Dedicated to the 25th anniversary of the closure of the Semipalatinsk Test Site

N.A. Nazarbayev, V.S. Shkolnik, E.G. Batyrbekov, S.A. Berezin, S.N. Lukashenko, M.K. Skakov

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Volume I

London, 2017

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The first volume presents the results of scientific, technical and engineering work to ensure the safety of the former Semipalatinsk Test Site, also known as the *Polygon*, performed between 1994 and the present day by the National Nuclear Centre of the Republic of Kazakhstan, in collaboration with representatives of the United States of America and the Russian Federation. During the course of the work the nuclear testing infrastructure was abandoned and large-scale measures were implemented to mitigate the proliferation risks of weapons of mass destruction and prevent access to nuclear waste within the test site. The results of work on mitigating proliferation risks were given a high rating, as stated in a joint declaration by the presidents of Kazakhstan, Russia and the USA, pertaining to their collaboration at the former Semipalatinsk Test Site, made at the Nuclear Security Summit in Seoul on 27 March 2012.

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From National Tragedy to National Pride!

Nursultan Nazarbayev

The Semipalatinsk Test Site was closed twenty-five years ago. Between 1949 and 1991 the Semipalatinsk Test Site saw 456 tests of all kinds of nuclear weapons, leading to the spread of radiation over a considerable territory. At the moment of its closure, the Polygon covered an area of 18,300 square kilometres, the equivalent of the area of Israel or Slovenia.

After the fall of the Soviet Union a significant quantity of nuclear weapons remained within the sovereign Kazakhstan, including strategic multiple independently targetable re-entry vehicles, long-range bombers and their corresponding atomic and thermonuclear shells. This all amounted to the world's fourth most powerful, deadly potential.

Recognising its global responsibility to the world, Kazakhstan abandoned its nuclear arsenal. Time has come to show that we took the only correct decision that could be made. This historical choice determined our country's future strategy in global security.

From this moment on, the preservation and reinforcement of non-proliferation of weapons of mass destruction became a priority direction in Kazakhstan's domestic and foreign policy.

Kazakhstan was one of the first countries in the CIS to accede to the Nuclear Weapons Non-proliferation Treaty and the Comprehensive Nuclear Test Ban Treaty.

Following our initiative, the United Nations declared 29 August, the date of the test site's closure, as the International Day Against Nuclear Tests.

With the signing of the Treaty of Semipalatinsk by five countries, Central Asia was declared a nuclear-weapon-free zone. This is the first nuclear-free zone to be created in the Northern Hemisphere, in a place where powerful nuclear weapons were once stored and tested.

The next step in the formation of the Global Anti-nuclear Movement was the UN's approval, at the suggestion of Kazakhstan, of the Universal Declaration on the Achievement of a Nuclear-Weapon-Free World. This was evidence of the international community's recognition and support of our country's contribution to reducing nuclear weapons, enhancing global stability and ensuring equal and total security for all.

At the same time, the creation of the IAEA's Low-enriched Uranium Bank in Kazakhstan further demonstrated the considerable contribution made by Kazakhstan into non-proliferation and its status of a reliable partner with extensive experience in handling nuclear materials. The LEU Bank is a unique mechanism for the guaranteed supply of low-enriched uranium to IAEA member states if they are unable to source it on the international commercial market. The joint declaration we signed at the 2016 Nuclear Security Summit in Washington with leaders of a number of foreign states on the IAEA LEU Bank notes that "Kazakhstan has wonderful credentials when it comes to nuclear non-proliferation and world peace".

These historical enactments have shown the whole world our commitment to a world free from the threat of war.

And yet the world is changing and becoming less safe and completely new challenges and threats are coming to the fore. Concern is growing over the proliferation of nuclear weapons, the spread of war and conflict. And now, with the world facing the threat of war, Kazakhstan again confirms that the key tools in politics must be the strengthening of international security, the development of cooperation between nations and the resolution of global problems and conflicts through negotiations. My new MANIFESTO: THE WORLD. THE 21st CENTURY proposes that the world should make "decisive steps towards demilitarisation" and develops a new *PROGRAMME: THE 21st CENTURY: A WORLD WITHOUT WAR*. We can lift the threat of global war if we activate the process of nuclear disarmament, eradicate war and set out a new development trend, based on fair and equal access for all nations to infrastructure, resources and markets. Only through common efforts may we take this decisive step to building a nuclear-free world.

With our extensive experience in non-proliferation it is important like never before to speak today about our collaboration experience and disseminate the practice of using the energy of the atom purely for peaceful ends.

Our wide-ranging work on abandoning the infrastructure and eradicating the consequences of nuclear weapons testing, the conversion of the former defence complex at STS to peaceful ends, the results of scientific and technical collaboration in safe atomic energy and radioecology, a new understanding of the problems of the test site and other aspects, implemented by the Kazakhstan National Nuclear Centre together with our international partners from the USA, Russia, France, the United Kingdom and Japan, represent a colossal achievement for Kazakhstan in building a peaceful and safe world and further confirmation of Kazakhstan's outstanding and unique contribution to non-proliferation, which is expressed not only in the country's active anti-nuclear stance, but in specific deeds as well.

Today it gives me great satisfaction to report that the territory of the former Semipalatinsk Nuclear Test Site is completely free of the consequences of the nuclear activity of the Soviet Union's defence industry infrastructure. By as early as the year 2000, tunnels and boreholes, designed for underground nuclear explosions, were rendered unfit for use as originally intended. Seven major operations were implemented at the three testing areas of the Polygon, which resulted in the partial rehabilitation of the contaminated territory and exclusion of possible access to nuclear waste.

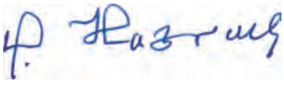
Considerable work has been done to prevent the proliferation of highly dangerous dual-use materials and technologies, decommissioning the BN-350 reactor and relocating spent nuclear fuel to long-term storage at the Baikal-1 reactor facility of the Kazakhstan National Nuclear Centre. This material is currently under an IAEA safeguards guarantee and poses no threat in terms of proliferation.

From a military threat, the Polygon has become a site for scientific research. More than 50% of the Polygon's area has already been examined, with more than 2 million field experiments and more than 100 thousand laboratory tests conducted.

The key means of counteracting the proliferation of highly dangerous nuclear materials has been and remains a reliable system of control and physical protection. It is to this end that a three-level physical protection system has been created at all STS facilities, ensuring reliable security. Secure, physical barriers have been put up to prevent unauthorised access to nuclear waste at 44 facilities.

So, in summarising 25 years of successful operations, it is clear that Kazakhstan has demonstrated a positive example of effective international collaboration in building a safe, stable and prosperous world. I think that the international community should take this opportunity and make use of the methods Kazakhstan has developed, tried and tested to reduce global threats, reinforce the principle of non-proliferation, perform joint scientific, technical and experimental design work, the effectiveness of which have been proven over time.

I believe the publication of this book is both important and timely. Looking at the results of the research of scientists and specialists, highly rated by international organisations, the world must know what the consequences of nuclear weapons are, what and how many resources are needed to eradicate these consequences and what harm can be done to the earth, the people and the environment. These are not unfounded statements, but the results of painstaking research work, the main stages and results of which are presented in this book.



President of the Republic of Kazakhstan

Nursultan Abishovich Nazarbayev

FOREWORD

It is most symbolic for Kazakhstan, which has shown the whole world through its own experience its openness in matters of nuclear disarmament and non-proliferation, that the anniversary of its independence coincides with the 25th anniversary of the closure of the Semipalatinsk Test Site. In this time our country has not only strengthened its own sovereignty, but has become one of the most peace-loving of all nations. Despite all political, social and financial difficulties, the country's President Nursultan Nazarbayev took the only correct decision that could have been made when he closed the Polygon. This decision lay at the heart of independent Kazakhstan's anti-nuclear policy, the relinquishing of te status of a nuclear power, the removal of strategic, offensive weapons from the country and the abandonment of its nuclear weapons infrastructure. From this moment on the country adopted a course of using the Polygon solely for peaceful purposes. As early as 15 May 1992, the President signed the Decree to create the National Nuclear Centre of the Republic of Kazakhstan at the Semipalatinsk Test Site, incorporating the corresponding scientific organisations and facilities located there.

The National Nuclear Centre set about resolving complex scientific and practical tasks for eradicating the consequences of nuclear weapons testing in Kazakhstan, radioecological research, development of the atomic energy industry and other projects. The time has now come to summarise the many years of our work, and this is the purpose of this book. Objective assessment of the scale and degree of radioactive contamination of the natural environment from nuclear testing at the Semipalatinsk Test Site, both atmospheric and underground, yielded results of considerable importance for Kazakhstan, along with the opportunity to develop existing scientific and technical potential for future projects.

It is specifically for this reason that the authors' main objective is the objective assessment of events and work that have been and are to be performed at the former Semipalatinsk Test Site after its closure, which to date have not been properly covered. This objective assessment is based on material from official publications, working reports and documents, which were used in the preparation of this monograph, devoted predominantly to ensuring nuclear and radiation safety, supporting non-proliferation of weapons of mass destruction, abandoning nuclear test infrastructure, transferring Polygon land over to the economy and to the results of research in justifying security for the atomic energy industry.

The preparation of the materials in this monograph used archive data that describe the main events that took place during the time of nuclear testing and a number of nuclear-physics experiments, and also subsequent publications from the *USSR Nuclear Tests* series.

The monograph consists of a preamble, thirteen chapters across three volumes, a conclusion and attachments. Each chapter presents a list of references used.

The first volume of this monograph presents the results of a series of scientific, technical and engineering work, devoted to rendering the area of the former Semipalatinsk Test Site safe. This volume consists of three chapters, which provide information on the creation and the equipment of the Polygon's testing areas, the nature of the Soviet nuclear programmes and the tests conducted, on work to abandon the nuclear test infrastructure and eradicate the consequences after the Polygon's closure.

The second volume presents contemporary data on the radioecological situation at the former Semipalatinsk Test Site, describing the current status concerning radiation at the key, radiation-hazard facilities, the radioecological state of the conventionally *background* areas of the Polygon and the radioecological state of adjacent areas. An evaluation is given of the opportunity and prospects for using the area for industry and farming.

The third volume presents the main results of scientific and research work, conducted at the experimental scientific and technical complex of the National Nuclear Centre, located at the former Semipalatinsk Test Site, during the course of which tasks were addressed, associated with the collection and storage of radioactive waste and ionising radiation sources, the storage of spent nuclear fuel, the conversion of research reactors and justification of security for the atomic energy industry.

The results of 25 years of work, presented in this book, represent the outstanding example set by Kazakhstan in transforming the Polygon from a military threat to a scientific research facility. The scientists and specialists from the National Nuclear Centre have played a particular role in this and have been recognised with awards from this government and from other countries.

The authors extend their heartfelt gratitude to the extensive team of scientists and specialists from the National Nuclear Centre and, primarily, to the Centre's directors at various stages in its history—Erlan Batyrbekov, Yuriy Cherepnin, Shamil Tukhvatulin and Kairat Kadyrzhanov—whose work to a great extent promoted the preservation and enhancement of peace in our nation, a country with high nuclear technologies that acts as a regional leader in the peaceful use of atomic energy.

INTRODUCTION

The decision to create the Semipalatinsk Nuclear Test Site was adopted by the Central Committee of the Communist Party of the Soviet Union and the Council of Ministers of the Soviet Union. By a Resolution enacted on 21 August 1947, the Central Committee of the Communist Party of the Soviet Union and the Council of Ministers of the Soviet Union founded the Mountain Seismic Station (Site 905) which, in 1948 was renamed the Training Ground of the USSR Ministry of Armed Forces and later renamed State Central Research Proving Ground 2. The first divisions of the test site (Military Unit 52605) began redeploying to the new concentration area on 1 June 1948. From 1947 work progressed on preparations for testing. In 1949, at the same time as preparations for facilities and structures for nuclear testing, construction began on a settlement on the banks of the Irtysh River (now the city of Kurchatov), which later became the administrative centre for the Polygon.

Nuclear weapons tests at the Semipalatinsk Test Site, conducted from 29 August 1949 to 19 October 1989 can be split into two stages:

Stage 1 – atmospheric nuclear explosions between 1949 and 1962.

Stage 2 – underground nuclear explosions between 1961 and 1989.

Underground nuclear explosions were both vertical (133 explosions in boreholes) and horizontal (215 explosions in tunnels and entries) for placing explosives (*Table 1.1*).

One underground explosion was performed as part of a Soviet-American experiment (SAE) in 1988, as a joint verification experiment with control using the CORRTEX method.

In addition to nuclear explosions, the test site also completed 175 explosions using chemical explosives. Of these, 44 charges, weighing in at over 10 tonnes, were detonated on the earth’s surface and, to external observers, could have been taken as nuclear blasts.

We should deem the last stage in the operations of the Semipalatinsk Test Site as the period from 1989 to 1991. In 1989 a final series of explosions was conducted, consisting of 7 underground nuclear tests. Since 1989 the test site has not seen a single explosion of any nuclear device.

Following the 29 August 1991 Decree No. 409 of the President of the Republic of Kazakhstan, the Semipalatinsk Nuclear Test Site was closed.

On 15 May 1992, following Decree No. 779 of the President of Kazakhstan, the National Nuclear Centre of the Republic of Kazakhstan (NNC) was founded at the site of the former Semipalatinsk Test Site and the corresponding scientific organisations and facilities within Kazakhstan. The Atomic Energy Institute, Radiation Safety and Ecology Institute, Geophysical Research Institute and Regional Treatment and Diagnostics Centre, all based in Kurchatov, and the Nuclear Physics Institute in the village of Alatau (near Almaty) all formed part of NNC.

The test site became the property of the newly independent state of Kazakhstan. Military Unit 52605, which performed work at the test site, was removed to Russia and the area of the former Semipalatinsk Nuclear Test Site was handed over to the National Nuclear Centre to manage.

Table 1.1. *Key features of nuclear tests, performed between 1949 and 1989 at the Semipalatinsk Test Site*

Type of test	Number of tests (explosions)	TNT equivalent (Mt)	Quantity of radionuclides, discharged into the atmosphere during the test period (mC)		
			^{137}Cs	^{90}Sr	$^{239,240}Pu$
Land-based	30	0.6	0.056	0.035	0.006
Atmospheric	86	6.0	0.200	0.120	0.020
Underground including: in tunnels in boreholes	340 (500) 212 (307) 128 (193)	11.1	~0.020	~0.010	~0
TOTAL	**456 (616)**	**17.7**	**~0.28**	**~0.17**	**~0.026**

Note:
1. *When conducting underground explosions, the number of tests does not correspond with the number of detonated nuclear charges, as one test often detonated several (up to five) nuclear charges.*
2. *The total number of underground nuclear tests includes 7 tests (9 explosions) that were performed for purposes of the national economy, to refine certain technological tasks and develop industrial charges themselves, with minimal power density on account of the fission reaction (up to 5%).*

The period between 1992 and 1994 can be called a time of transition from the destruction of all the test site's structures to the creation of a scientific complex there, the main element of which was NNC. With the creation of this centre, new, extremely complex tasks were addressed at the test site, associated with assessing the consequences of its operations and the search for possible uses of the area for the national economy. A critical and primary stage was the work performed on abandoning the nuclear weapons infrastructure.

CHAPTER 1. CREATION, ACTIVITY AND CLOSURE

The main requirement used as a guide when selecting the site to build the nuclear test site was that it had to be a location with almost no population, one that was expansive and without any farmland. In addition, this region had to be close to at least a minimum of transport links and have the capability of establishing a local airstrip to receive freight aircraft as, not only did a large volume of cargo have to be shipped, but there had to be an active and operational communication set up [1, 2]. According to preliminary calculations, the required diameter for the test site had to be at least 200 km. After protracted searches, given the main requirement, such a region was found in the steppes of Semipalatinsk Region in Kazakhstan.

1.1. General Information about the Test Site

Geography. The area of the Semipalatinsk Test Site is situated on the left bank of the Irtysh River, at the point where the East Kazakhstan, Pavlodar and Karaganda regions all meet and it occupies an area of some 18,300 square kilometres.

The city of Kurchatov is located about 120 km downstream of the Irtysh from Semipalatinsk and the two centres are linked by a railway and a road. The test site stretches from the Irtysh River for 180 km in a south-westerly direction.

Hydrology. Located in the eastern part of the Kazakh hummocky topography, with an arid climate, the test site has no rivers with a continuous flow, apart from the Irtysh, which borders the territory of the test site from the north-east. The hummocky topography contains valley-like relief, associated with a large quantity of salt marshes, saltwater lakes, dry channels of streams and rivers that have run dry. The largest of them is the Tundyk in the west and the Shagan, with its tributary the Ashysu, to the east of the test site. Flood waters of the Shagan reach the Irtysh, while the Tundyk flows into a saltwater, inland lake.

Geomorphology. Geomorphological elements replace one another from north-east to south-west. The key morphogenetic element that determines the overall geomorphological plan is the Kulundinskaya Plain with the Irtysh river valley, which crosses a denudation plain toward the south-west, to the Kazakh hummocky topography with hill-like ridges and conical relief. In an easterly direction, the Kazakh hummocky topography is replaced by mountainous formations of the Altai-Tarbagatai suture-shear country. In the south-west of the area, there is a low-hill terrain with mountain groups, with elevations exceeding 1000 metres. The elevations become smaller towards the Irtysh river valley, up to 200 metres and lower.

Climate. Average monthly temperatures in July range from +19^{o}C to +22^{o}C and in January from -14^{o}C to -18^{o}C, characterising the region's climate as sharply continental. At the same time a change of climate belts is observed from dry (along the Irtysh river valley with average annual temperatures from +0.6^{o}C to +5^{o}C and average annual precipitation of 250–300 mm) to moderately humid (in the mountainous margins of the region, where average annual temperatures range from +1^{o}C to -4^{o}C and average annual atmospheric precipitation reaches as much as 400–600 mm). The heaviest rainfall comes in May to June and October to November. The distribution of wind direction and speed forms a very complex picture in the region. Wind direction and speed change often, even in the course of a single day. Nevertheless, it is noted that in winter and autumn the wind is predominantly south-easterly and, less so, westerly, with an average speed of 4–5 m/s; in summer the wind is mostly northerly with an average speed of 3–4 m/s.

