indicator for each working line downstream of the dividing breeching. Now we take the pressure value that would be at the dividing breeching inlet as PMP. Data on the loss in hoses and pressure at the nozzle is taken according to the flow rate item that was originally considered the desired value at the nozzle: 100 L/min.

PMP – h – LHL – PHN = 18.3 – 1 – 0.36 × 2 – 8 = 8.58 > 0, the line is operational.

To increase the efficiency, replace one RS–50 nozzle with a RS–70 nozzle. When designing an asymmetric line, make calculations according to the line that requires more water or has greater loss. If such a line works, other lines downstream of the dividing breeching will work, too.

The minimum flow rate in the green zone for the RS-70 nozzle is 160 L/min. In other words, there must be a flow rate of at least 320 L/min upstream of the dividing breeching.

The calculation is: PMP – h – LHL = 19 – 2 – 0.43 × 10 = 12.7.

Next, we make a calculation for the line with a higher flow rate, with the initial desired flow rate of 160 L/min and the RS-70 nozzle.

PMP – h – LHL – PHN = 12.7 – 1 – 0.92 × 2 – 8 = 1.86 > 0, this means that such a line will be operational, and it is possible to replace one RS-50 with RS-70.

Because the values downstream of the dividing breeching are valid for each line, it would be possible to replace both RS-50s with RS-70s. However, only one GP 51-66 coupling head is indicated in the equipment set, which means that only one RS-70 can be connected to the operational line.

Result. It is possible to supply water simultaneously into the lines with RS-50 and RS-70 nozzles, using a pressure suitable for extinguishing peat fires.

Task 3.

A fire in a rocky area; a peaty forest floor at an altitude of approximately 15 m is burning at a distance of 200 m from the water. It is necessary to completely water the entire area exposed to fire. Equipment available: Honda WB30 and Honda WX15 motor pumps, twenty 77mm hoses, ten 51mm hoses, RT-80 three-way dividing breeching, four GP 51-77 fire hose coupling heads and three RS-50 nozzles.

Is it possible to supply water into three fire hose nozzles to reduce the time of fire suppression?

Solution.

Similar to the solution to Task 2, we will make calculations taking the values of Honda WB30 motor pump as the one with a higher flow rate. According to Table 12, the minimum flow rate required to extinguish a crawling forest fire by the RS-50 is 80 L/min. So, for three RS-50 nozzles, a 240 L/min flow rate will be required.

Let us calculate the pressure upstream of the dividing breeching: PMP – h – LHL = 21 – 15 – 0.24 × 11 = 3.36. Next, we calculate one working line at a time (all lines are identical after the dividing breeching: one 51mm hose and one RS-50 nozzle).

PMP – h – LHL – PHN = 3.36 – 0 – 0.23 × 1 – 5 = -1.87 < 0, i. e., one Honda WB30 motor pump cannot feed three RS-50 nozzles.

Let us try to make calculations with the condition that we use all available motor pumps and lay the pumping line.

A scheme of such a fire may look like this *(Fig. 112)*:

To design a line for pumping, it is necessary to sum up the pressure indicators of both motor pumps. We make a calculation based on the required flow rate of 80 L/min.

Upstream of the dividing breeching: PMP1 + PMP2 – h – LHL = 21 + 5 – 15 – 0.24 × 11 = 8.36

For a working line: PMP – h – LHL – PHN = 8.36 – 0 – 0.23 × 1 – 5 = 3.13 > 0; i.e., when laying a pumping line with two motor pumps, three RS-50 nozzles will work with a flow rate of about 80 L/min.

Result. Yes, it is possible to supply water into three RS-50 nozzles to perform this task.