Soil. The soil zoning in the test site is clearly expressed and is dependent upon geomorphological and climatic zoning, with variability in a south-westerly direction. Brown and light-brown soil of the Irtysh river valley is replaced in the direction of the Kazakh hummocky topography with solonetzic soils and then brown and light-brown, low-grade and poorly developed, rubble formations, with sections of low-hill, brown soils.

Landscape. The area of the test site has a plain-like landscape of a dry-steppe and semi-desert type. Within the valley there are several landscape zones, the nature of which is also conditioned by geomorphological and climatic zoning, There is a valley along the Irtysh River with mixed-grass vegetation, such as sheep fescue and feather grass. The Shagan river valley takes the form of an alluvial-proluvial plain with shrub, sagebrush and grain vegetation. Further in a south-westerly direction, the denudation, hill plain with shrub, bunch grass and feather grass are replaced by hummocky topography.

Population. The area of the test site has an extremely sparse population – less than one person per square kilometre. There are no permanent settlements on the test site itself. There are several small settlements, 30 to 60 kilometres from the borders of the test site, with a population of no more than 10,000 people, The principal occupation is of the rural population is livestock farming. Major industrial centres are 100–200 kilometres from the borders of the test site.

1.1.1. Features of the region's geological structure.

The geological structure of the test site area is very complex and has been studied in less detail than the surrounding areas, given the lack of access to the site for research over the long operating term of the test site.

Tectonics. The complexity of the geological structure of the region is determined by its position in an intersection of two major suture-shear structures of different ages: the Chingiz-Tarbagatai Caledonian and the Zaisan Hercynian ages. These folded or suture-shear systems are divided by the deep Kalba-Chingiz Fault, which appears as a zone of broken structures in the low hundreds of metres wide to a few kilometres wide. The Kalba-Chingiz Fault has been an area of intensive tectonic movements over the entire geological history of the region. In addition to the Kalba-Chingiz Fault, the deposits of both suture-shear systems contain a whole number of major faults, mostly facing a north-westerly direction and which divide the structures with different geological histories. The largest of them is the Main Chingiz Fault.

Structure and lithology. The largest and most ancient structure in the region is the Chingiz-Tarbagatai Anticlinorium, which occupies the entire central part of the test site. The rocks of the anticlinorium are jasper-diabase, andesite diabase-basalt, volcanogenic-terrigenous formations of the Cambrian period, carbonate-terrigenous, volcanogenic-terrigenous and continental terrigenous deposits of the

Silurian-Ordovician period. The Cambrian formation is composed of basalt and diabase porphyrites, spilites and bedrock of andesite basalts, red-brown jaspers, shaly aleurolites, less often sandstone, limestone and conglomerates. Deposits of the Silurian-Ordovician formation are predominantly siliceous, calcareous and siliceous aleurolites, quartz-feldspar sands and andesite-dacitic and andesitic porphyrites, their tuffs and lava-breccias.

The Main Chingiz Fault separates another major structure from the Chingiz-Tarbagatai Anticlorium – the Abralin Synclorium, the deposits of which make up the south-western part of the region. Rock of the Silurian-Ordovician formation is more widespread here; of the Cambrian, less so. In terms of the substances they contain, the Cambrian deposits of the Abralin Synclorium are similar to the rock of the Cambrian formation of the Chingiz-Tarbagatai Anticlorium. The Silurian-Ordovician deposits form the axial part of the Abralin Synclorium and are tuffs and lavas of andesite and basalt porphyrites with interlayers of sandstone, aleurolite and conglomerates.

Located in the north-eastern part of the test site, adjoining the Chingiz Tarbagatai Mega-anticlorium, is the Zharmin Synclorium and the Char suture-shear zone, which are comprised of sedimentary and sedimentary-volcanogenic rocks of the Middle and Upper Devonian (andesite porphyrites and their tuffs, sandstone, aleurolite, jasper and basalt porphyrites) and of the Carboniferous period (polymict and quartz-feldspar sandstone, conglomerates, gritstone, carbonaceous-argillaceous, carbonaceous-siliceous and siliceous aleurolites, calciferous sandstone and limestone).

As a result of intensive tectonic movements, the deposits of both suture-shear zones are crushed into various, often steep, folds, with many fractures and manifestations of intrusive activity, which led to the formation of rock blocks, predominantly of a north-westerly orientation with an anisotropy of physical and mechanical properties.

Magmatism. The region is characterised by the widespread development of effusive and intrusive magmatism. Intrusive magmatism is mostly manifested within the Chingiz-Tarbagatai Anticlorium, where the largest mountain groups are formed (up to 2,500 square kilometres) of the Silurian, Devonian and Permian periods. They appear as a broad band of rock from gabbro to granitic, while they are mostly granites and granodiorites.

Covering deposits. In the north-eastern part of the region Palaeozoic formations are covered by Neogene-Quaternary and Palaeocene arenaceous-argillaceous sediments of the southern, outer part of the Irtysh depression and, universally, by Quaternary clay loam and sand. The thickness of the Quaternary sediments in the lowlands of the relief reaches 10 to 20 metres, while the Neocene-Palaeocene bedrock grows in a north-easterly direction (into the Irtysh depression) up to tens and hundreds of metres.

1.1.2. Hydrogeology.

The Semipalatinsk Test Site is located in an area with fresh and salt water with mineralisation of up to 3 g/L, rarely more. The subsurface water of the region can be divided into water of Neocene-Palaeocene sediments, ground water of Quaternary sediments and fissure vein water of Palaeozoic formations.

Head water. The north-eastern part of the region is the southern edge of the Ishim-

Irtysh artesian basin, bordered in the south by the Kazakh hummocky topography and in the east by the Altai-Tarbagatai mountainous suture-shear region. Palaeocene-Neocene and Neocene-Quaternary sediments with bedded, confined aquifers make up the area of the Irtysh river valley, overlapping Palaeozoic formations and making up the valleys of the Tundyk and Shagan rivers. The aquifers of Palaeocene sediments are fine-grain sand from 5 to 30 metres thick and lying at depths of up to 50 or 60 metres. Flow rate reaches 10–20 L/s. The water is mostly fresh, hydrocarbonate-sodium-sulphate with mineralisation up to 1 g/L. In the Neocene-Palaeocene sediments, sand-gravel aquifers up to 10–25 metres thick lay at depths of up to 30–40 metres, with a flow rate of up to 2–15 L/s. The water is fresh (0.5 g/L) and has a hydrocarbonate-sulphate-calciferous composition.

Fissure vein water. Palaeozoic formations on exposed sections, especially in the south-western part of the site, are characterised by a fairly broad spread of fissure vein water with a hydrocarbonate-calciferous composition with mineralisation up to 1 g/L. Flow rate of the springs reaches 0.2–0.5 L/s. The main subsurface water catchment basins are in the zones of the region’s mountainous margins. The general flow of the subsurface water is in a north-easterly direction, deep into the Ishim-Irtysh artesian basin. The local sites for discharge and drainage are small lakes and non-gravity springs in the lowlands of the relief which, as a consequence of evaporation, often become solonetzic soil.

Ground water. The Quaternary sediments that hold the groundwater aquifers are spread across the entire region and contain levels of sand up to 10–15 metres thick, with fresh water and a flow rate of up to 1 L/s.

1.2. Main Stages in Construction and Equipment of Test Site Facilities

From the time of the first geodetic surveys in the chosen region, the second period in creating the USSR’s nuclear shield began. That said, the determination of this moment is, of course, used figuratively, as preparations for testing the first nuclear charge began almost at the same time as the development of the charge itself. Pursuant to the August 1947 Resolution of the USSR Council of Ministers and Central Committee of the Soviet Communist Party, the test site was named the Mountain Seismic Station or *Site 905* for field tests of nuclear weapons.

The design work for equipping the Experimental Field of the test site, as well as other sites, needed for its successful functioning, was performed under the requirements specifications of the Chemical Physics Institute at a special design institute of the First Main Department under the Council of People’s Commissars, GSPI-11. A number of outstanding scientists worked at the Chemical Physics Institute, including David Frank-Kamenetskii, Yulii Khariton, Yakov Zel’dovich, A.F. Belyaev, Alfred Apin, Boris Stepanov and others.

In accordance with the programme, the test site was to have a complex, extensive structure with all the vital elements needed, a scientific and technical basis to meet the requirements of the day and a considerable volume of knowledge and facilities, located at various facilities within the area of the test site. Construction of the test site was started by engineer corps of the Armed Forces. The first group of construction workers, officers of the 36th Defence Construction Division, arrived at the future test site, a steppe land devoid of people, in September 1947. Military units were formed, survey work and the design of the site's facilities were conducted all simultaneously.

In 1948 Site 905 was renamed Training Ground No. 2 of the USSR Ministry of Armed Forces and later, State Central Research Proving Ground No. 2. Thereafter it became known as the Semipalatinsk Test Site (STS).

The test site, or Polygon, reported directly to the Special Department of the General Headquarters of the Armed Forces. It is worth noting that a number of different specialist organisations were engaged in designing facilities at the test site. Technological and instrument structures at the Experimental Field, the construction of facilities to house experimental animals, creation of a power supply system for the instrument structures, laboratories and a residential camp complex, power facilities, water supply and road building were all performed by a specialist design institute in Leningrad (GSPI-11). The experimental fortifications were designed by a specialist design office of engineer corps, while the airfield structures were designed by the Central Design Institute of the Air Force.

The central command of the test site and its divisions were responsible for managing the work at the test site's facilities and their acceptance into operation. The first person to be appointed director of the test site was Lieutenant-General of the Artillery Petr Rozhanovich, who had commanded an artillery corps during the Second World War.

Those involved in the nuclear tests know that the test site was an enormous and complex facility, which included three main zones: the Experimental Field, staff facility and administrative centre. The Experimental Field, which housed various testing areas and instrument structures, occupied a territory which is visibly an almost perfect circle, measuring 20 km in diameter. A safety buffer zone circled the Experimental Field, covering about 45,000 square kilometres. The staff facility, marked *Sh* was constructed 14 km to the north-east of the Experimental Field centre (*Figure 1.1.*). It was designed for the temporary location of test staff, issuing personal protective clothing and dosimeters, performing sanitary treatment and decontamination procedures.

Some 60 km to the north-east of the Experimental Field, on the banks of the Irtysh River, the construction of a residential and administrative centre (marked *M*) began at the same time as erection of the test facilities. This centre was to later become the city Semipalatinsk-21 and today it is the city of Kurchatov. At one end of the residential zone, a site (*A*) began to be built, which consequently became a military encampment, housing numerous military units, vehicle pools and other support facilities. At another end of the residential zone, along the road to the Experimental Field, construction work began on site *O*, the experimental and scientific part of the test site (Sector No. 5) with laboratory buildings. Today this is the location of the National Nuclear Centre and its branch, the Radiation Safety and Ecology Institute, which forms part of NNC. An airfield was built near to site *O* with an unpaved runway and this airfield became the base for transport aircraft and helicopters.

The building of the test site headquarters was erected at site *M* on the banks of the Irtysh River, a two-storey cottage for the test site director, where Lavrentiy Beria and his security guards would always stay when visiting the test site, the Officers' House, hotels and other vital facilities for the soldiers, officers and their families and those involved in the testing.

During the nuclear tests, both atmospheric and underground, site *M* (Kurchatov) always remained the central zone of the test site, as it was the location of the test site's directorate, its experimental and scientific base and the residential and barracks facilities. The city covered a total area of 3200 hectares.

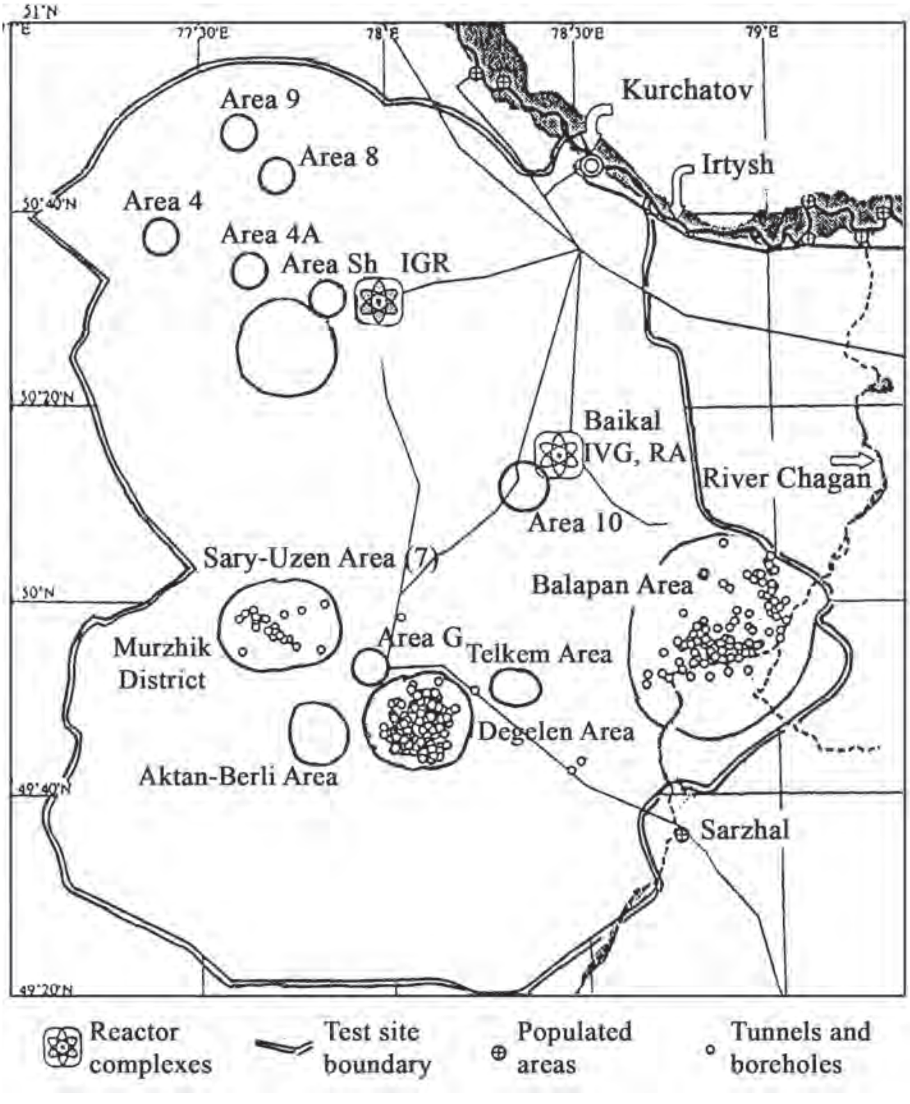


Figure 1.1. *Location of facilities at the Semipalatinsk Test Site*

Site *N* was equipped near the Experimental Field, around its eastern radius, from where a good view was afforded over the facilities of the Experimental Field. For this reason it was decided to construct a command point as well as several facilities for the nuclear weapons developers.

The scientific management of all matters pertaining to preparing the test site for nuclear weapons tests, from 1948, was performed by Deputy Director of the Chemical Physics Institute of the USSR Academy of Science Mikhail Sadovskiy.

In the harsh winter months of 1947–1948 the number of military personnel (Special Construction Department 310, or SCD-310) exceeded 9,000. The basic arrangement of the construction organisation and the location of a number of ancillary bases and workshops appeared as follows:

- the base depot was situated on the outskirts of Semipalatinsk, near the station of Zhana-Semey, to where trains with equipment, preassembled structures, materials, provisions and so on would arrive. Ancillary shopfloors were built here as well, to manufacture fixtures and casing, joinery and slag blocks, which meant that qualified workers could be engaged from Semipalatinsk;
- the mechanics base, repair workshops, the vehicle park and the construction administration itself were located in the test site's residential construction zone (site *M*);
- concrete and cement preparation installations were assembled at each site of the Polygon;
- provision was made for using the navigable Irtysh River to transport oversize structures and heavy freight from the base depot to site *M*, where berthing and unloading facilities were erected;
- the main unsurfaced roads were maintained in a passable condition in any weather, all through the year, which required considerable effort on the part of the construction workers.

A considerable volume of the work, associated with the construction of complex and varied facilities, and the fact that there was no qualified workforce near to the production base made the task facing the test site's managers and builders incredibly difficult. The working conditions for the builders were very tough, especially in the first winter of 1947–1948. All these issues simply had to be addressed from scratch. The endless, desert-like steppes, the hurricane-force winds and fierce winter blizzards, the hot winds and dust storms in summer, the sharp change in weather and temperature, the lack of quality potable water, especially in the Experimental Field, where up to 50% of the construction personnel were working, the complete lack of main roads, power lines and communications near all the facilities (areas) at the test site all affected the speed of the construction.

In winter many soldiers and officers suffered from frostbite and some even had fingers and toes amputated. For almost two years the soldiers and officers had to live in tents and dugouts. The builders operated at all sites in two and three shifts. In a word, the living conditions differed little from those at the front lines: the same dugouts, monotonous camp food, rationing of food and clothing, living away from the family and strict conditions. Every letter written bore a stamp, reading *Passed military censorship*. Therefore, the construction of the test site, on which, in fixed, pre-war prices the sum of 183 million roubles was spent, can easily be rated among the nation's heroic achievements.

With the coming of the spring of 1948, construction work got underway simultaneously at all areas of the test site and the work rate picked up considerably. Construction of the larger facilities at the Experimental Field, the test site's main facility, notably accelerated.

The summer months of 1949 were especially tense. Construction work on all facilities at the Experimental Field was coming to an end and the equipment and instrumentation were being installed simultaneously. The test site command was completing the formation of divisions and the training of the staff in the operating rules for the instrument structures. In addition, it obliged the operations specialists to monitor the construction of various facilities and to take part in their initial acceptance from the builders and the trials of the engineering systems, equipment and so on.

In order to determine the unequivocal readiness of the testing areas for the appointed deadline for the tests (August 1949), a commission arrived at the test site, headed by the Head of the Special Department of the General Headquarters Alexander Osin. Together with the Capital Construction Department and the construction management (SCD-310), the commission reviewed the volume of work on the construction of the priority facilities and specified a fixed launch deadline. The volumes of building work on barracks and residential buildings were cut, limiting work to building unsurfaced roads, and other restrictions and simplifications were adopted. This decision was clearly justified under the specific circumstances. The launch deadline was approved by Marshal of the Engineer Corps Mikhail Vorobiov. He set the strict schedule and sequence for the handover to the customer, primarily referring to the facilities of the Experimental Field.

At the moment of its closure, the Semipalatinsk Test Site was a complex scientific research facility, consisting of the following elements:

The Experimental Field (P) – a site in the north-west of the test site, covering a total area of about 300 km^2. It was used to conduct atmospheric nuclear charge tests (atmospheric and land-based explosions). The main work was performed to perfect the nuclear weapons, to research emergency operating modes of the nuclear weapons and to study the adverse factors of the nuclear weapons;

Degelen (D) – an area in the south of the test site for underground tests in tunnels (horizontal mines) within Degelen Mountain, covering a total area of 331 km^2. As a rule, it was used to conduct low-yield tests (no more than tens of kilotonnes), to perfect the nuclear weapons, study emergency operating modes of the nuclear weapons and to resolve issues concerning materials science, the radiation resistance of materials, investigate how the radiation interacts with the substance, refine the techniques for recording nuclear explosion parameters and so on;

Balapan (B) – an experimental area in the south-east of the test site, on the left bank of the Chagan River. Total testing area: 100 km^2. It was used to conduct underground tests in boreholes (vertical mines) up to 120 kilotonnes and individual tests up to 150 kilotonnes. The main work at this site was performed to perfect the nuclear weapons;

Sary-Uzen, Murzhik (S) – an area in the steppes in the south-west of the test site. Total area: 500 km^2. It was used to perform underground tests in boreholes;

Telkem (T) – an area in the south of the test site. It was used to perform underground tests in boreholes;

Area No. 10 – the Baikal reactor complex (site No. 300); Area *Sh* – IGR reactor complex (site No. 100).

Residential settlements and engineering complexes for maintenance and storage of equipment:

Point *M* – the city of Kurchatov, the former administrative centre of STS and the location of the experimental and scientific part;

Point *G* – the base camp for the test specialists, mining, construction and installation organisations that performed the work at the Degelen Area;

Point *Novy Balapan* – the base camp for the test specialists, drilling, construction and installation organisations that performed the work at the Balapan Area;

Point *Sh*– a residential settlement for those involved in the atmospheric tests at the Experimental Field and the IGR reactor complex personnel;

Residential settlement for the Baikal reactor complex personnel;

Point *N* – a set of stationary structures to locate measuring instrumentation and control apparatus for atmospheric tests;

Engineering facilities for assembling and storing the nuclear charges were located at points *M*, *G*, *Novy Balapan* and *N*, while the Airfield was located at point *M* (Kurchatov).

The test site had a well-developed infrastructure: a railway, linking Kurchatov with the city of Semipalatinsk and the Balapan Testing Area, a network of surfaced roads, water mains, power and communication lines.

1.3. Main Testing Areas and Facilities

Land-based and atmospheric tests were performed within the Experimental Field [3].

Underground nuclear tests, the first of which was performed on 11 October 1961 and the last, on 19 October 1989, were performed predominantly at three operational areas of the test site:

- the Degelen Area, the total area of which within Degelen Mountain stood at 33,100 ha, was used for underground explosions in tunnels (horizontal mines);
- the Balapan Area, with a total area of about 100,000 ha, was used for underground explosions in boreholes;
- the Sary-Uzen (Murzhik) Area – this was an ancillary area for underground explosions in boreholes.

1.3.1. Experimental Field Testing Area

The Experimental Field was the first testing area of the Semipalatinsk Test Site and was designed for land-based and atmospheric tests between 1949 and 1962. The area was a plain, measuring some 20 km in diameter, surrounded on three sides (the south, west and north) by small mountains. In the east of this kind of valley were small hills [4]. The Experimental Field had an area of about 300 km^2 with a perimeter of 64 kilometres (*Figure 1.2*). The first test of a nuclear device in this area was performed at 7 am local time on 29 August 1949. The first thermonuclear device was tested on 12 August 1953 and the first hydrogen bomb, on 22 November 1955.

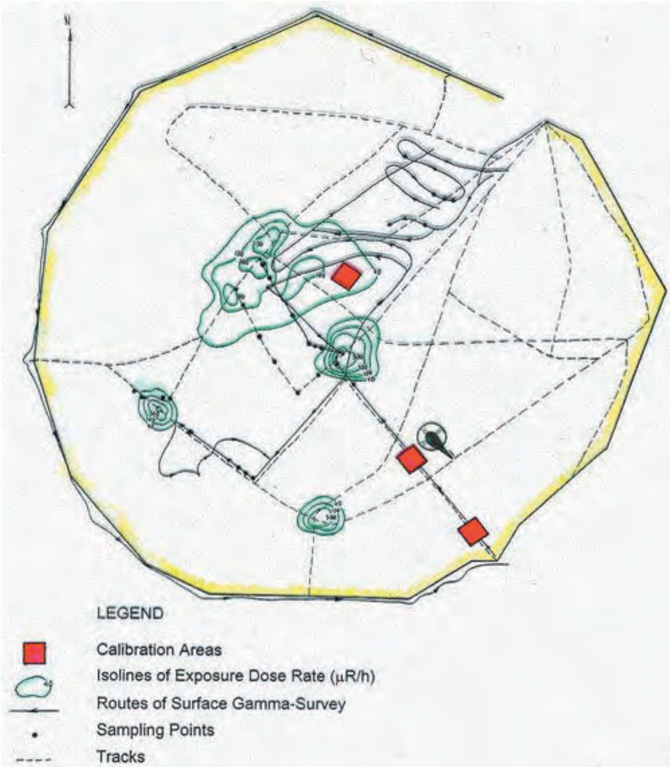


Figure 1.2. *Experimental Field (atmospheric nuclear explosions)*

The Experimental Field was a large-scale complex of engineering and construction facilities, designed for testing and recording the parameters of nuclear blasts in conditions of a field experiment. Individual fragments of instrument and fortification structures remain to this day, with traces of the effect of a nuclear explosion. The centre of the Experimental Field houses a place for running a number of tests, including the very first: the epicentre. The first nuclear device was placed on a 30-metre metal tower. The power of the nuclear charge calculated as the equivalent of a regular explosive (TNT) stood at 20 kilotonnes. In future, this same place was used for two further tests: on 24 September 1951 and 12 August 1953.

The last nuclear test in this area was performed on 24 December 1962 and it was a land-based explosion of just 28 tonnes of TNT equivalent, used to study the possible emergency modes that may arise when using a nuclear weapon. The Experimental Field was used not only for nuclear tests but also for model, non-nuclear explosive (hydronuclear and hydrodynamic) experiments. The last such experiment was conducted on 12 August 1965 at the technical area P-2G of the Experimental Field. Thereafter, all hydronuclear experiments were transferred to other areas [5, 6]. This was when the Experimental Field actually ceased to be used for various kinds of nuclear experiments. A diagram showing the locations of the key testing areas of the

Experimental Field and conventional coordinates are presented below (*Figure 1.3, Table 1.2*).

Table 1.2. *Conventional coordinates of the Experimental Field testing areas [7]*

Coordinates	Quantitative characteristics of area coordinates relative to P5 (km)						
	P5	**P1**	**P2**	**P3**	**P6A**	**P7**	**N**
x	0	4.2	4	-2.3	11.5	5.7	14
y	0	-2.2	-9	-4.2	-8	-8.6	-1.6

It is noteworthy that from the very start of operations at the Experimental Field, its area was enclosed by wire fencing and was guarded by the staff of four troop companies, united in a special security battalion. There were 12 outposts around the perimeter of the field, each with a permanent station. During the day the security was provided from two observation towers, connected with telephone communication and field telephones. At night, guards would patrol in pairs to both sides of the outpost. Monitoring the wire fence attentively, they had to patrol to the boundary of the neighbouring security outpost and exchange tokens with the patrols of that neighbouring outpost. Troop company officers would monitor the work of these patrols. There was also an all-round perimeter defence near the outposts, with trenches dug to full height. All soldiers and officers lived in dugouts [2, 8].

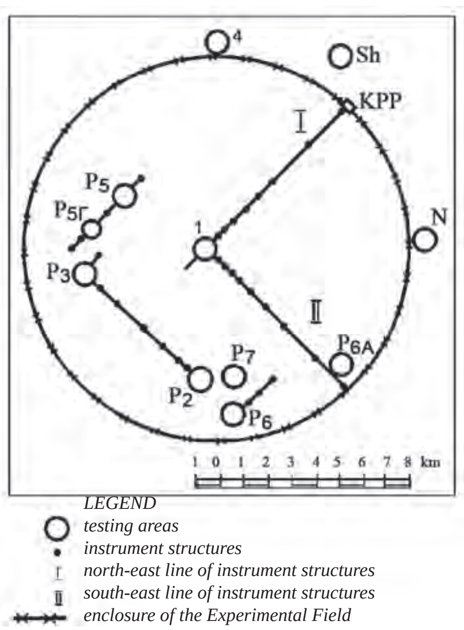


Figure 1.3. *Main testing areas and instrument structures of the Experimental Field*

Details on the scale and degree of radioactive contamination of the regions in the affected area of the nuclear tests became available only in the 1990s [9, 10 and others]. The traces of fallout from the radioactive cloud that formed after an explosion, which remained in the Experimental Field, represent areal sources of ionising radiation. Areas are fitted with equipment on these traces for calibrating aircraft-based radiometric devices, used for environmental protection research in Kazakhstan and CIS countries. A total of 30 land-based and 86 atmospheric nuclear explosions were performed at the Experimental Field.

1.3.2. Degelen Testing Area

The Degelen Area, located in the mountain range of the same name, was the site of underground testing in horizontal mines, or tunnels (*Figure 1.4*).

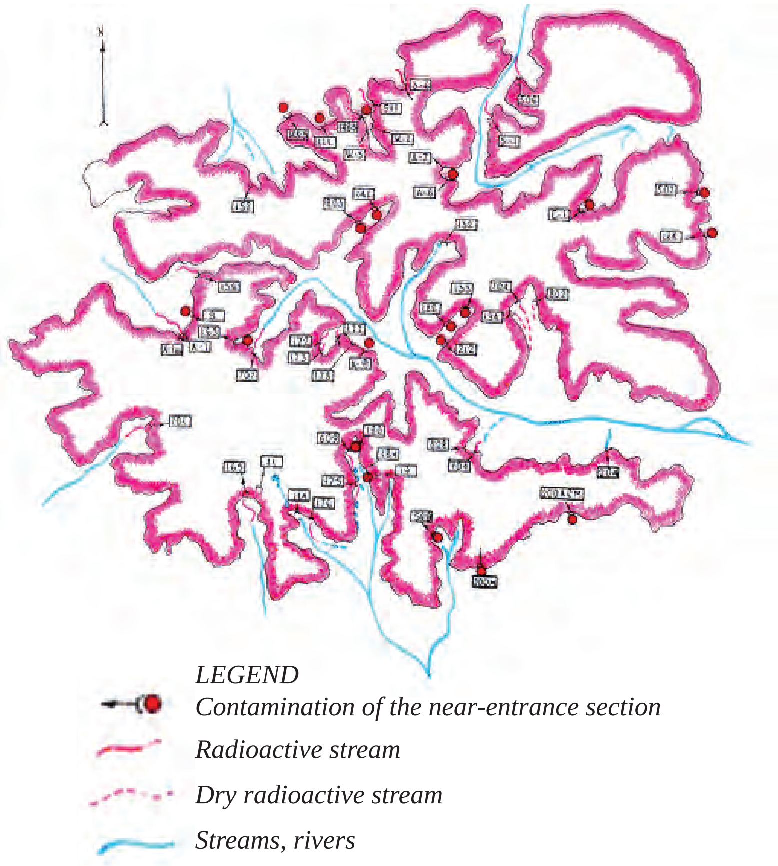


Figure 1.4. *Degelen Mountain (underground nuclear explosions in tunnels)*

By 1991, 181 tunnels had been made at Degelen Mountain, with a cross-section measuring from 9 to 25 square metres and from 300 and more metres long. Nuclear tests were performed in 163 mines.

The nuclear charge was placed at the end of the tunnel, in a specially equipped box. To prevent the escape of fission products onto the daylight area, the tunnel was fitted with a special plugging system, a combination of cement plugs and crushed rock backfilling. Measurement instrumentation was placed either inside the tunnel or at the near-entrance site before the entry to the tunnel.

In the period from 1961 to 1989, 213 nuclear tests were performed in tunnels within Degelen Mountain (295 underground nuclear blasts).

1.3.3. Balapan Testing Area

Underground nuclear blasts in boreholes were performed at the Balapan Area (*Figure 1.5*). A borehole is a vertical mine, partially cased by pipes of varying diameter; below – an open shaft with a diameter of up to, but rarely more than, 900 mm. The borehole depths varied from 240 to 500–600 metres.

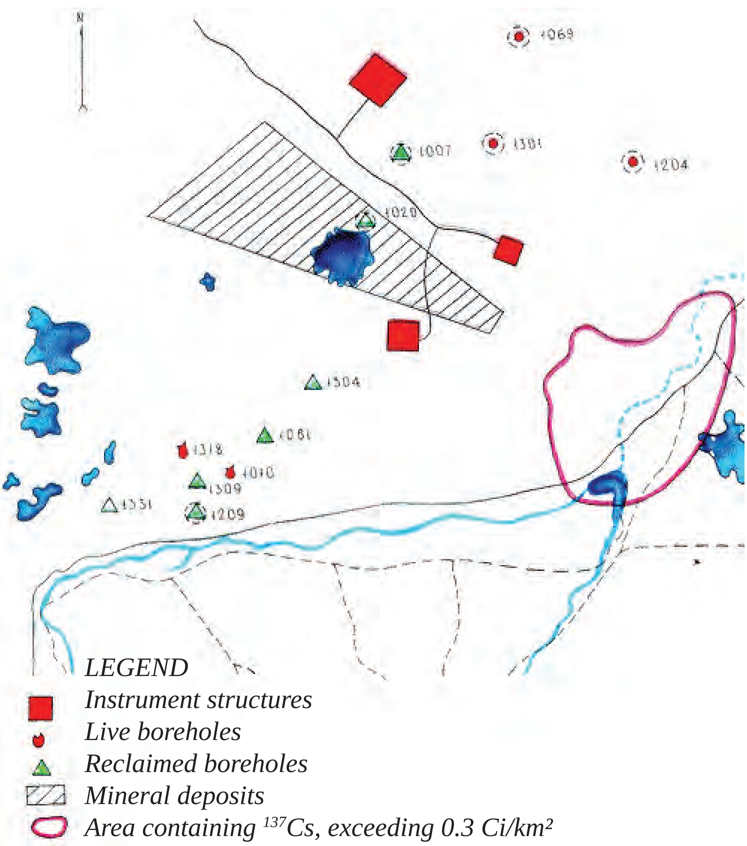


Figure 1.5. *Balapan Testing Area (underground nuclear explosions in boreholes)*

The test charge was lowered to the bottom part of the borehole on a special lowering string. Suspended instruments were lowered into the borehole together with the charge, fitted with sensors to measure the blast parameters. Measurement instrumentation was located on the surface, in mobile systems, held at a safe distance from the emplacement hole. Once the charge was lowered, the borehole would be plugged to full depth. The plugging system design involved a combination of power-operated and process elements: cement plugs and sections of crushed rock backfilling.

In 1965, an artificial reservoir was formed at the Balapan Area, at the confluence of the Chagan and Ashchi-Su rivers, known to the local population as the *Atomic Lake*, which was formed as a result of the ejection of soil during an underground nuclear blast of a TNT equivalent of 140 kilotonnes [2].

Pursuant to the 3 July 1974 Treaty on the Limitation of Underground Nuclear Weapon Tests underground nuclear tests were performed on 17 August 1988 at the test site in Nevada, USA and on 14 September 1988 at the Semipalatinsk Test Site (the Balapan Area) to develop effective measures to monitor performance of the Treaty between the USSR and the USA. For the first time mutually controllable benchmark values were obtained for the parameters of underground nuclear explosions.

In total 105 nuclear explosions were made in boreholes at the Balapan Area. The last underground nuclear explosion at the Semipalatinsk Test Site was made in one of the boreholes at the Balapan Area on 19 October 1989.

Underground nuclear tests were also conducted at the Sary-Uzen, Murzhik and Telkem areas.

Between 1965 and 1980 underground nuclear explosions were conducted in 24 boreholes at the Sary-Uzen Area. A further underground nuclear explosion was conducted at the Murzhik Area, in the immediate vicinity of the Sary-Uzen Area. Two underground nuclear tests were conducted at the Telkem Area with soil discharge: a single explosion, Telkem-1 and a group explosion, Telkem-2.

In the period from 1968 to 1989, a total of 131 nuclear tests were performed in tunnels at the Semipalatinsk Test Site (196 underground nuclear blasts).

1.4. Final stage of operations and closure of the test site

The final stage of operations at the Semipalatinsk Test Site should be seen as falling between 1989 and 1991.

Information on the concluding series of tests there in 1989, when Kazakhstan was still part of the Soviet Union, may be of undoubted interest.

In 1989, underground nuclear tests in the Soviet Union were conducted exclusively at the Semipalatinsk Polygon, while the Novozemelsky Polygon remained “silent”. In a series of 7 tests in tunnels at the Degelen Area and in boreholes at the Balapan Area, STS detonated 11 nuclear charges, the force of which, according to official, recorded data, ranged from 0.001 to 150 kilotonnes. *Table 1.3* presents data that describe the underground nuclear test, conducted at STS in 1989 [13].

Table 1.3. *Brief description of nuclear tests, performed at STS in 1989, the final year of its operation*

Nuclear test catalogue number [1] and the date it was performed	Venue	Force (kt TNT)	Note
708, 22 Jan 1989	Balapan, borehole 1328	0.001–20 20–150	
709, 12 Feb 1989	Balapan, borehole 1366	20–150	Radiation from the flow of radioactive gases was recorded in the settlements of Chagan and Komsomolsky. This generated a negative reaction among the local population in the Semipalatinsk region.
710, 17 Feb 1989	Degelen, tunnel 139	0.001–20	This test was the reason for an even more negative view of nuclear testing at STS.
711, 8 Jul 1989	Balapan, borehole 1352	20–150	Representatives of the Nevada-Semipalatinsk anti-nuclear movement and the press were present at the testing.
712, 2 Sep 1989	Balapan, borehole 1410	0.001–20 0.001–20	Representatives of the Nevada-Semipalatinsk movement are outraged by the testing, calling it a “gift” to the schoolchildren, returning to their classes after the summer holidays.
713, 4 Oct 1989	Degelen, tunnel 169 / 2	0.001–20	The USSR Defence Ministry held a press conference in Moscow for domestic and foreign journalists following this test.
714, 19 Oct 1989	Balapan, borehole 1365	20–150 0.001–20 0.001–20	TASS reported that this test, with a force of from 20 to 75 kt, as the last at STS in 1989. This test was indeed the last to be performed at STS in the history of its operation.