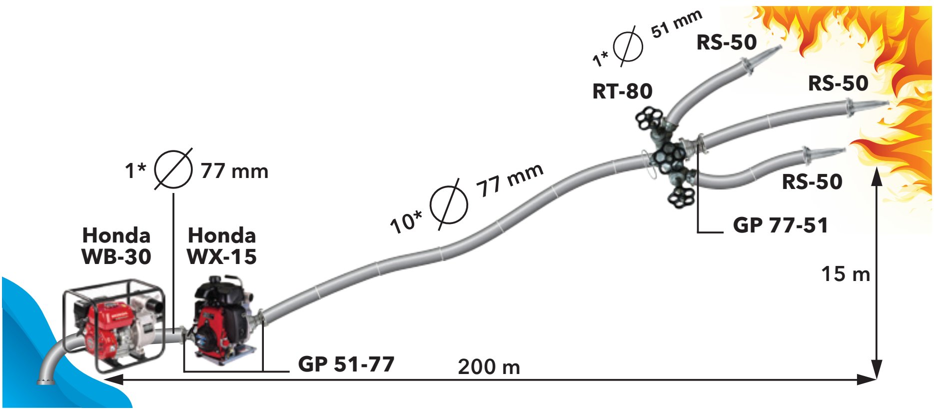


Fig. 112. Schematic of a hose line

The pumping lines or the lines with several nozzles are more difficult to make because they include dividing breechings and fire hose coupling heads. The pressure loss in these elements of the line is insignificant and can be ignored. The pressure at the inlet to the next pump in the line should be at least 5 mWC so that the hose does not collapse. The location of the second motor pump can also be calculated. If more water is supplied, with more pressure than the next pump in the line can handle, this will not only slow down the entire line but may also break down the impeller of the pump.

If the calculated pressure is insufficient, try increasing the diameter of the hoses or taking nozzles of a smaller diameter, where the sufficient pressure will be achieved with a lower flow rate.

Table 12 shows the data on widespread volunteer equipment: RS-25, RS-50 and RS-70 nozzles, GP 25-51 fire hose coupling head; hoses with a diameter of 25-77 mm; Honda WB30, Koshin SEM-50V, Koshin SERM-50V, Honda WB20, Honda WX15, Subaru-Robin PTG-110. If you use the equipment that is not in the calculation tables, use the table "Specifications of Some Motor Pumps" in Appendix 5, and select the motor pump whose specifications are closest to those of your motor pump.

The design of hose lines helps choose the best combination of equipment for a specific terrain relief, the type of fire and the number of people involved in fire extinguishment.

APPENDIX 5. SPECIFICATIONS OF SOME MOTOR PUMPS

Type (model name) of the pump, weight in kg	Nominal performance with suction depth of 1 m (L/min) Pressure (mWC)	Recommended number and type of fire hose nozzles with a 20 m main hose line and (or) 20 m working lines with a 5 m terrain uplift.	Diameter of the inlet(s)/ outlet(s). Diameter of particles (openings of the filter)
Honda WX15 9 kg	240 L/min 40 m	1 ea. RS-50 or 2 ea. RS-25, 2 ea. TS-1 (deep peat nozzle)	38 mm/38 mm/6 mm
Honda WB20 21 kg	600 L/min 32 mWC	1 ea. RS-70 or 2 ea. RS-50	51 mm/51 mm/8 mm
Honda WB30 27 kg	1100 L/min 28 mWC	3 ea. RS-50	77 mm/77 mm/8 mm
Koshin SEM50V 25 kg	500 L/min 50 mWC	1 ea. RS-70, 1ea. RS-50	51 mm/51 mm/8 mm
Koshin SERM50V 37 kg	500 L/min 90 mWC	1 ea. RS-70, 1 ea. RS-50	51 mm/51 mm/8 mm
Koshin SERH50V 47 kg	540 L/min 60 mWC	2 ea. RS-25 (or TS-1) and 1 ea. RS-50 or 4 ea. TS-1	1 × 51 mm 2 × 25 mm/51 mm/7 mm
Subaru-Robin PTG110 5,1 kg	130 L/min 35 mWC	RS-50, RS-25	25 mm/25 mm/5 mm
Subaru-Robin PTG209 24 kg	600 L/min 28 mWC	3 ea. RS-50	66 mm/66 mm/10 mm
Subaru-Robin PTG307ST 28 kg	1000 L/min 23 mWC	2 ea. RS-50 + 1 ea. RS-70	77 mm/77 mm/20 mm
Sprut 22 kg	400 L/min 55 mWC	2 ea. RS-25 (or TS-1) and 1 ea. RS-50 or 4 ea. TS-1	1 × 51 mm 2 × 25 mm/51 mm/7 mm
MLV-1M 18 kg	1.2 L/sec (72 L/min) 120 mWC	RS-25	25 mm, 5 mm
ML1-SO 9.8 kg	1 L/sec (60 L/min) 100 mWC	RS-25	25 mm, 5 mm
High-Pressure Firefighting System Yermak 62 kg	12 L/min 1600 mWC	Special high pressure nozzle	High-pressure hose, particles up to 0.5 mm

APPENDIX 6. EQUIPMENT AND TOOLS SET FOR A VOLUNTEER FOREST FIREFIGHTERS TEAM (UP TO 10 PEOPLE)

This set is designed for fire suppression at a forest peat fire or a peat fire for several days.