1.5. The nuclear heritage of the Republic of Kazakhstan: nuclear weapons, Semipalatinsk Test Site and “Atomic Conversion” [11–14]

The fall of the Soviet Union was a unique event in the history of international relations as a whole and in the non-proliferation of nuclear weapons in particular. This was the first time that a nuclear state had collapsed, so the situation that unfolded after such an unprecedented event, both in the country and across the world, was difficult and was characterised by a number of factors, particularly in reference to the following:

- the post-Soviet states’ lack of real conflicts in power, in relations between themselves and in relations with other world states, who had demanded the use of military force, which led to nuclear weapons losing their value as a tool to maintain stability in intergovernmental relations;

- the high degree of involvement of developed industrial nations in carving up the “Soviet legacy” in nuclear terms, which affected not only the fate of the nuclear weapons themselves, but also the technological knowledge that had been accumulated in the nuclear weapons industry;
- the continual process of negotiations on the legal status of the nuclear infrastructure, equipment and various facilities, located outside the Russian Federation.

It should be noted that in 1992–1994 there was a risk, and one that even intensified, of the broader proliferation of nuclear weapons as a consequence of the disintegration that was ongoing in the former USSR. It was only after the end of 1994 and into early 1995 that the risk began to diminish; to a great extent this was promoted by the establishment of national systems for monitoring nuclear exports in Kazakhstan, Ukraine and Belarus and also the adoption of IAEA safeguards guarantees by these countries.

Even before the collapse of the USSR, Soviet military figures, as if anticipating the possibility of such an event, grouped the key tactical nuclear ammunition within Russia, Ukraine and Belarus, which helped considerably reduce the threat of nuclear proliferation. However, not everything went smoothly: certain political forces tried to hamper the nuclear weapons non-proliferation process by force. In 1990, after the well-documented events in Baku, the removal of nuclear ammunition from Azerbaijan was seriously complicated by an attempt on the part of certain forces, associated with the Azerbaijani Popular Front Party, to hinder this process. The runway at one military airfield was blocked by a group of people, who prevented aircraft from taking off. The situation was so tense that crews were forced to use weapons. Fortunately, after shots were fired, the crowd dispersed, the matter was resolved without casualties and the aircraft were able to leave.

The main problem, however, was the presence of the strategic nuclear arsenal of the Soviet Union in these newly formed sovereign states of Russia, Belarus, Kazakhstan and Ukraine. The fate of these weapons was the focus of attention for the political circles of most countries around the world and, particularly, of the USA and Russia. All manner of the most varied issues came to the fore. Here are just some of them:

- how to ensure the security of nuclear weapons;
- how to maintain uninterrupted accounting and control over nuclear materials in accordance with international standards;
- how to avoid the expansion of the “nuclear club” and ensure that Kazakhstan, Ukraine and Belarus acceded to the Nuclear Weapons Non-proliferation Treaty;
- how to prevent the leakage of sensitive information, associated with nuclear weapons, from the nuclear states;
- how to ensure complete and unequivocal continuity in observance of the former USSR’s obligations in the non-proliferation of weapons of mass destruction (WMD), of nuclear weapons in particular;
- how to ensure the application of the IAEA safeguards guarantees to nuclear facilities, located within the CIS.

In 1992, nine countries of the CIS (Armenia, Belarus, Kazakhstan, Kyrgyzia, Moldavia, Tajikistan, Uzbekistan and Ukraine) officially reported that they supported Russia’s involvement in the Nuclear Weapons Non-proliferation Treaty as a state with nuclear weapons and they were prepared to accede to this Treaty as non-nuclear nations. This was how the matter of continuity was resolved in legal terms, while the Russian Federation became the legal successor of the USSR as regards ownership of nuclear weapons.

So how many nuclear weapons were there in Kazakhstan? Documents bear witness to the fact that, by December 1991, when Kazakhstan declared its independence, it held 1,410 strategic nuclear warheads, installed on various carriers, including on 104 silo-based RS-20 (or SS-18 missiles under the American classification), located at missile bases in Zhangyz-Tube and Derzhavinsk. In addition, the settlement of Chagan housed a group of strategic Tu-95 bombers, equipped with cruise missiles.

In 1994 Kazakhstan became a fully-fledged party to the Nuclear Weapons Non-proliferation Treaty, with non-nuclear status. The security of operations at all facilities of civilian nuclear infrastructure, which include research nuclear reactors and other civilian facilities, is guaranteed by the IAEA. By April 1995, the last nuclear warhead had been removed from Kazakhstan and taken to Russia.

It is worth noting that the nuclear weapons non-proliferation measures taken by Kazakhstan's leaders almost completely excluded any threat that could create an uncontrolled collapse of the once powerful Soviet nuclear weapons industry to the detriment of international relations.

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CHAPTER 2. ABANDONMENT OF NUCLEAR TEST INFRASTRUCTURE

2.1. Start of work on demilitarisation of the Semipalatinsk Test Site

On 24 September 1993, according to the joint Protocol of Intent between the governments of the USA and Kazakhstan, a group of specialists from these two countries was assembled to perform a preliminary study of the harm caused to the Kazakh population and economy by the nuclear tests at the former Semipalatinsk Test Site. A group of specialists from the USA, headed by the former head of the Nevada test site Don Linger, arrived in Kurchatov, the home of the General Directorate of NNC, on 9 November 1993. Linger expressed the wish that Russian specialists should also be involved in this work. This suggestion was accepted. This group of specialists, which included the experts Yu.V. Dubasov, V.A. Logachev, A.M. Matushchenko, A.K. Chernyshev and others who had been involved in the nuclear tests at this site, was headed by Russian Academy of Science Academician Yu.A. Trutnev from VNIIEF (Russian Federal Nuclear Centre).

During this trilateral meeting at NNC, reports and information were heard from former operatives of the Semipalatinsk Test Site, as well as experts from Russia, Kazakhstan and the USA. This meeting was to mark the start of further collaboration between the three parties on a whole range of issues, associated with the activity of the Semipalatinsk Nuclear Test Site, including its demilitarisation and the destruction (erasure) of so-called sensitive information.

Soon after Kazakhstan's accession to the Nuclear Weapons Non-proliferation Treaty in late 1993, the country signed five separate agreements with the USA, pursuant to which the latter undertook to give Alma-Ata 85 million dollars in aid to further nuclear disarmament. In the Russian Federation the then Minister of Defence Pavel Grachev signed Directive No. 314/4/01363 on 17 December 1993 on the disbandment of military units at the former Semipalatinsk Test Site.

2.1.1. Organising abandonment of nuclear weapons test infrastructure

The nuclear weapons test infrastructure at the former Semipalatinsk Test Site was abandoned as part of the intergovernmental agreement between the Republic of Kazakhstan and the United States of America, the Cooperative Threat Reduction (CTR) Programme, elaborated by the USA to render assistance to Kazakhstan, Russia, Ukraine and Belarus, and the Agreement between the governments of the Russian Federation and the Republic of Kazakhstan *On Kolba Containment Vessels* and special process equipment, housed at the former Semipalatinsk Test Site, dated 28 March 1997.

On 24 September 1993, the United States and Kazakhstan signed a Joint Declaration of Intent, under which the USA undertook to provide help to Kazakhstan to assess the consequences of the Soviet nuclear tests at the former Semipalatinsk Test Site. The Joint Declaration was signed by Ambassador James Goodby, the USA's chief mediator on safety issues surrounding the dismantling of nuclear weapons, and the head of the department for international security and arms monitoring of the Kazakh Foreign Ministry Bolat Nurgaliyev.

On 11–14 November 1993, a group of experts from the USA paid a visit to conduct a preliminary assessment of the impact of the Soviet nuclear weapons test programme at the Semipalatinsk Test Site on the environment and public health. These results were to evaluate the radiological situation within the former Semipalatinsk Nuclear Test Site in the interests of Kazakhstan, Russia and the United States.

On 13 December 1993, Kazakhstan and the United States signed an agreement on the destruction of shaft-located intercontinental ballistic missile launch installations, eradication of the consequences of accidents and prevention of nuclear weapons proliferation.

On 3 October 1995, an agreement was signed between the US Department of Defence (US DOD) and the Kazakh Ministry of Science and New Technologies on the destruction of nuclear infrastructure.

The Defence Nuclear Agency (DNA), later the Defence Special Weapons Agency (DSWA) and now the Defence Threat Reduction Agency (DTRA), is responsible for analysis and distribution of information on the consequences of nuclear tests, including the consequences of nuclear tests at the test sites of the former Soviet Union. In accordance with the obligations and experience of the DNA, the US Defence Department appointed the DNA the executive agency of the Tunnel Neutralisation Project at Degelen Mountain.

The United States undertook to render the necessary assistance in the safe destruction of the nuclear weapons infrastructure by providing the services and equipment needed, and by training personnel in the safe and permanent closure of the nuclear test tunnel system at Degelen Mountain of the Semipalatinsk Test Site.

Under the terms of the Agreement, the Kazakh Ministry of Science and New Technologies (later the Kazakh Ministry of Science and Higher Education and then the Ministry of Energy, Industry and Trade) was empowered to appoint an executive agent for this programme to represent Kazakhstan. The Kazakh Ministry of Science and New Technologies appointed the National Nuclear Centre as the executive agent for this programme [1].

Prior to implementation of the Degelen Mountain Tunnel Neutralisation Programme, the DNA allocated several contracts for the National Nuclear Centre in order to implement the Joint Declaration of Intent of 24 September 1993:

- *Technical requirements for data and analysis of the radiation situation at the former Semipalatinsk Test Site of the Republic of Kazakhstan*. The National Nuclear Centre analysed known sources of radiological data and presented several reports, including detailed contour maps.
- *Creation of a database on Kazakhstan, containing radiological data for assessment and use in clearing and reclamation work*. The National Nuclear Centre created a national database to support future rehabilitation projects.
- *Kazakhstani field measurements, field sampling and laboratory analysis for 10 areas located at the former Semipalatinsk Test Site of the Republic of Kazakhstan*. Experts from the National Nuclear Centre measured gamma activity in collaboration with teams from the USA and the Russian Federation during a joint terrestrial survey at the former Semipalatinsk Test Site in July 1994 [2].

After initiation of the Agreement between the US Department of Defence and the Kazakh Ministry of Science and New Technologies on destruction of nuclear infrastructures, on 3 October 1995, the DNA signed Contract DNA001–95–C–0179 with the National Nuclear Centre named the *Degelen Mountain Tunnel Characterisation Programme*. Under this contract, NNC had to conduct the necessary geological and radiological characterisation of every tunnel at Degelen Mountain. After completion of this work and allowing for the data obtained, the following contracts were then executed and performed in sequence:

- Preparation of the infrastructure and demo closure of one of the tunnels at Degelen Mountain (Contract DNA001-96-C-0067 dated 6 February 1996). Upon completion of this stage of the work, infrastructure was prepared at the areas *G* and *Baikal* at the former Semipalatinsk Test Site for the personnel engaged in closing the tunnels and the DSWA field team, monitoring the work directly at the former test site. This work culminated in the demo closure of Tunnel No. 192, completed successfully on 2 April 1996 in the presence of the US Ambassador in Kazakhstan, official representatives of the US Department of Defence, the DSWA and members of the Kazakh Government.
- Work on sealing 58 tunnels at Degelen Mountain (Contract DNA001-96-C-0099 of 2 April 1996), during which, by 31 January 1997 they were completely abandoned according to agreed and ratified closure methods (the first stage).
- Work on sealing 64 tunnels at Degelen Mountain (Contract DSWA01-97-C-0027 of 9 January 1997), during which they were completely abandoned according to agreed and ratified closure methods.

As a result of the work performed in 1996 and 1997, the entrances to 124 tunnels were sealed.

The entrances to the remaining 57 tunnels were planned for closure in 1998 as part of the Works Plan of 20 November 1997 to Contract DSWA01-98-C-0016 of 28 November 1997. However, a number of changes to the Works Plan made certain adjustments to the course of closure of the remaining tunnel entrances. As of 29 July 2000, 14 changes had been made to Contract DSWA01-98-C-0016 of 28 November 1997 (modifications P0001 – P0014).

The modifications stipulated seismic calibration experiments to some of the remaining tunnels, experimental closure of entrances, work to provide for the run-off of water from the tunnels, the opening of a previously closed entrance and a series of accompanying work, performance of which ensured the safe completion of the entire range of research.

The concluding stage in the liquidation of the remaining tunnel entrances was preceded by the following:

- the closure of the remaining tunnel entrances at Degelen Mountain, including tunnel closure studies (Contract DSWA0198-C-0016 of 28 November 1997 with subsequent modifications), during which 56 tunnels were sealed (including 9, sealed using an experimental method), and a 100-tonne seismic calibration experiment called Omega was performed in Tunnel No. 214, using chemical explosives;
- performance of a 100-tonne seismic calibration experiment in Tunnel No. 160, using chemical explosives, a post-experimental geological survey of Tunnel No.

214 and an experimental repeat entry into a previously sealed tunnel (Contract DSWA01 98 C 0016 of 28 November 1997 with subsequent modifications). On 25 September 1999, the Omega-2 seismic calibration experiment was successfully completed. As a result of the experiment, Tunnel No. 160-B, made specially to lay explosives, was sealed. The entrance of Tunnel No. 190, opened for experimental entry, was sealed once more;

- performance of a 100-tonne seismic calibration experiment in Tunnel No. 160, using chemical explosives (Contract DSWA01-98-C-0016 of 28 November 1997 with subsequent modifications (P0008 dated 21 September 1999)). On 29 July 2000, the Omega-3 seismic calibration experiment was successfully completed. As a result of the experiment, Tunnel No. 160-C, made specially to lay explosives, was sealed [3].

As a result of the work, the entrance of the last tunnel at Degelen Mountain was sealed on 26 August 2000.

On 13 August 1996, with Decree No. 1002, the Government of Kazakhstan officially approved the status of the National Nuclear Centre relative to all programmes for destroying the nuclear weapons infrastructure at the Semipalatinsk Test Site, including programmes for sealing tunnels at Degelen Mountain and the boreholes at the Balapan Testing Area.

After approval of the Balapan Area programme by the US Department of Defence, the DSWA drew up Contract DSWA01-97-C-0015 for NNC - *The Programme for Characterisation of the Balapan Area*, for the necessary geological and radiological characterisation of each unused borehole in this area.

Soon after this the DSWA executed Contract DSWA01-97-C-0094 on closing the first three test boreholes by December 1997. The remaining test boreholes at the Balapan Area were closed and the experimental calibration explosions during the closure process were performed as part of Contract DSWA01-98-0064.

The National Nuclear Centre engaged its own institutes to perform the work:

- the Radiation Safety and Ecology Institute (Kurchatov);
- the Geophysical Research Institute (Kurchatov);
- the Nuclear Physics Institute (Almaty);

and the following subcontractors:

- the Regional Treatment and Diagnostics Centre (Kurchatov);
- Degelen LLP;
- the Kazakh State Scientific Production Centre for Explosive Work;
- the Institute of Chemistry of the Kazakhstan National Academy of Sciences;
- Kazakhvzryvprom, a republican public enterprise;
- Design and Engineering Organisation LLP, a commercial production association.

The organisational structure of the work is presented in the diagram (*Figure 2.1*).

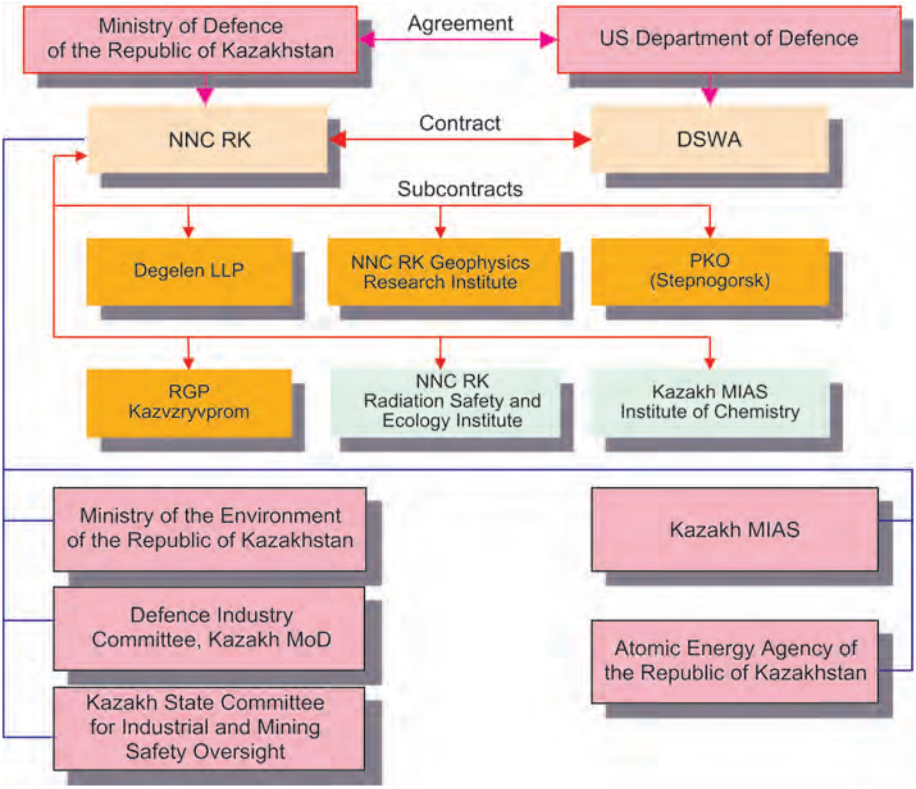


Figure 2.1. *Works Management Plan*

The work was conducted in close collaboration with the following Kazakh ministries and departments:

- the Ministry of Science – Academy of Sciences of Kazakhstan;
- the Kazakh Ministry of Natural Resources and Environment;
- the Kazakh Ministry of Defence;
- the Kazakh Atomic Energy Agency;
- Gosgortekhnadzor under the Kazakh Emergency Situations Committee.