No.	Equipment	Quantity, ea.
1	RP-18 Yermak backpack forest fires extinguisher (or an analog)	10
2	Repair kit for the backpack forest fires extinguisher	10
3	Extra hand pump for the backpack forest fires extinguisher	5
4	Honda WX15 motor pump (or an analog), equipped with GM-50 coupling heads at the inlet and outlet	1
5	Honda WB30 motor pump (or an analog), equipped with GM-80 coupling heads at the inlet and outlet	1
6	Suction hose with a 50 mm coupling head	1
7	Filtering hose strainer with a 50 mm coupling head	1
8	Suction hose with a 80 mm coupling head	1
9	Filtering hose strainer with a 80 mm coupling head	1
10	51 mm discharge fire hose	20
11	77 mm discharge fire hose	20
12	RT-80 three-way dividing breeching	1
13	RD-50 two-way dividing breeching	1
14	RS-50 fire hose nozzle	5
15	RS-70 fire hose nozzle	2
16	TS-1 deep (peat) nozzle	2
17	Fire hose coupling heads 51 × 66 (GP 50–70)	2
18	Fire hose coupling heads 66 × 77 (GP 70–80)	2
19	Fire hose coupling heads 51 × 77 (GP 50–80)	4
20	Fire hose coupling heads 51 × 25 (GP 25-50)	2
21	Wetting agent mixing tube	1
22	Wetting agent tablets	20

No.	Equipment	Quantity, ea.
23	Hose spanners	1–2 pairs
24	Hose clamp	2
25	Handheld radio transceiver	10 + 2 spare
26	GPS/GLONASS tourist navigator	4
27	Sharpened shovel with a metal handle	10
28	Pulaski axe	2
29	Mid-size axe	2
30	Chainsaw with the necessary tools for sharpening and regulating the chain tension	2
31	A spare chain for the chainsaw	2
32	2 tons mechanical lever hoist	1
33	Canisters for fuel and lubricants*	5
34	Water bucket	4
35	Funnels for water and fuel	4
36	Floats for suction hoses	2
37	Poles for motor pumps carrying	1–2 pairs
38	Frame systems for carrying loads	3
39	Probe thermometers	2
40	Autonomous or smartphone-based thermal imager	2–3
41	Red and white signal tape (100 m)	1
42	Flexible fabric stretcher	1
43	Group first-aid kit	1
44	Group flashlight	2

* Canisters must be clearly and unequivocally marked with indelible ink.

Additional necessities are canisters for drinking water, gas burner (stove), dishes, tents, mats, awnings, gasoline generator, manual and electric tools for equipment repair and other field inventory for a camp of 10 people.