2.2 Closure of tunnels at Degelen Mountain

2.2.1. Study of the radiation situation at the former Semipalatinsk Test Site [4]

Prior to the start of the work NNC drew up and agreed with the DNA a detailed research plan and a group of managers from different fields was organised to implement the main part of the work. The group determined a list of organisations and individuals who owned radioecological information on STS and they compiled a list of banks of radioecological information on each holder of such information. In future this information was partially acquired by or handed to NNC. On the basis of the information obtained a requirements specification was drawn up for the work, a programme of control measurements was elaborated and control measurements were performed. The banks of data on the radiation situation at STS was also compared and subjected to preliminary analysis, allowing for the results of measurements performed by the DOE using a high-purity germanium detector. Based on the results this yielded, preliminary maps of isolines were compiled based on separate radionuclides and the geographical coordinates of the sampling sites were clarified.

During the course of the work, sampling techniques and criteria were refined and reliable data were assessed, maps were drawn up of updated data, standards were gathered, as used in assessment of the radiation situation, along with standards of Kazakhstan and the former USSR for STS, and IAEA and US standards were compared.

Based on the study results, tables were compiled for analysis and degrees of contamination were established, including plutonium data.

The search for radiological information on STS was conducted to reveal information, obtained only by Kazakh researchers or under orders placed by Kazakh organisations, on the assumption that the information in reports compiled at the behest of the USSR Defence Ministry would be presented to a suitably full extent by the Russian side.

Research performed by Kazakhstan on STS was predominantly conducted in 1993 under an assignment of the republic's Environment Ministry and related to contamination, mostly by caesium-137, of the soil and bottom sediment of the "Atomic Lake", the water courses at Degelen Mountain and in Lake Balyktykol (by the border of the test site). The degree of contamination of vegetation and farm produce by isotopes ^{90}Sr, ^{137}Cs and ^{210}Pb was determined systematically over 10 to 15 years by the Kazakh Ministry of Agriculture, in areas adjoining STS. Research of this kind was conducted all over the republic, but the group from the National Nuclear Centre gathered information solely concerning the area of STS. Moreover, in November 1993, an IAEA mission determined about 7 radionuclides in 34 samples of soil, water and foodstuffs from STS. Atmospheric radiation over the last 30–35 years was observed systematically by the republic's Weather Service, although all data were handed over to the USSR Weather Service and none are held in Kazakhstan's archives.

The Environment Ministry's research group collected and analysed materials pertaining to the radiation situation at STS that this ministry had at its disposal. It was ascertained that, in the period from 1960 to 1993, research was performed, the results of which are set out in 46 reports. Using references to recorded literature, the availability of such reports was established. Some of them were discovered during an inspection of file materials at Military Unit 52605. However, the group did not have a full collection of these reports and only brief extracts from them actually contained any material on radiation contamination. The ministry held only four complete reports.

When conducting its research, the group proceeded from the following tasks at hand:

- Divide the area of the test site into sectors contaminated with radiation and those uncontaminated, which can be used without restriction for economic and commercial purposes.
- To reduce the volumes of areal studies, verify the hypothesis about the spread of

artificial radioisotopes that formed in the course of nuclear tests, only within the confines of their fallout over the traces of radioactive clouds.

- Assess the veracity of aerogeophysical work to study radioactive contamination of the area by artificial isotopes.

All materials for the test site that the researchers had at their disposal were analysed to resolve the set tasks. The aerogamma-ray spectrometry survey, performed in 1990 by the scientific and production association Aerogeologiya was used as the basic approach. Maps of anomalous concentrations of uranium, thorium, potassium, caesium, strontium and plutonium, and of the degree of exposure dose and total state of knowledge on radiation for the entire test site were compiled. The veracity of these data was evaluated, both in terms of absolute levels of radiation contamination and in terms of the accuracy of the methods used in the measurements. In the 1994 survey season, an earth-based gamma spectrometry survey [5] was performed within the critical zones at STS while, in 1993, an areal study was performed of the spread of artificial radioisotopes at the part of the test site within the Abralinsky District.

The results obtained from this work confirmed the data from the previous aerogamma-ray spectrometry survey and helped conclude that it would be advisable to perform a study of artificial alpha- and beta-emitters within the territory of the spread of caesium-137. This facilitated a substantiated tracing of specific volumes of future work to be performed in this direction.

It was resolved to commence the development and population of automated databases simultaneously, to enhance the efficacy of the work with the obtained results.

The radiological database system was designed to accumulate, systematise and process data on the radiation monitoring of the former Semipalatinsk Test Site, the spread of certain isotopes there and information on the impact of the tests on the health of the local population and the environment. The processing of the accumulated data was used to prepare annual scientific and statistical reports and analyse the impact factors of the consequences of the tests on the environment and public health, allowing for the influence of geophysical, geological and hydrogeological factors [6].

When the work was being performed, the data were located in various Kazakh organisations, including the Ministry of Health, the State Committee for Land Tenure, Kazhydromet, the Kazakh National Hydrometeorological Service, and the Ministry of Agriculture. A large proportion of the data on the study of STS was also held in scientific and public organisations of the Russian Federation.

Available data were collated and subjected to preliminary analysis under Contract DNA001-94-C-0031, for their further use in the work. Equipment support requirements were determined, including the necessary computing parameters and components for the radiological database system to operate successfully.

Provision was made in the radiological database system for possible electronic communication with other organisations that operate automated radioecological monitoring systems, such as the Kazakh Health Ministry, the Kazakh Environment and Bioresources Ministry and others.

Testing was performed using the DOS 6.2 and Windows 3.1 operating systems. Visualisation functions were implemented based on ArcView, the operating visualisation module of the ArcInfo application package. ArcView operates in Windows 3.1, which also supports other program modules.

The Clipper 5.01 DBMS (Russian version) was used. The Flipper system was used to work with graphic functions. Certain functions from the Clipper Tools2 package were also used.

Digital maps were drawn up based on geographic maps with a scale of 1:100,000, including 25 standard sheets of the test site area.

About 8,500 cells of the map were filled with radiological data. The dimensions of one such cell were selected according to a geographic grid, corresponding approximately to 1–1.5 km in the locality.

All maps were displayed using ArcView, operating in the Windows 3.1 operating system. Distribution data were displayed with the map being coloured depending on level of activity, radionuclide content or other data.

2.2.2. Program for characterising tunnels at Degelen Mountain

Tunnels at Degelen Mountain at the former Semipalatinsk Nuclear Test Site were characterised in 1995–1996 by NNC, under Contract DNA001-95-C-0179 dated 3 October 1995 [7].

Studies of this kind were needed to assess the pending volume of work on tunnel closure (*Figure 2.2*) and served as grounds for drawing up technical design documentation and for organising work on sealing the Degelen tunnels.

A total of 181 tunnels (tunnel entrances) were discovered and inspected, of which 18 were not used for nuclear tests (tunnels 011, 022, 126, 134, 147, 151, 158, 169, 170, 174, 178, 198, 207, 210, 212, 214, 420 and 430).

The research obtained the following main data, characterising each tunnel:

- number (conventional name) of tunnel;
- entrance coordinates (a marker, installed 20 m from the entrance), specifying the latitude, longitude and altitude above sea level, measured using Magellan GPS;
- geometric dimensions of the entrance (height and width in metres);
- the year when nuclear tests were performed and the force of the nuclear blast (in TNT equivalent) in the given tunnel;
- the condition of the tunnel entrance;
- survey depth of the tunnel in metres from the tunnel entrance;
- the presence of structures near the entrance, that have an impact on the work on tunnel closure;
- the presence of support fixtures near the entrance, outside the entrance and in the cut trench;
- water flow (L/min);
- maximum equivalent dose of γ-radiation, recorded near the entrance or in the tunnel (μR/hr);

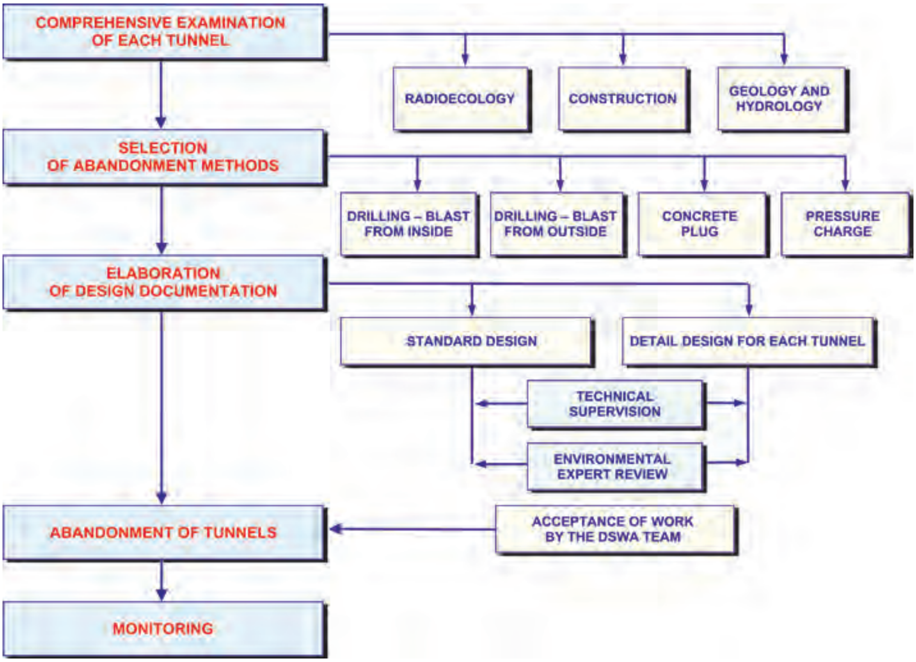


Figure 2.2. *Organisation plan for abandoning the infrastructure*

- maximum flux density of β-particles, recorded near the entrance or in the tunnel (particles/(min×cm^2));
- maximum specific activity of caesium-137 in soil or smear samples, taken in the given tunnel (Bq/kg);
- maximum specific activity of americium-241 in soil or smear samples, taken in the given tunnel (Bq/kg);
- maximum specific activity of caesium-137 in water samples, taken in the given tunnel (Bq/L);
- presence and maximum specific activity of tritium in water samples, taken in the given tunnel (Bq/L).

Tunnels determined as radiation-hazardous, in which additional measures were needed to protect personnel, were marked separately. Based on analysis of the results of tunnel inspection and allowing for the maximum safety of operating personnel who would work on sealing the tunnels, systems were elaborated for closing the tunnels at Degelen Mountain.

Closure methods were developed for each tunnel, allowing for individual features, including either one of the methods detailed below or, as a rule, a combination thereof. The closure method of separate tunnel entrances was amended after agreement with the DTRA representative, as stipulated under contract.

Table 2.1 presents certain features for the application and implementation of approved methods. In addition, two tunnels, that were dug for experiments (160-B and 160-C) were sealed using blasts of 100 tonnes of explosives in the blast chambers of these tunnels. Each stage in liquidation of the tunnel entrance concluded with backfilling of the trench or crater that formed after the blasting work and levelling to reinstate the natural relief.

Table 2.1. *Certain features of tunnel closure methods*

No.	Liquidation method	Conditions of use	Main types of work performed
1.	Experimental closure	The ability to install a drilling rig at the tunnel entrance with minimum costs, the availability of a crown over the entrance	Preparation of the entrance section, drilling of 2–10 horizontal boreholes with a diameter of 102 mm and up to 30 m long and triggering of borehole explosive charges
2.	Pressure charges (collapsing the entrance to the tunnel with pressure charges)	Unstable rock in the tunnel, the lack of or undermined support, radioactive contamination and the slope relief do not allow drilling work to proceed.	Triggering of explosive pressure charges with the filling of natural cavities over the entrance
3	Drilling of blast holes from within (drilling-and-blasting method with the drilling of blast holes from inside the tunnel and the collapsing of the tunnel crown and side walls on the set line with a blast)	Stable rock in the tunnel, a satisfactory condition of supports, no radioactive contamination, a thick layer of covering rock or an inability to perform drilling from the surface	Preparation of the tunnel section, drilling of blast holes in the tunnel cover and walls and triggering of blast hole explosive charges
4.	Drilling from the surface (drilling and blasting with the drilling of boreholes from the surface and the collapsing of the tunnel crown at the set length)	Unstable rock in the tunnel, the lack of or undermined support, a significant amount of repair and recovery work in the tunnel, radioactive contamination and the slope relief allow drilling work to proceed.	Preparation of the surface section, drilling blast holes or boreholes with a 102 mm diameter over the tunnel cover, including into the entrance crown and triggering borehole charges
5.	Installation of concrete plugs (creation of a cast-in-place concrete (reinforced concrete) plug on the set length of the tunnel)	Radioactive contamination in the tunnel, the presence of metal supports or pipes of large diameter, the presence of pre-installed concrete barriers, the inability to drill from the surface and a considerable thickness of the covering rock and high costs in preparation of the blast hole drilling inside the tunnel	Preparation of the tunnel section and erection of the concrete plug

6.	Combined: surface charges and concrete plug	Radioactive contamination of the tunnel, the presence of metal supports, high costs in preparation of the blast hole drilling inside the tunnel, many flaws in the cover and a considerable flow of water	Drilling blast holes and boreholes from the surface, including into the entrance crown, triggering borehole explosive charges and erecting the concrete plug
7.	Combined: drilling from inside and the concrete plug	A lack of radioactive contamination in the tunnel, presence of metal supports or concrete lining of walls and cover, the inability to drill from the surface or a considerable thickness of covering rock, and a high flow of water	Preparation of the tunnel section, drilling of blast holes in the tunnel cover and walls, triggering of blast hole explosive charges and erection of the concrete plug
8.	Performance of experiment, 100 tonnes of explosives	Performance of experiment	Triggering 100 tonnes of explosive in the tunnel blast chamber

2.2.3. Creation of infrastructure for closing tunnels at Degelen Mountain and demo closure of Tunnel No. 192 [8]

Despite the fairly detailed information that describes the condition of the tunnels and the thorough elaboration of technical design projects for their closure, the specialists were faced with questions that only an experiment could answer. They needed to:

- make sure that the chosen techniques for tunnel closure would facilitate the reliable plugging of possible passages and cavities in the tunnels;
- assess the safety and cost of work for closing down the tunnels;
- create an infrastructure, needed to close down all the tunnels and which would ensure the work was performed as efficiently, swiftly and economically as possible.

As far as the specialists were concerned, Tunnel No. 192 was the most suitable site for resolving these tasks. Two nuclear blasts were conducted in this tunnel, excavated in 1961: the first was in October 1975 and the second was in November 1979, both with a force of up to 20 Kt.

The contracted Works Plan on demo closure of the tunnel included the following tasks:

- elaboration of a plan and programme of work for the closure of Tunnel No. 192;
- development of a system for coordinating and managing the work on tunnel closure;
- acquisition of materials, needed for work on closing Tunnel No. 192 (explosives, etc) and provision for their safe storage;
- the demo closure of Tunnel No. 192;
- preparation of temporary residential and administrative premises at designated working areas;
- training staff in safe working methods.

Specialists from NNC performed the following work, engaging Kazakh project participants in the process:

- a plan and schedule were prepared for the demo closure of the tunnel on 25 March 1996. The actual date of the demo closure was determined finally by the DNA. The plan described in detail the key work on preparing for the demo closure of Tunnel No. 192, including the selection of the type and quantity of materials to be used (explosives etc);
- project design documentation was prepared, including the drawing up of work permits, required for work on closure of Tunnel No. 192;
- residential and medical premises were arranged, designed for DNA technical managers and Kazakh specialists, those involved in work on Area 10 (Baikal) and in the work camp of area G. These premises were subsequently used by field teams during performance of seasonal work;

***Figure.* 2.3.** *Tunnel No. 192 (blast)*

Figure 2.4. *Tunnel No. 192 (after backfilling of the entrance)*

- NNC's subcontractor, the company Degelen, bought up the required quantity of explosives and materials, conducted the building and assembly work, using their own corporate equipment (drilling installations, generators, ventilation systems, lighting, trucks, bulldozers etc).

Three days after the closure of the tunnel by blasting (*Figure 2.3*), the entrance section had been landscaped, returning the natural relief of the locality (*Figure 2.4*).

2.2.4. Closure of tunnels at Degelen Mountain

The work on closure of the tunnels at Degelen Mountain can be divided into 3 stages:

- closure of the first 58 tunnels (Contract DNA001-96-C-0099 dated 2 April 1996 [9]), during the course of which 58 tunnels were abandoned;
- closure of 64 tunnels (Contract DSWA01-97-C-0027 dated 9 January 1997 [10]), during the course of which 64 tunnels were abandoned;
- closure of the remaining tunnels (Contract DSWA01-98-C-0016 dated 28 November 1997 with subsequent modifications [11]), during the course of which the remaining tunnel entrances were liquidated and a considerable amount of experimental work was performed. The main document that determined the volumes and types of work under each contract was the Works Plan, constituting Appendix No. 1 to the given contract. All amendments made to the Works Plan

after contract execution were agreed and drawn up as modifications to the main financial document, the contact itself.

The Works Plans and their modifications determined that NNC was conducting the necessary work for the full closure of the tunnels at the Degelen mountain test complex at the former Semipalatinsk Test Site.

The Works Plan consisted of a number of sections, a part and the content of some of which are presented below.

Preparatory work on closing down the tunnels at Degelen Mountain and on conducting experiments included the elaboration of design plans for the tunnel closure and experiments, the preparation of the infrastructure and support for DSWA technical managers at the test site, preparation and maintenance of the infrastructure for the Kazakh working groups at Area G, preparation of plans for occupational health and safety in all aspects of the contractual work, drawing up technical documentation, performing technical and environmental expert reviews on the projects for the closure of each tunnel, plus staff training, equipment preparation, procurement and delivery of equipment and materials, as needed for the contractual works.

Tunnel closure design plan. Proceeding from the number of tunnels to be closed and the methods adopted to do this, and also given the work on experiments, design plans were elaborated for closing down the tunnels at Degelen Mountain, including calibration experiments, the experimental closure of a number of tunnels, the opening and repeat closure of one of the tunnels and the abandonment of tunnels 160-B and 160-C, excavated to lay explosives under the Omega-2 and Omega-3 experiments. The plans specified the main stages of the work and their contents, the persons involved, including subcontractors, and the deadlines for each stage of the work, based upon the contractual requirements, to complete the closure of all tunnels by the end of the Omega series of seismic calibration experiments.