REFERENCES

Literature in original Russian language

1. Batuev V.I., Novikov S.M., Usova L.I., Korotkevich A.E. *Metodicheskie ukazaniya po raschetam stoka s neosushennykh i osushennykh bolot* [Methodological guidelines for calculation of runoff from undrained and drained mires]. Saint Petersburg, Peterburgskii modnyi bazar Publ., 2011, 150 p. (In Russian)
2. Boch M.S., Mazing V.V. *Ekosistemy bolot SSSR* [Mires ecosystems in the USSR]. Leningrad, Nauka Publ., 1979, 188 p. (In Russian)
3. *Bol'shaya sovetskaya entsiklopediya* [Great soviet encyclopedia]. Ed. A.M. Prokhorov. Moscow, Sovetskaya entsiklopediya Publ.,1969-1978. (In Russian)
4. Chugaev R.R. *Gidravlika* [Hydraulics]. Leningrad, Energoizdat Publ., 1982, 672 p. (In Russian)
5. Federal Forestry Agency, Aerial Forest Protection Service (Russia), Volunteer Forest Firefighters Society, Greenpeace Russia. *Spravochnik dobrovol'nogo lesnogo pozharnogo* [Volunteer forest firefighter handbook]. Moscow, 2017, 155 p. (In Russian)
6. Ganzhara N.F. *Pochvovedenie* [Soil science]. Moscow, Agrokonsalt Publ., 2001, 394 p. (In Russian)
7. Grishin A.M. O matematicheskom modelirovanii torfyanykh pozharov [On mathematical modelling of peat fires]. *Vestnik Tomskogo Gosudarstvennogo Universiteta: Matematika i mekhanika* [Tomsk State University Journal of Mathematics and Mechanics], 2008, no.3(4), pp.85-94. (In Russian)
8. Ivanov K.E. *Vodoobmen v bolotnykh landshaftakh* [Water exchange in wetland landscapes]. Leningrad, Gidrometeoizdat Publ., 1975, 280 p. (In Russian)
9. Kats N.Ya. *Bolota i torfyaniki* [Swamps, mires and peatlands]. Moscow, Uchpedgiz Publ., 1941, 399 p. (In Russian)
10. Kornevich I.A., Petrova N.A. *Obvodnenie pozharoopasnykh torfyanikov. Vosstanovlenie bolot vokrug pos. Bol'sheorlovskoe v Borskom raione Nizhegorodskoi oblasti. Pervyi etap: Obvodnenie torfyanogo mestorozhdeniya «Bol'shoe Orlovskoe»: proektnaya dokumentatsiya, vtoroi variant. Obshchaya poyasnitel'naya zapiska* [Rewetting fire hazardous peatlands around the Bolsheorlovskoye town in Borsky District of Nizhny Novgorod region. First stage: rewetting Bol'shoe Orlovskoye peat deposit site: project documentation, second variant. General memo]. Nizhny Novgorod, OOO Vodproekt Publ., 2013, 84 p. (In Russian)
11. Kozhevnikov N.N. *Proektirovanie i stroitel'stvo zemlyanykh plotin* [Design and construction of earthen dams]. Moscow, Izdatel'skie resheniya Publ., 2016, 26 p. (In Russian)
12. Kozulin A.V., Tanovitskaya N.I., Vershitskaya I.N. *Metodicheskie rekomendatsii po ekologicheskoi reabilitatsii narushennykh bolot i po predotvrashcheniyu narushenii gidrologicheskogo rezhima bolotnykh ekosistem pri osushitel'nykh rabotakh* [Methodological recommendations for environmental rehabilitation of disturbed mires and prevention of disruptions in the hydrological regime of mire ecosystems during drainage operations]. Minsk, Al'tiora — Zhivye kraski Publ., 2010, 39 p. (In Russian)

13. Kuz'min G.F. *Bolota i ikh ispol'zovanie* [Mires and their utilization]. Saint Petersburg, Vserossiiskii nauchno-issledovatel'skii institut torfyanoi promyshlennosti Publ., 1993, no.70, 140 p. (In Russian)

14. Maslov B.S. *Melioratsiya torfyanykh bolot* [Peatlands amelioration]. Tomsk, Tomsk State Pedagogical University Publ., 2006, 195 p. (In Russian)

15. *Metodicheskie ukazaniya po kursovomu proektirovaniyu po kursu “Gidrotekhnicheskie sooruzheniya”. Chast' 1 “Proektirovanie gruntovykh plotin” dlya studentov spetsial'nostei vodokhozyaistvennogo stroitel'stva* [Methodological design guidelines as part of the hydrotechnical constructions course. Part 1 "Design of earthen dams" for students of the water construction specialization]. Moroz M.F., Vodchits N.N. (Eds.). Brest, Brest State Technical University Publ., 2007, 37 p. (In Russian)

16. *Metody izucheniya i rascheta vodnogo balansa* [Methods of water balance survey and calculation]. Vuglinskii V.S., Klein G.S. et al. (Eds.) Leningrad, Gidrometeoizdat Publ., 1981, 398 p. (In Russian)

17. *Neishtadt M.I. Metody issledovaniya torfyanykh bolot. Chast' 1. Polevye issledovaniya* [Methods for the mires and peatlands studies. Part 1. Field studies]. Moscow, Narkomat Zemledeliya RSFSR Publ., 1939, 172 p. (In Russian)

18. Nikiforov V.A. *Razrabotka torfyanykh mestorozhdenii i mekhanicheskaya pererabotka torfa* [Peat deposit sites exploitation and mechanical processing of peat]. Minsk, Vysshaya shkola Publ., 1979, 400 p. (In Russian)

19. NKVD USSR, Bureau of the technical report on the construction of the Moskva-Volga canal. *Kanal Moskva-Volga. Torf na stroitel'stve kanala. 1932—1937 gg.* [The Moskva-Volga canal. Peat and the construction of the canal]. Moscow, Leningrad, Gosudarstvennoe izdatel'stvo stroitel'noi literatury Publ., 1940, 189 p. (In Russian)

20. P'yavchenko N.I. *Lesnoe bolotovedenie* [Forested peatland science]. Moscow, Akademiya nauk SSSR Publ., 1963, 191 p. (In Russian)

21. P'yavchenko N.I. *Osnovnye printsipy izucheniya bolotnykh biogeotsenozov* [Basic principles for the mires biogeocenoses studies]. Leningrad, Nauka Publ., 1972, 121 p. (In Russian)

22. P'yavchenko N.I., Kornilova L.I. O diagnosticheskikh pokazatelyakh torfa [On the diagnostic peat indicators]. *Pochvovedenie* [Soil Science], 1978, no.10, pp.146–153. (In Russian)

23. *Perspektivnoe ispol'zovanie vyrabotannykh torfyanykh bolot* [Perspective use of exploited peatlands]. Panov V.V.(Ed.). Tver, Triada Publ., 2013, 280 p. (In Russian)

24. Romanov V.V. *Gidrofizika bolot* [Hydrophysics of mires]. Leningrad, Gidrometeoizdat Publ., 1961, 359 p. (In Russian)

25. Romanova E.A. *Geobotanicheskie osnovy gidrologicheskogo izucheniya verkhovykh bolot* [Geobotanical bases of bogs hydrological survey]. Leningrad, Gidrometeoizdat Publ., 1961, 244 p. (In Russian)

26. Rusetskas Yu. *The impact of ditch berms and slopes vegetation on the state of the forest drainage network. Bolota i zabolochennye lesa v svete zadach ustoichivogo prirodopol'zovaniya. Materialy soveshchaniya* [Proceedings of the “Mires and paludified forests for the purposes of sustainable environmental management” meeting]. Moscow, GEOS Publ., 1999, pp. 278–280. (In Russian)

27. Shchetinskii E.A. *Sputnik rukovoditelya tusheniya lesnykh pozharov* [Handbook for forest fires incident commander]. Moscow, All-Russian Research Institute for Silviculture and Mechanization of Forestry Publ., 2003, 96 p. (In Russian)

28. Shpynev V.N. Self-heating of milled peat in peat piles and ways of slowing it down. *Doklad на simpoziume "Nedelya gornyaka — 2001" v MGGU* [Report at the "Miner's Week — 2001" Symposium at Moscow State Mining University]. (In Russian) Available at http://bit.do/fJSCW (accessed 28 September 2020).

29. Sobol' I.S., Ezhkov A.N., Gorokhov E.N. *Proektirovanie plotiny iz gruntovykh materialov: metodicheskie ukazaniya dlya vypolneniya kursovykh proektov i vypusknykh kvalifikatsionnykh rabot* [Design of earthen dams: methodological guidelines for term projects and final qualifying papers]. Nizhny Novgorod, Nizhny Novgorod State University of Architecture and Civil Engineering Publ., 2010, 91 p. (In Russian)

30. Sobol' S.V., Sobol' I.S. *Derevyannye sooruzheniya v prirodopriblizhennom gidrotekhnicheskom stroitel'stve* [Wooden structures in close-to-natural hydrotechnical construction]. Nizhny Novgorod, Nizhny Novgorod State University of Architecture and Civil Engineering Publ., 2007, 225 p. (In Russian)

31. Spitsyn I.P., Sokolova V.A. *Obshchaya i rechnaya gidravlika* [General and river hydraulics]. Leningrad, Gidrometeoizdat Publ., 1990, 358 p. (In Russian)

32. *Spravochnik po gidravlicheskim raschetam* [Hydraulic calculation reference book]. P.G. Kiselev (Ed.). Moscow, Energiya Publ., 1972, 312 p. (In Russian)