The design plans specified the content and the stages of the work (including the work of subcontractors), the delivery schedule of the equipment and materials, the locations for their storage and use, physical security measures for personnel and the secure storage of equipment and materials, the locations of temporary housing, canteens, medical facilities and other aspects.

Support of DSWA technical managers. The team of DSWA technical managers was responsible for monitoring the closure of the tunnels, preparation and performance of experiments directly at Degelen Mountain for almost the entire time that work was conducted there.

Upon request, the team of DSWA technical managers was granted access to all available technical documentation and any information that had any bearing on the contractual work.

Housing was provided for the DSWA technical team in Kurchatov, residential and administrative premises at Area 10 (Baikal), housing at Area G and medical care both in Kurchatov and at the areas.

The team of DSWA technical managers had road transport with a driver (escort) provided round the clock and they had independent access to all tunnels at Degelen Mountain, the work camp at Area G, the residential centre at area 10 and unrestricted travel in Kurchatov. NNC also arranged for the receipt and transport of equipment, produce and personal effects of the entire team of technical managers and ensured their safekeeping when the team members were away.

Preparation of occupational health and safety plans. Detailed plans on occupational health and safety were drawn up for each type of work pertaining to closure of the tunnel entrances, preparation and performance of contractual calibration experiments, which were presented to DSWA as individual reports.

Occupational health and safety plans included the following:

- a detailed description of the working process;
- names of the managers of the work;
- steps taken to prevent or avoid certain hazards;
- punitive measures for violation of regulations;
- a list of persons, responsible for training staff in occupational health and safety regulations;
- a description of the emergency notification process;
- a list of persons, responsible for addressing emergencies;
- a list of regulations and standard documents.

Preparation of the infrastructure for the Degelen working team. Residential, canteen and office premises were organised and remained operational at Area G for the working team throughout the period of the work. A duly staffed medical station operated round the clock, equipped with the necessary medical equipment, medications and an ambulance.

All premises at Area G were provided with an uninterrupted water, electricity and heating supply.

Meals were arranged for the personnel as was their transport by road between Kurchatov and Area G, between Area G and the tunnels throughout the course of the work.

Technical documentation and expert review.

All the work related to the tunnel closures was conducted based on the Standard Plan for Tunnel Closure at Degelen Mountain, elaborated pursuant to the Works Plan section. The Standard Plan completed state technical expert review at the Department for State Supervision of Emergency Situations, Safe Performance of Industrial Work and Mining of the Kazakh State Committee for Emergency Situations (the former Gosgortekhnadzor) and state environmental expert review at the Kazakh Ministry of the Environment and Bioresources (Almaty).

Based on this Standard Plan, allowing for the features of each tunnel, Working Designs were elaborated for the closure of each of the tunnel entrances, which had undergone technical expert review at the Central District of the Department (in Stepnogorsk) and environmental expert review at the Semipalatinsk Regional Administration for the Environment and Bioresources of Kazakhstan (in Semipalatinsk) or at the Kazakh Ministry of the Environment and Bioresources (Kokshetau).

An individual closure plan was developed for each tunnel in accordance with the decisions, adopted at joint technical conferences. Where necessary and as agreed between the responsible executives of both Parties, the technical closure plan could be amended or supplemented. The description of the technical plan and amendments were recorded in the Report Sheet for Preparatory Work Inspection. Plans and schedules for implementing the Degelen Tunnel Closure Programme and engineering analyses, prepared by NNC, were approved by the Contracting Officer's Technical Representative (COTR). The features of the technology, the terms and the results of the closure of each tunnel were documented as a special report sheet, as prescribed under the terms of the contracts. Each report sheet was signed by the chief project manager from NNC and the team leader of DSWA technical managers and then transferred to the chief project manager from DSWA as the document to confirm the closure of the given tunnel.

The closure of the tunnels, preparation and performance of seismic calibration experiments were monitored on site by representatives of the team of DSWA technical managers.

Monthly reports on the state of affairs, including work schedules, a list of tunnel entrances that had been closed in the given period, a detailed description of the project status, the course of the work and problems that arose were all discussed as working meetings of specialists from NNC and DTRA. Where necessary, unscheduled working meetings and sessions were held.

Each stage of the work was documented in a works report.

Preparation of equipment and materials. Prior to work on closing the tunnel entrances, preparing and conducting experiments, existing equipment was prepared and missing equipment and the materials needed for the work and for maintaining the infrastructure were procured, including explosives.

Detailed lists of equipment and materials, needed for specific work under separate contracts, were presented to DSWA as reports on stages, specifying costs.

Photo and video documentation. During the process of closing the tunnels and performance of other work, as stipulated under the contracts, the most indicative aspects were photographed and recorded on video in line with the requirements, to reflect the technological features and to confirm in documentary form the closure of each tunnel (*Figure 2.5*) or to conduct any other work under the contracts.

Repairs to access roads. Damaged sections of the road between Kurchatov and Area G were repaired to ensure safe transport of personnel, equipment and materials. The repaired sections stretch to a total of over 1 km. Work was performed on an ongoing basis to maintain the unsurfaced roads between Area G and the tunnel entrances.

prior to closure

preparatory work

fragment of the blast

Figure 2.5. *Fragments of photographic reports*

Abandonment of tunnels. Work on tunnel preparation (construction) and closure (destruction) was performed by the same Kazakh working team that was involved directly in the building of Degelen Mountain tunnels (the firm Degelen). The Defence Special Weapons Agency of the US Department of Defence (DSWA) retained the right to have its representatives from the team of technical managers present on site to inspect the preparatory work and successful closure and to assist in tunnel closure on a non-intervention basis.

The method for closure of each specific tunnel was defined in the Works Plans to the contracts.

The results of liquidation of the tunnel entrances and the closure dates are presented in Table 2.2.

Table 2.2. *Results of tunnel closure at Degelen Mountain*

No.	Tunnel No.	Results of closure				Closure date
		collapse length from entrance, in metres			length of concrete plug (m)	
		when drilling and blasting from outside	when drilling and blasting from inside	upon blasting with a pressure charge		
1	192	+	+			02.04.96
2	132	-	15	-	5	04.11.96
3	162	-	15	-	5	21.11.96
4	169 / 1	-	15	-	5	27.10.96
5	709	30	-	-	-	23.12.96
6	181	15	15	-	-	24.11.96
7	902	-	-	-	15	04.10.96
8	34	-	15	-	5	27.10.96
9	707	30	-	-	-	11.12.96
10	158	-	15	-	-	25.01.97
11	174	-	15	-	5	13.12.96
12	163	-	25	-	-	18.11.96
13	168	-	15	-	5	11.11.96
14	901	-	17	-	5	27.10.96
15	806	-	-	-	15	13.09.96
16	186	-	-	-	15	06.10.96
17	195	40	-	-	-	13.01.97
18	608	-	-	-	5	24.10.96
19	147	15	15	-	-	02.11.96
20	807	50	-	-	-	05.01.97
21	164	-	-	-	15	18.07.96
22	803	-	15	-	5	07.12.96
23	187	-	15	-	5	14.01.97
24	705	30	-	-	-	14.09.96

No.	Tunnel No.	Results of closure				Closure date
		collapse length from entrance, in metres			length of concrete plug (m)	
		when drilling and blasting from outside	when drilling and blasting from inside	upon blasting with a pressure charge		
25	K2/1	-	-	-	15	28.09.96
26	133	-	15	-	5	28.12.96
27	607	-	40	-	-	12.01.97
28	172	-	13	-	5	20.10.96
29	179	-	-	-	15	01.08.96
30	190	-	15	-	5	23.01.97
31	NCR/2	-	18	-	-	08.12.96
32	NCR/1	-	15	-	-	24.12.96
33	24	20	-	-	-	12.12.96
34	103	-	-	5	-	25.07.96
35	25	-	15	-	-	05.01.97
36	215	-	15	-	-	25.12.96
37	605	-	-	-	14	20.10.96
38	606	16.5	-	-	-	19.11.96
39	119	-	15	-	5	10.11.96
40	708	15	-	-	-	27.12.96
41	803	10	-	-		10.12.96
42	141	-	-	-	15	22.07.96
43	173	-	-	-	15	27.07.96
44	706	25	-	-	-	10.01.97
45	204	15	-	-	5	26.09.96
46	205	-	15	-	-	25.11.96
47	201	15	-	-	-	08.10.96
48	208	-	15		5	06.11.96
49	101	30	-	-	-	15.08.96
50	710	15	-	-	-	15.08.96
51	193	-	-	-	15	22.10.96
52	K2/2	-	-	12	-	24.07.96
53	196	28	-	-	5	24.09.96
54	194	20	-	-	-	20.09.96
55	704	-	15	-	5	11.11.96
56	129	15	15	-	-	10.01.97

No.	Tunnel No.	Results of closure				Closure date
		collapse length from entrance, in metres			length of concrete plug (m)	
		when drilling and blasting from outside	when drilling and blasting from inside	upon blasting with a pressure charge		
57	510	15	-	-	-	17.09.96
58	***802***	-	15	-	-	08.01.97
59	203	-	15	-	5	01.11.96
60	A-4		15			25.10.97
61	A-5			+		25.04.97
62	A-6	15				20.06.97
63	A-7			+		24.04.97
64	A-8			+		24.04.97
65	Б-2/80-1			+		13.05.97
66	Б-2/80-2			+		11.05.97
67	Zh-3			+		21.05.97
68	Zh-4			+		21.05.97
69	3-1	15				08.07.97
70	3-5			+		02.08.97
71	3-6			+		27.11.97
72	1	15				04.10.97
73	022		15		5	07.07.97
74	106		15			26.06.97
75	107	20				17.10.97
76	110	15				10.07.97
77	011		15		5	04.08.97
78	151		15			09.08.97
79	152		15			28.05.97
80	***156***	15				17.06.97
81	120	10				19.10.97
82	E-1	15				14.11.97
83	E-2	15				05.11.97
84	3-3	Chamber charges above the tunnel				16.11.97

No.	Tunnel No.	Results of closure				Closure date
		collapse length from entrance, in metres			length of concrete plug (m)	
		when drilling and blasting from outside	when drilling and blasting from inside	upon blasting with a pressure charge		
85	111	Drilling blast holes into the entrance crown				31.10.97
86	143	11				07.12.97
87	170	15				20.06.97
88	130		21			27.07.97
89	134				10	19.07.97
90	135	20				29.07.97
91	136	15				29.07.97
92	139				10	17.08.97
93	148 / 1		15		5	05.08.97
94	148 / 2		15			25.05.97
95	148 / 5		15			25.05.97
96	150		15		5	09.08.97
97	157	Collapsed sections backfilled				18.06.97
98	169	Backfilled				19.06.97
99	178		15		5	28.08.97
100	420				15	12.09.97
101	505				15	24.07.97
102	507	30				24.09.97
103	603		15			26.05.97
104	604	15				17.10.97
105	703		15		5	11.08.97
106	801		15			29.09.97
107	113		15			27.09.97
108	114		15			21.09.97
109	115	15				02.10.97
110	122		15			23.06.97
111	123		15		5	01.07.97
112	126				15	09.09.97

No.	Tunnel No.	Results of closure				Closure date
		collapse length from entrance, in metres			length of concrete plug (m)	
		when drilling and blasting from outside	when drilling and blasting from inside	upon blasting with a pressure charge		
113	127		15			03.11.97
114	128	15				06.07.97
115	156-T		15			14.06.97
116	504	15				31.07.97
117	506	20				24.08.97
118	3-2		15			26.10.97
119	138		15			29.11.97
120	***511***		15			03.12.97
121	Zh-1	7				05.12.97
122	Zh-2	10				04.12.97
123	140	3				06.12.97
124	149				15	29.08.97
125	8			+		19.06.98
126	11	4				28.09.98
127	13	Experiment 20				08.10.98
128	14		15			25.06.98
129	17	5				13.07.98
130	18	Experiment 35				06.08.98
131	19	5				11.07.98
132	21	Experiment 22		+		06.10.98
133	***104***		15		5	10.08.98
134	105	Experiment 35				21.08.98
135	108	Experiment 31				26.07.98
136	109			+		05.06.98
137	***165***		15			22.06.98
138	169/2-1				5	28.09.98
139	169/2-2			+		17.06.98
140	169/2-T		15			19.06.98

No.	Tunnel No.	Results of closure				Closure date
		collapse length from entrance, in metres			length of concrete plug (m)	
		when drilling and blasting from outside	when drilling and blasting from inside	upon blasting with a pressure charge		
141	175	15				04.07.98
142	***176***	Experiment 35				02.08.98
143	***177***		15		5	08.08.98
144	180		15		5	04.10.98
145	184	15				09.07.98
146	185		15		5	01.10.98
147	191		15			17.07.98
148	207	15				13.06.98
149	210	Experiment 35				07.08.98
150	216				10	22.08.98
151	430		15		5	05.09.98
152	501	15				11.10.98
153	502	15				11.10.98
154	503	Experiment 25				20.07.98
155	508			+		28.06.98
156	509	Experiment 35				10.08.98
157	601			+		08.06.98
158	609	15				08.10.98
159	610	Experiment 25				21.08.98
160	611	5				20.07.98
161	701	Experiment 25				22.07.98
162	809	5				26.09.98
163	810	15				05.07.98
164	A			+		04.06.98
165	A-1			+		03.05.98
166	B			+		03.06.98
167	G			+		16.04.98
168	K-85				10	01.09.98

No.	Tunnel No.	Results of closure				Closure date
		collapse length from entrance, in metres			length of concrete plug (m)	
		when drilling and blasting from outside	when drilling and blasting from inside	upon blasting with a pressure charge		
169	Metro			+		10.05.98
170	198		15		5	19.08.98
171	200ASM-L				10	29.05.98
172	200ASM-P			+		15.05.98
173	200M-bis				10	19.08.98
174	200M-A				10	25.08.98
175	Metro-X			+		11.05.98
176	NCR3	8				30.05.98
177	B-1				10	12.09.98
178	B-2			+		06.06.98
179	160-B	Omega-2 experiment				25.09.99
180	212	24				30.04.00
181	214	Experiment 30				15.04.00
182	160-C	Omega-3 experiment				29.07.00
183	160	12				26.08.00
	190 (repeat)	Experiment 30				10.10.99

***Note:** The tunnel closure date is deemed the date when work was completed on backfilling the entrance. The tunnels where water ingress was recorded after closure are indicated in **italics**.*

The photographs (*Figure 2.6*) indicate some of the main methods used to liquidate the tunnel entrances.

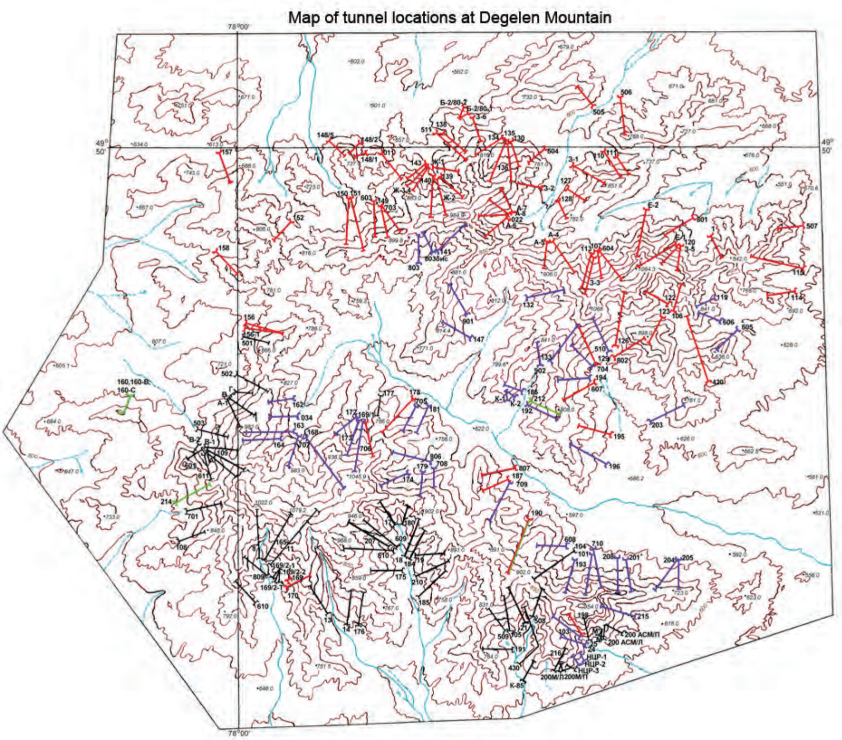
Boring - blast from inside

Boring - blast from outside

Concrete plug

Pressure charge

Figure 2.6. *Tunnel closure methods at Degelen Mountain*



LEGEND

Tunnels closed in 1996 (49)
Tunnels closed in 1997 (75)
Tunnels closed in 1998 (54)
Tunnels closed in 1999–2000 (5)

Figure 2.7. *Tunnel layout diagram*

The layout diagram of the tunnel entrances at Degelen Mountain is presented in *Figure 2.7*.

Closure of tunnels using a concrete plug construction method was accompanied by additional (independent) quality control of the concrete being laid.

Concrete samples from each concrete plug were sent to the Semipalatinsk Centre for Standardisation, Metrology and Certification of the Kazakhstan Cabinet of Ministers Committee for Standardisation, Metrology and Certification. Copies of independent test log sheets for control specimens of concrete and a consolidated table of results of express analysis of specimens of the ready-mix concrete were attached to the reports.

Tunnel No. 160

Tunnel No. 214

Figure 2.8. *Tunnel entrance type before and after backfilling*

Each stage in liquidation of the tunnel entrance concluded with backfilling of the trench or crater that formed after the blasting work and levelling to reinstate the natural relief (*Figure 2.8*).

Water monitoring. Water monitoring was conducted during the course of work on tunnel abandonment in the mountain range and this monitoring continues.

In October 1999 the entrance to the last aquiferous tunnel, No. 609, was sealed off. Since that time, observations have been ongoing on the water flow near the entrances of sealed tunnels.

Filters were installed at the entrances to ten tunnels that had a continuous flow of water: crushed aggregate was added by the former entrances to tunnels 156-T, 504 and 503 in areas measuring 30 x 30 m, and then levelled (*Figure 2.9*); trenches were dug by tunnels A-1, 165, 176, 177, 609, 511 and 104, drainage pipes were laid and then filled with coarse, crushed aggregate and levelled (*figures 2.9* and *2.10*).