33. Tanovitskaya N.I. *Gidrogeologicheskie i gidrologicheskie osobennosti i sovremennoe sostoyanie vodoreguliruyushchikh sooruzhenii dlya vosstanovleniya gidrologicheskogo rezhima bolota El'nya: otchet* [Hydrogeological and hydrological specifics and the current state of water regulating structures for the restoration of the El'nya Bog hydrological regime: the report]. Minsk, EU/UNDP Project Publ., 2012, 65 p. (In Russian)

34. Ternov A.F. *Gidravlika gruntovykh vod* [Groundwater hydraulics]. Tomsk, Tomsk State University of Architecture and Building Publ., 2010, 63 p. (In Russian)

35. Tyuremnov S.N. *Torfyanye mestorozhdeniya* [Peat deposit sites]. Moscow, Nedra Publ., 1976, 488 p. (In Russian)

36. Voitekhov M.Ya. *Metody vosstanovleniya osushennykh leso-bolotnykh ugodii* [Rewetting methods for drained forested wetlands]. Moscow, 2003, 40 p. (In Russian)

37. Vomperskii S.E. *Biologicheskie osnovy effektivnosti lesoosusheniya* [Biological bases for the effectiveness of the forest drainage]. Moscow, Nauka Publ., 1968, 312 p. (In Russian)

38. Zelenin G.V., Sitnyakov N.M. *Nivelirovanie poverkhnosti po kvadratam: metodicheskie ukazaniya* [Land surface levelling by squares: methodological guidelines]. Tambov, Tambov State Technical University Publ., 2011, 16 p. (In Russian)

Literature original in German or English language

39. Bodenkundliche Kartieranleitung: 5 verbesserte und erweiterte Auflage. Hrsg. von der Bundesanstalt für Geowissenschaften und Rohstoffe in Zusammenarbeit mit den Staatlichen Geologischen Diensten. Schweizerbart Stuttgart, 2005, 438 p.

40. Edom F. Moorlandschaften aus hydrologischer Sicht. In: Succow & Joosten (Eds.): Landschaftsökologische Moorkunde. Schweizerbart Stuttgart, 2001, pp. 185–228

41. Edom F., Wendel D. Moore in Sachsen. Staatsministerium für umwelt und Landwirtschsft (Hrsg.): Naturschutzgebiete in Sachsen. Dresden, 2010, pp. 49–58

42. FAO leads the way to clearer peatland mapping and monitoring. Available at http://www.fao.org/news/story/en/item/1265487/icode/ (accessed 27 September 2021).

43. Joosten H., Clarke D. Wise use of mires and peatlands — Background and principles including a framework for decision-making. International Mire Conservation Group and International Peat Society, 2002, 304 p.

44. Joosten H., Couwenberg J., Moen A., Tanneberger F. Mire and peatland terms and definitions in Europe. In: Mires and peatlands of Europe. Status, distribution and conservation. Joosten H., Tanneberger F., Moen A. (Eds.) Schweizerbart Stuttgart, 2017, pp. 65-96.

45. Kessler K., Edom F., Dittrich I., Wendel D., Feger K.-H. Informationssystem Moore. Erstellung eines Fachkonzeptes für ein landesweites Informationssystem zur Lage und Verbreitung von Mooren und organischen Nassstandorten (SIMON): Schriftenreihe des LfULG 14/2011. Dresden: Textband, 2011, 89 p. & 2 Anlagenbaende

46. Luthardt V., Schulz C., Meier-Uhlher R. Steckbriefe Moorsubstrate, 2. Auflage. Hochschule für nachhaltige Entwicklung Eberswalde (Ed.), 2015, 154 p.

47. Ramsar Information Paper no. 1: What are wetlands? Available at https://www.ramsar.org/sites/default/files/documents/library/info2007-01-e.pdf (accessed 19 November 2021).

48. Schulz C., Meier-Uhlherr R., Luthardt V., Joosten H. A toolkit for field identification and ecohydrological interpretation of peatland deposits in Germany. Mires and Peat, 2019, vol. 24, article 32, pp. 1-20.

49. Schulz C., Meier-Uhlherr R., Luthardt V., Joosten H. Portraits of peatland deposits. HNE Eberswalde, 2019, 95 p.

50. Sirin A., Minayeva T., Yurkovskaya T., Kuznetsov O., Smagin V., Fedotov Yu. Russian Federation (European Part). In: Mires and peatlands of Europe. Status, distribution and conservation. Joosten H., Tanneberger F., Moen A. (Eds.). Schweizerbart Stuttgart, Germany, 2017, pp. 589–616.