Figure 2.9. *View of Tunnel No. 503 section*

Figure 2.10. *Filter structure by entrance to Tunnel No. 176*

The examination of these tunnels in September 2000 indicated that the filters at five of the entrances ensured complete absorption of the water in the rock dump. By increasing the thickness of the crushed aggregate by the entrances, water flows from tunnels A-1, 156-T and 165 were completely isolated. At the tunnel entrances where the flow intensity exceeds 200 L/min, the water washes the channels and reaches the nearest valley. Under a high intensity, the water quickly saturates the rock dump, resulting in waterlogged areas forming around the dump (Tunnel No. 504).

Complete isolation of the water flows requires that large sections are additionally covered with a coarse rubble material.

After the closure of all aquiferous tunnels, water continues to escape through the sealed structures. Seven tunnels with a continuous flow were found (*Table 2.2*).

Flows of water from the tunnels are contaminated to a varying degree with radioactive isotopes, which are brought to the surface.

It was found that the waters of the regional basin, which was sampled at the foot of the external slopes of the mountains, were contaminated with tritium, and the distribution of this contamination beyond the Degelen Area remains unclear.

Similar tritium contamination was recorded in surface and ground water in all valleys beyond the mountain range. The waters of the regional basin and the ground water of the valleys display no caesium-137 contamination, which evidences the high isolation potential of the Degelen geological structures.

2.3. A series of calibration experiments of the monitoring network for Omega nuclear tests

The use of chemical explosives to obtain control data and to calibrate seismic sensors is perhaps the only means of obtaining the necessary information for effectively fulfilling the terms of the Comprehensive Nuclear Test Ban Treaty (CNTBT). This technology is needed for various geological environments and conditions worldwide, where unauthorised nuclear tests may be performed, and it is critical in non-proliferation work. This chapter describes the preconditions and the importance of perfecting the techniques for inspecting performance of CNTBT terms and conditions.

Preconditions. On 22 September 1993, the Department for Energy, supported by the DTRA, triggered 1.2 million kg of blasting agent in the Rainier Mesa tunnel at the Nevada Test Site, during the first large-scale experiment to study many aspects pertaining to inspecting the performance of CNTBT terms and conditions. The results of this non-proliferation test form a multitude of control databases for assessing technical aspects, associated with verification of observance of treaty performance, but the results of this test are applicable only for one geological environment: the tuffs of the Nevada Test Site. Specialists believed that other geological environments were also of considerable interest, particularly solid rock, typical for mining work all over the world.

The purpose of such experiments was to facilitate testing and/or improve verification techniques to support the Comprehensive Nuclear Test Ban Treaty, provide for regional (teleseismic) calibration, improve research into detecting low-frequency EMR and to enable inspections in situ.

The general objective of the programme is to perform an end-to-end assessment of the ability to identify, determine the location and characterise suspected, unauthorised nuclear testing, using chemical explosives to imitate a nuclear blast. The specific tasks that constitute this end-to-end assessment are described below.

Under Contract DSWA01-98-C-0016 and its modifications (P0001, P0006 and P0008), three seismic calibration experiments were conducted in tunnels of Degelen Mountain, each experiment involving the triggering of 100 tonnes of Granulotol chemical explosive. This series of experimental blasts was given the name *Omega* [11].

- Omega – performed on 22 August 1998 in Tunnel No. 214;
- Omega-2 – performed on 25 September 1999 in Tunnel No. 160-B;
- Omega-3 – performed on 29 July 2000 in Tunnel No. 160-C.

Identical explosives were used in all seismic calibration experiments.

2.3.1. Preparation and performance of the Omega experimental calibration blast

The research programme for preparing the Omega experiment in Tunnel No. 214 (*Figure 2.11*) included a package of work pertaining to the geological, geophysical and hydrogeological examination of the tunnel, to assess the background medium of the calibration blast and to develop the charge design to satisfy the blast requirements.

The preparatory work was completed by charging the explosive chambers, positioning the measuring instrumentation in the tunnel and at the surface and forming the concrete plugs (*Figure 2.11*).

Prior to the experiment, the National Nuclear Centre performed the following preparatory operations:

- installation of tunnel ventilation and lighting systems to ensure a safe working environment;
- repairs to the tunnel railway line so that during the heavy equipment and materials for the experiment could be brought safely into and out of the tunnel;
- geological mapping of Tunnel No. 214, from the survey mark at 600 m from the end of the tunnel complex, including seismic tomography of the section housing the measurement instruments;
- acquisition and provision of safe storage of the necessary quantity of explosives;
- placement of explosives in a pre-selected, already available experimental recess inside the tunnel, located at least 100 m below the daylight surface;
- all necessary work on the design of the charge, to ensure the full and simultaneous triggering of all the explosives;
- work on erecting a concrete connecting section, 15 m long in total, to ensure maximum interaction (coupling) of the blast energy with the rock. In addition, for safety reasons, a 5-metre long concrete plug was made near the survey mark at 600 m;
- triggering the charge;
- work on ensuring safe entry into the tunnel after the blast;
- repeat studies of the tunnel condition.

The explosive charge was detonated on 22 August 1998.

Entrance to Tunnel No. 214

Blast diagram

Figure 2.11. *Tunnel No. 214*

2.3.2. Preparation and performance of the Omega-2 experimental calibration blast

The Omega-2 and Omega-3 experimental calibration experiments were performed near Tunnel No. 160, located in the western part of Degelen Mountain, 13 km to the south of the Degelen workers' settlement.

The isolated position of Tunnel No. 160 is a favourable factor for conducting a series of experimental blasts here (*Figure 2.12*).

Figure 2.12. *View of the Tunnel No. 160 section*

Tunnel No. 160 was built by the northern foot of the mountain.

Excavation of the tunnel was completed in 1985. It was drilled in fissured basalts. The tunnel cover and walls to the survey mark at 129.5 m are reinforced with metal supports, which are in a satisfactory condition. The tunnel mouth is at an elevation of 636.97 m. The maximum thickness of covering rock is 109 m and at the end of the main tunnel is it about 97 m. The main tunnel was excavated from south to west. The straight tunnel is 380 metres long. Directly beneath the ridge, at an interval of 347–350 m, a 166.3-m shaft is made in the straight wall, in a westerly direction.

No nuclear weapons tests were performed in Tunnel No. 160. In 1985 and 1987, chemical explosives of up to 500 tonnes were detonated on the tunnel surface.

All work on the 100-tonne seismic calibration experiment in Tunnel No. 160, using chemical explosives, was performed pursuant to the Project for the Preparation and Performance of a 100-tonne Chemical Experimental Calibration Blast in Tunnel No. 160-B at Degelen Mountain of the Semipalatinsk Test Site.

The project underwent state technical expert review at the Department for State Supervision of Emergency Situations, Safe Performance of Industrial Work and Mining (Almaty) on 8 January 1999 and state environmental expert review at the Environmental Protection Committee of the Ministry for Natural Resources and Environment Protection (Kokshetau, North Kazakhstan Region) on 19 April 1999. The project was revised based on the critical feedback of the state environmental expert review of 25 February 1999 as regards increasing the depth of the explosive chamber and with the following conditions:

- the population of the Semipalatinsk region must be informed of the pending blast through the media and administrative channels;
- state environmental protection control must be provided by the East Kazakhstan Regional Administration for Environment Protection and the work performed, supervised by NNC. The following preparatory mining works were performed in accordance with the project:
- Tunnel No. 160 was restored to the survey mark at 300 m;

- nine vertical instrumentation boreholes with a 190-mm diameter were drilled from Tunnel No. 160 towards the charge in Tunnel No. 160-B;
- a horizontal passage was excavated – No. 160-B;
- a 100-t explosive charge chamber was made;
- explosives were placed in the charge chamber;
- the charge was detonated;
- the tunnel was prepared for post-blast research.

Tunnel No. 160-B was built 20 m above the cover of Tunnel No. 160. The tie-in point has an absolute elevation of 660.8 m. Both tunnels are located in one vertical plane. Coordinates of the blast chamber: 49°46'54.68'' north latitude and 77°57'58.68'' east longitude.

Uniform basalts are traced throughout Tunnel No. 160-B. From 24 metres to the bottomhole (133 m) the rock is very stable, despite the considerable quantity of primary cracks.

Upon completion of the construction of Tunnel No. 160-B, a tomographic survey was performed on the rock mass between the tunnels. Results of material processing confirmed there are tectonic zones near to the previously designed blast chamber and that the blast chamber should be placed more remotely than had been previously decided.

Based on geological and geophysical research of the mass of tunnels No. 160 and 160-B, it was decided to move the blast chamber to the 257-metre mark (centre of the chamber), to a mass of the most solid rock, damaged by a minimal quantity of tectonic cracks.

The 100-tonne Granulotol charge with primers was placed in a specially built blast chamber measuring 4.8 x 4.8 x 4.8 metres, both packaged and loose. The total volume of the chamber is 110 m^3. Sensors for measuring detonation speed were placed in the blast chamber at the same time as the explosive. 39 crystals were installed in the explosive charge on three instrument cables.

The arrangement of the blast triggering during the experiment involved 6 primers in a row. The triggering arrangement included a current probe, which activated (launched) the DTRA measuring instrumentation. Tunnel No. 160 was used to study the impact of the rock on the distribution of various waves. In light of this, various devices and sensors were installed in it and the tunnel cover and walls were painted different colours across four zones, to determine the order of their collapse upon the explosion.

All measuring instrumentation was housed in a specially prepared instrument bunker. The cables for connecting the sensors in the tunnels with the measuring instrumentation in the bunker were laid in a trench and backfilled with soil.

The 100-tonne seismic calibration experiment in Tunnel No. 160 using chemical explosive was performed on 25 September 1999 at 12.00 hours and 05.98 seconds local time. As a result of the experiment, Tunnel No. 160-B was liquidated.

2.3.3. Preparation and performance of the Omega-3 experimental calibration blast

All work associated with preparation of the mine and the blast conducted in it, along with the engineering behind various measurements during the course of the calibration experiment, was performed pursuant to the Project for the Preparation and Performance of a 100-tonne Experimental Calibration Blast in Tunnel No. 160-C at Degelen Mountain of the Semipalatinsk Test Site.

The detail design was performed based on Directive No. 05 5/295 of the Chairman of the Interdepartmental Committee on execution of the Agreement between the Kazakh Ministry of Science and New Technologies and the US Department of Defence on destruction of nuclear infrastructures of 3 October 1995, Minutes of the Technical Meeting of 12 April 1996 on arranging tunnel abandonment at Degelen Mountain at the former STS and the Contract on Additional Closure (Abandonment) of 57 sites at Degelen Mountain, with corrections and amendments, as stipulated under Contract DSWA01 98 C 0016 P0008 of 21 September 1999, in accordance with Kazakh design standards, safety requirements, current instructions and normative documents.

The design, elaborated by the Kazakh State Scientific Production Centre for Explosive Work and approved on 24 November 1999, was subjected to technical expert review at the Department for State Supervision of Emergency Situations, Technical Work and Mining on 23 November 1999 (Minutes of technical meeting) and environmental expert review at the Department for State Environmental Expert Review and Environmental Monitoring at the Ministry for Natural Resources and Environment Protection on 9 December 1999 (Conclusion of State Environmental Expert Review No. 2 3/726).

The following preparatory mining work was performed during the preparation and performance of the experiment, in line with the design:

- Tunnel No. 160 was restored to the survey mark at 235 m;
- seven 190-mm-diameter inclined instrumentation boreholes were drilled from Tunnel No. 160 towards the centre of the explosive chamber;
- a horizontal passage was excavated – No. 160-C;
- a 100-t explosive charge chamber was made;
- explosives were placed in the charge chamber;
- the charge was detonated;
- the tunnel was prepared for post-blast research.

Tunnel No. 160-C was constructed to run parallel to Tunnel No. 160. The centre of the blast chamber was located at the survey mark at 230 m, 25.96 m higher than it and 26.0 m to the east of the tunnel axis (*figures 2.13* and *2.14*). The tie-in point had an absolute elevation of 660.8 m. The true bearing of the direction of the tunnel axis was 182°. The tunnel, including the blast chamber, was 94.3 m long.

Coordinates of the blast chamber: 49°46’55.39” north latitude and 77°57’59.97” east longitude. The absolute elevation of the centre of the explosive chamber was 665.15 m in the Baltic System of Heights.

The 100-tonne Granulotol charge with six booster primer-detonators was placed both in packaged and in loose form into a specially built blast chamber, forming a hemisphere in its lower part (*Figure 2.15*). The radius of the hemisphere stood at 3 metres. The dimensions of the chamber during the drilling process stood at 4.8 x 4.8 x 4.8 metres.

Sensors for measuring detonation speed were placed in the blast chamber at the same time as the explosive (*Figure 2.16*).

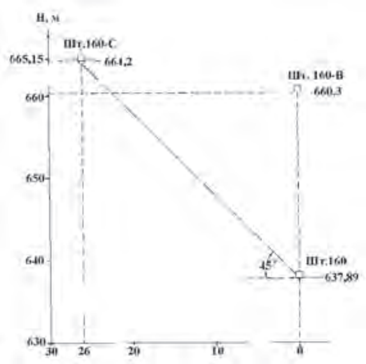


Figure 2.13. *Exploratory tunnel layout diagram*

Figure 2.14. *Entrance of Tunnel No. 160-C*

Figure 2.15. *View of the blast chamber*

Figure 2.16. *View of the blast chamber with measuring sensors, primers and template*

To obtain a directed blast in the direction of Tunnel No. 160, the booster primer-detonators were positioned perpendicular to the directional axis of borehole No. 1 and No. 2 (*Figure 2.17*). The intermediate primer-detonators were laid in the charge according to a specially made template, pre-installed in the blast chamber. To ensure the simultaneous triggering of the entire explosive mass, the intermediate primer-detonators with triggers from detonator cable were placed evenly in a set plane, in a circle with a radius of one metre.

The detonator cable, at an equal distance of 1.3 metres from all primers, was laid in a sand bed to exclude detonation at different times at these stages and was gathered into a single bundle – a trunk line to which, 40 minutes prior to the blast, 10 electric detonators were connected. All measuring instrumentation was housed in a specially prepared instrument bunker. The cables for connecting the sensors in the tunnels with the measuring instrumentation in the bunker were laid in a trench and backfilled with soil. The firing station was located 2,300 metres from the centre of the charge.

At 13.10 hours and 4.250 seconds local time on 29 July 2000, a 100-tonne calibration experiment was performed in Tunnel No. 160 – Omega-3.

As a result of the blast, Tunnel No. 160-C, which housed the blast chamber, almost completely collapsed and was abandoned. Tunnel No. 160 collapsed partially from the survey mark at 215 metres and it collapsed completely from the survey mark at 218 metres.

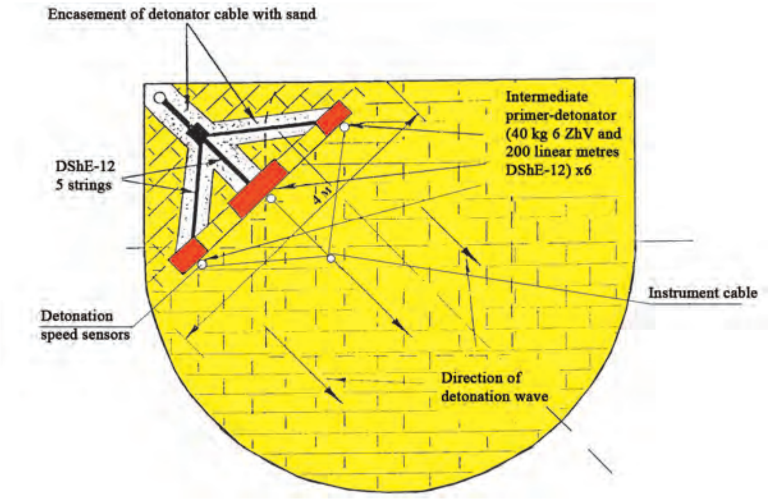


Figure 2.17. *Sectional diagram of the charge*

The essence of the Omega series of seismic calibration experiments facilitated the measurement of a number of the blast's parameters. The following were organised and performed across all experiments:

- observations of temporary seismic networks, located in the near-field zone, during the blast;
- observations of temporary seismic networks, located in the near-field zone, after the blast;
- observations of stations of the NNC seismological network;
- observations of infrasonic radiation during the blast. The following were added during the Omega-2 experiment:
- observations of the parameters of the atmospheric impact wave in the near-field zone. The following were added during the Omega-3 experiment:
- observations of the cross-section from Tunnel No. 160 to the Makanchi seismic station during the blast;
- observations of the cross-section from Tunnel No. 160 to the Bystrovsky Vibro-Seismic Test Site (Novosibirsk) before, during and after the blast;
- doppler radio-sounding of the ionosphere during the blast. Seismic observations in the near-field zone and observations of aftershocks during all calibration experiments were performed on the same network of temporarily installed seismic stations, six REFTEC DAS-type stations with short-period L4 C 3D model 72A 08 seismic sensors and one station equipped with an FBA-type accelerometer (*Figure 2.18*).

According to the Omega-2 and Omega-3 experiments, the source was localised based on records of the near-field zone stations S1–S7 and the stations of the National

Nuclear Centre and the Kazakh Seismic Network. The obtained localisation results are in close accordance with the real coordinates of the blast site and blast time. The nature of amplitude change for the two blasts, Omega-2 and Omega-3, are generally alike, but the absolute amplitude values on the latter blast are systematically lower than for the former.

According to data from the seismic stations of the National Nuclear Centre, the mean energy class of the Omega-3 blast is lower than for the Omega-2 blast (according to S5 by 0.30 and to MAKZ, by 0.73).