51. Steiner G. M. Österreichischer Moorschutzkatalog: 4. Auflage. Bundesministerium für Umwelt, Jugend und Familie. Graz: Verlag Ulrich Moser, 535 p.

52. Succow M. Landschaftsökologische Moorkunde. Gustav-Fischer-Verlag, Jena, 1988, 340 p.

53. Succow M., Jeschke L. Moore in der Landschaft. Urania-Verlag, 1986, 268 p.

54. Succow M., Joosten H. Landschaftsökologische Moorkunde. Schweizerbart Stuttgart, 2001, 622 p.

55. Succow M., Stegmann H. Torfarten. In: Succow & Joosten (Eds.): Landschaftsökologische Moorkunde, kap. 3.1.2. Schweizerbart Stuttgart, 2001, pp. 58–62.

56. TGL 24 300/04 Fachbereichsstandard Aufnahme landwirtschaftlich genutzter Standorte — Moorstandorte. Akad Landwirtsch DDR, Berlin, 1986.

57. Wendel D. Autogene Regenerationserscheinungen in erzgebirgischen Moorwäldern und deren Bedeutung für Schutz und Entwicklung der Moore: diss. Technische Universität Dresden, Fakultät für Forst-, Geo-und Hydrowissenschaften Tharandt, 2010, 232 p.

Recommendations for the Peat Fires Extinguishment in Drained Peatlands: Russian Experience

Edition adapted for global perspective

Authors and contributors:

Dmitrii Isaev is the Head of the Chair of Hydrologic(al) surveyat Russian State Hydrometeorological University (RSHU, St. Petersburg), Candidate of Sciences in Geography.

Nikolai Korshunov is the Head of Forest Pyrology and Forest Fire Protection Department at the All-Russian Research Institute for Silviculture and Mechanization of Forestry (VNIILM), Candidate of Sciences in Agriculture. In 2013 to 2017, Nikolai Korshunov headed the Department of Forest Fire Protection at the All-Russian Institute for Advanced Training of Forestry Leaders and Specialists (VIPKLH).

Sofia Kosacheva is the Head of wildfires program Greenpeace Russia

Mikhail Kreindlin is the Protected Areas Program Head at Greenpeace Russia.

Grigory Kuksin is the Wildfires Unit Head at Greenpeace Russia.

Yulia Petrenko is the Lead Video Producer at Greenpeace Russia in 2019-2020.

Ivan Semenov is the Peatland Rewetting Program Head at Greenpeace Russia in 2018-2020.

Frank Edom is a German hydrologist and peatland scientist. He has been involved in environmental protection, hydrology and geoecology of mires and peatlands as well as mire rewetting for more than 30 years. He cooperates with environmental organizations and non-profit associations in Germany, the Czech Republic, Russia, Ukraine and Belarus. He teaches the “Introduction to mire and peatland hydrology” course at the Dresden Technical University.

Scientific consultant:

Nikolai Zav’yalov is the Head of Science at Rdeisky Nature Reserve and Doctor of Sciences in Biology.

Consultant for the pump/hose lines design:

Mikhail Levin is a volunteer forest firefighter and co-founder of the Volunteer Forest Firefighters Society.

Photo credits:

Maria Vasilieva, Evgenii Grin, Vlad Zalevsky, Pavel Luzan, Natalya Maksimova, Yulia Petrenko, Ivan Semenov, Frank Edom

Illustration credits:
Olesya Volkova, Tatyana Khakimulina

Editor-in-chief of the English edition:
Lyuda Kryuchkovskaya, Managing Director at NGO Wildfire Prevention Center

Editors of the Russian edition:
Oksana Ilyushina, Ivan Semenov, Maria Vasilieva

Picture editors: Maria Vasilieva, Ivan Semenov

Design: Dmitrii Vetrov

Translation and layout: LOGRUS GLOBAL LLC

Proofreading: Kathryn Miller, **independent science consultant, writer, researcher, editor**

DOI 10.35075/GPWFIRE.2022.79.74.001

GREENPEACE

ВИПКЛХ

2022