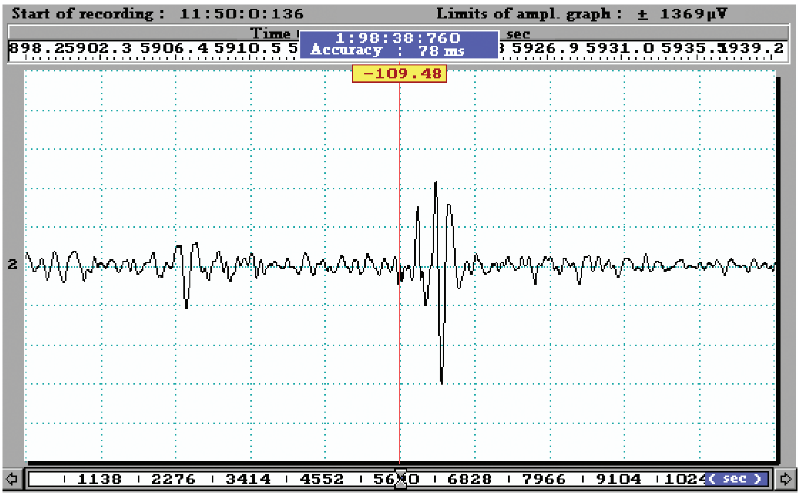


Figure 2.18. *Fragment of the acoustic signal record for point No. 7*

The magnitudes (mb) of the latter blast proved to be 0.28 less than for the former. At the same time the magnitude, when compared with data from the international observation network, appears overstated, which indicates that the V-C curve at regional distances is not suitable for this region.

Data from Kazakhstan's stations also confirms the conclusion of the International Data Centre (IDC) that the seismic effect from the Omega-3 blast is considerably lower than from the Omega-2 blast. Omega-2 was recorded by a number of stations and seismic groups in the IMS system around the world. The Omega-3 blast was recorded by only the ZAL (Zalesovo) station and the HFS seismic group. As a result this blast was not entered in the REB catalogue, as the number of IMS stations that recorded it is fewer than 3.

The Omega-3 seismic calibration experiment, prepared and successfully conducted on 29 July 2000, fulfilled its set objective.

Heads of Kazakh ministries and high-ranking officials from the USA were present at the experiment (*Figure 2.19*).

Figure 2.19. *Minister V.S. Shkolnik and former head of the Nevada Test Site D. Linger*

As a result of the work performed between 1996 and 2000, the entrances to 181 tunnels at Degelen Mountain were fully liquidated and sealed. In addition, using the energy from chemical explosive blasts, three seismic calibration experiments were performed.

The tunnel abandonment programme is fully complete.

2.4. Closure of boreholes of the Balapan Testing Area

2.4.1. Balapan Area characterisation programme. Identification and examination of unused boreholes, designed for nuclear tests

Under Contract DSWA01-97-C-0015 [12], the National Nuclear Centre examined unused boreholes and the SS-18 silo launchers, all subject to closure at the Balapan Testing Area of the former Semipalatinsk Test Site.

In all, 13 unused boreholes were detected and examined (*Figure 2.20*), located in different parts of the testing area, covering an area of 30 x 12 km, in varying geological and hydrogeological conditions. Materials from previous years were used to describe the geological aspects, hydrogeological features, physical and mechanical properties of the rock.

The coordinates of the unused boreholes, determined with GPS, are presented in *Table 2.3.*

Table 2.3. *Coordinates of test boreholes*

Borehole number	Coordinates (GPS)	
	North latitude	East longitude
1071-bis	49°58'51.7”	78°45’21.6”
1074	49°55’24.6”	78°45’06.8”
1327	49°55’53.3”	78°47’13.7”

1330	49°54’46.4”	78°44’55.6”
1343	49°54’31.1”	78°51’21.9”
1383	49°52’20.6”	78°38’52.0”
1386	49°52’48.5”	78°41’31.4”
1389	49°52’42.8”	78°45’36.4”
1409	50°02’08.4”	79°00’41.1”
1419	50°03’27.2”	78°56’19.3”

Examination of unused boreholes involved the performance of the following work:

- radiometric field measurements at the head sections of boreholes;
- examination of the current state of the boreholes, description of silo heads and measurements of the spatial position of sites (GPS);
- borehole logging research: caliper logging, directional survey, resistivity logging and gamma logging;
- hydrological borehole studies: dewatering, observations of stream discharge and water sampling;
- gamma-spectrometric and radiochemical analysis of soil and water sample analysis for ^{137}Cs and tritium.

The information obtained during the examination helped develop and recommend methods for sealing each unused borehole and elaborate safe working measures.

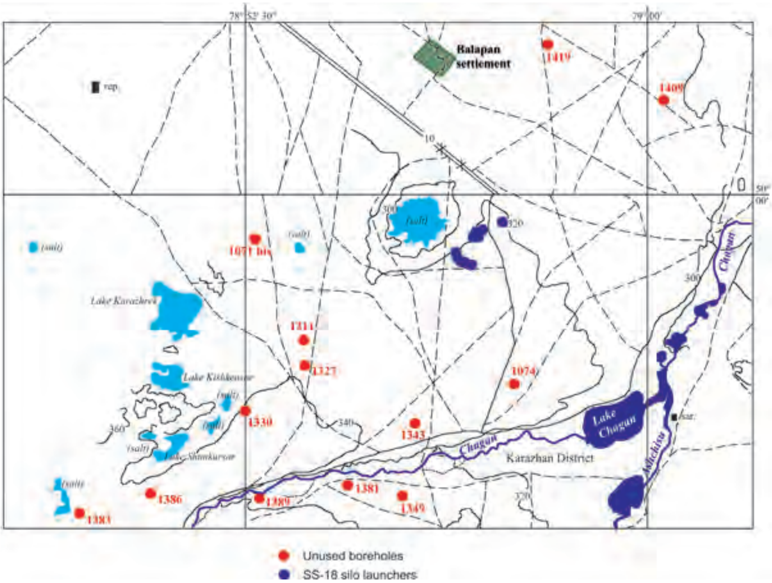


Figure 2.20. *Placement of unused boreholes and SS-18 silo launchers*

A detailed description of the Balapan Area involves its geological aspects, hydrogeological conditions and the radiological situation in the regions where boreholes were closed, along with the design of these boreholes and the condition of the borehole shafts during the research. This is all included in the Expanded Report on All Thirteen Unused Boreholes and Results of Examination of SS-18 Launch Silos.

A feature of the geological aspects of the sector is the broad development of Neocene clays, which cover the deposits of the foundation with a thickness from several metres to 70–80 metres.

The regional system of subsurface water at the Balapan Area is associated with a zone of exogenous fractures of Palaeozoic and Mesozoic rock.

The specific nature of the geological aspects (development of aquitard clays, which have a varying thickness given the uneven surface of the Palaeozoic foundation) determines the occurrence depth of the aquifer cover: from several metres to 70–80 metres.

The aquifer, coinciding with the zone of exogenic fractures, is opened up by all boreholes. The filtration capacity of the aquifer rock is assessed as low and very low: from 2.8 x 10^{-10} to 3.5 x 10^{-7} m/sec.

The chemical composition of subsurface water is mostly potassium, sodium, sulphate and chloride, with extremely low hydrocarbonate anion content.

As a result of the boreholes being open for a long period with an insignificant circulation of subsurface water (because of the presence of borehole casing), two key processes take place, pertaining to a change in the water's composition.

The first process is linked with the penetration of atmospheric precipitation into a large-diameter borehole (about 10 m) with an open mouth and with the demineralisation of water in the upper part.

The second main process in the change in water composition is the intensive increase in total mineralisation in the lower parts of the boreholes because of the practical lack of circulation in intervals below 100–150 metres.

The surface of the Balapan Area is level, with a general incline to the north-east.

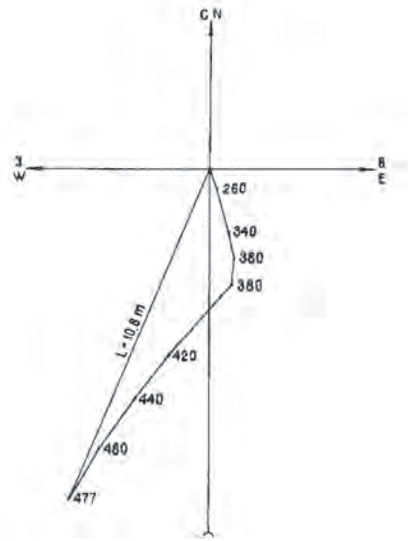


Figure 2.21. *Directional survey diagrams for borehole No. 1383*

The Shagan River valley, the left tributary of the Irtysh River, is well expressed in the relief. A system of closed-drainage cavities with dry lakes is noted. In the south, the Balapan sector is bordered by a chain of hills, rising 100–120 m above the surrounding locality.

The unused experimental boreholes at the Balapan Area were drilled in different years, to varying depths and in differing geological and hydrological conditions, so each borehole has its own specific design features. The current state of the boreholes is also mixed.

The boreholes take the form of almost vertical underground excavations with a round cross-section from 820 mm in diameter and up to 640 m deep, designed for testing nuclear devices within them.

The top diameter of the majority of the boreholes (7 boreholes) is equal to 1,640 mm. Five boreholes have a top diameter of 1,440 mm and one borehole (1071 bis), 2,100 mm. The end diameter of the boreholes is 1,020 mm and 840 mm. The borehole 1071 bis, drilled to a depth of 240 m, has an end diameter of 1,440 mm.

Provision was made for the drilling of strictly vertical boreholes, but the deepest of them have slight deviations in vertical and horizontal planes. Five such boreholes were made and the directional survey of one of them (No. 1383) is presented below (*Figure 2.21*). To a depth of 380 metres, the borehole shaft deviates in a south-westerly direction and then turns back to the south-west. Total deviation in the vertical plane stands at 10.8 metres.

The remaining boreholes have a practically vertical shaft. In the horizontal plane the deviations run in different directions and to different extents, from 3.05 to 7.8 metres from the vertical.

To give stability to the borehole, steel pipes were used with a 2,100-mm diameter and 16-mm wall thickness, a 1,640-mm diameter and 14–15-mm wall thickness, a 1,440-mm diameter and 12–14-mm wall thickness, a 1,020-mm and 820-mm diameter and 10–12-mm wall thickness.

All borehole casing was brought to the surface and forms the head of the borehole (*Figure 2.22*). The spaces between the pipes are filled with mortar.

Borehole No. 1389

Borehole No. 1071-bis

Figure 2.22. *Heads of boreholes at the Balapan Area*

The current state of the boreholes is also varied. Only 5 of the 13 boreholes transpired to be accessible for inspection to a depth close to the initial depth. The lower parts of the majority of the boreholes were silted up with settled drill mud and filled with extraneous items, while borehole No. 1074 was full of extraneous waste and crushed aggregate to a level of 38 metres. A column of drill pipes was left in borehole No. 1343, at the lower end of which there is a steel plate, blocking access to the borehole at a depth of 210 metres. Hydrological equipment was left in borehole No. 1389, designed for process water sampling. It has now been raised to the surface and dismantled.

2.4.2. Radiation situation at the Balapan Area

A radiological survey of the sectors of unused boreholes included field measurements of the level of radiation contamination and analytical work. The field studies included the following:

- determination of the exposure dose level of gamma radiation at an elevation of 1 metre above the surface of the GPS marker and in 10 points in a 100-m radius around each borehole in increments of 50 m;
- determination of the flux density of beta particles on the surface in these same points;
- measurement of the activity of alpha-emitting radionuclides in the point with maximum contamination, determined when measuring β- and γ-activity, and sampling of soil for radiochemical analysis;
- soil sampling at a distance of up to 5 metres from the borehole opening for gamma-spectral analysis;
- water sampling after dewatering for analysis of ^{137}Cs and tritium. The maximum exposure dose level varied from 21 to 29 μR/hr, while the maximum flux density of α-particles did not exceed 0.1 to 0.5 particles/(min x cm^2). Low-intensity β-radiation was recorded at sites near boreholes 1343 and 1389. Gamma-spectral analysis, likewise, did not record an increase in the maximum activity of natural radionuclides.

The maximum activity of uranium-238 isotope (^{238}U), 46 Bq/kg, was recorded in borehole No. 1330 (where the norm is 57 Bq/kg).

Contamination of the soil with radionuclides of industrial origin over and above permissible levels was recorded in individual, disparate points. Significant values of the specific activity were established for ^{137}Cs, ^{90}Sr and $^{239,240}Pu$ isotopes (*Table 2.4*).

The table shows that by nearly all the boreholes there are increased values of specific activity for plutonium-(239,240) while, in the region of borehole No. 1419, for strontium-90 as well.

According to the Temporary Criteria for Restricting Irradiation of the Public When Transferring Land into Business Use (KPRZ-97), there are no restrictions on work on the borehole head sites.

Gamma-logging of boreholes showed there were no high gamma activity values. The level corresponds to the natural activity of the rock.

Radiochemical research of underground waters, conducted in 1997 and 1998, indicated a considerable increase in the MPC of tritium and strontium-90 only in a water sample taken from borehole No. 1419 (*Table 2.5*).

Table 2.4. *Results of laboratory studies into the soil of borehole head sites*

Borehole No.	Content in soil (Bq/kg)					
	^{40}K	^{232}Th	^{238}U	^{137}Cs	$^{239,240}Pu$	^{90}Sr
1071-bis	781.0	33.0	22.0	<6.0	9.0	23.4
1074	531.0	20.0	25.0	10.0	<1.0	6.8
1327	504.0	13.0	38.0	24.0	11.2	7.9
1330	779.0	24.0	46.0	7.0	23.0	14.2
1343	556.0	15.0	35.0	13.0	17.2	7.8
1383	611.0	22.0	25.0	20.0	14.1	9.6
1386	536.0	20.0	28.0	<6.0	11.2	2.8
1389	496.0	24.0	30.0	7.0	2.3	7.7
1409	695.0	26.0	33.0	25.0	20.7	9.1
1419	675.0	27.0	24.0	13.0	38.4	59.7
MAC	1130.0	61.0	57.0	370.0	3.7	37.0

Table 2.5. *Results of radiochemical studies of underground waters*

Borehole No.	Year	Unit activity of radionuclides		
		^{137}Cs (Bq/L)	^{90}Sr (Bq/L)	^{3}H (kBq/L)
1330	1998	4±40	104±16	<4
	1997		2±100	<1.3
1383	1998	<4	0.14±27	<4
	1997		2±100	<1.3
1386	1998	<4	43±16	<4
	1997		<2	<1.3
1409	1998	2±90	1.7±19	<4
	1997		<2	<1.3
1419	1998	3±50	1990±16	1850±12
	1997	<2	255	1076

Proceeding from the situation, revealed based on the results of preliminary examination of the state of borehole shafts and borehole head sites, the following factors were taken into account when selecting the means of destruction:

- a lack of restrictions on work on borehole head sites;
- the presence of drill pipes in the shafts of boreholes 1074 and 1343;
- the presence of poorly silty soils or sediment at the borehole bottom;
- a significant content of the radioactive elements strontium and tritium in underground waters of borehole No. 1419.

2.4.3. Abandonment of test boreholes

The unused test boreholes at the Balapan Area were abandoned by the National Nuclear Centre in collaboration with the Kazakh State Scientific Production Centre for Explosive Work and Degelen LLP in two stages:

– closure and full sealing of three boreholes
  Contract No. DSWA-0094 [13];
– closure and full sealing of ten boreholes
  Contract No. DSWA 0064 [14].

The first and foremost task behind this work was to close and completely seal off the unused boreholes; the second was to conduct experiments involving blasts of 25 tonnes of explosives in four boreholes to be destroyed.

The work was conducted in accordance with the Project for Experimental Blasts to Close Test Boreholes at the Balapan Area of the Semipalatinsk Test Site and the Project for Blasts to Close Remaining Test Boreholes at the Balapan Experimental Area (Semipalatinsk Test Site).

The projects for blasts to close test boreholes at the Balapan Area of the Semipalatinsk Test Site were elaborated by the Kazakh State Scientific Production Centre for Explosive Work and approved by the Department for State Supervision of Emergency Situations, Safe Performance of Industrial Work and Mining of the Kazakh Committee for Emergency Situations, and they underwent environmental expert review.

In 1997 three boreholes were subject to closure with the performance of calibration experiments –1311, 1349 and 1381.

In 1998 ten test boreholes were subject to closure:

1071-bis, 1074, 1327, 1330, 1343, 1383, 1386, 1389, 1409 and 1419, with a calibration experiment performed in borehole No. 1071-bis.

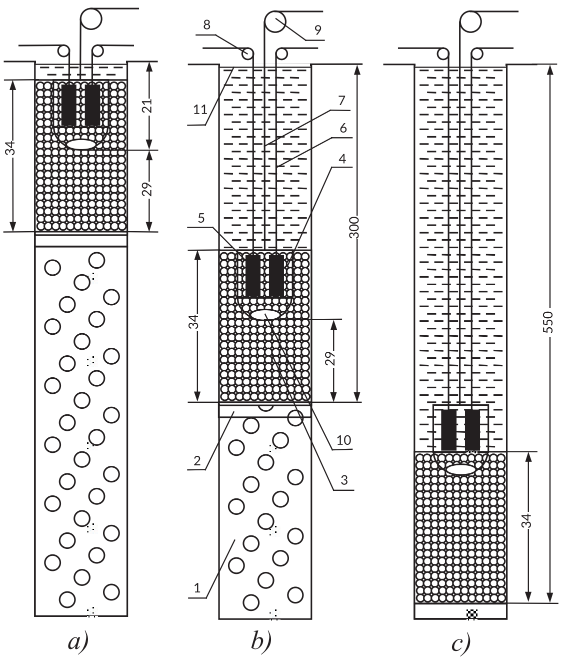
Calibration experiments. Proceeding from the state of the borehole shafts prior to experimental work and given the need for further experiments to study the operational integrity of explosive materials in natural conditions and charge fabrication technologies, the following sequence of work was adopted on calibration experiments, in coordination with DSWA representatives:

1. An experimental blast in Borehole No. 1311 at a depth of 50 metres.
2. An experimental blast in Borehole No. 1381 at a depth of 300 metres.
3. An experimental blast in Borehole No. 1349 at a depth of 550 metres.
4. An experimental blast in Borehole No. 1071-bisat a depth of 28 metres.

The design of charges in the boreholes is illustrated in the diagram (*Figure 2.23*).

In light of the consequences of the blasts, the fitting of concrete plugs at the boreholes was replaced (in agreement with DSWA representatives) with the backfilling of the formed craters with falling soil from the borehole and local, natural materials.

Borehole No. 1311. When preparing the borehole for the experimental blast, the shaft, from the surface to an elevation of 51.0 metres, was backfilled with local, natural materials, such as clay loam, sand with gravel and crushed aggregate. Then a 1-metre thick cement plug was installed with a drilling unit, with its base resting on the backfilled soil.



a) Borehole No. 1311
b) Borehole No. 1381
c) Borehole No. 1349

1. *gravel backfilling*
2. *concrete floor plate*
3. *main Granulotol charge*
4. *containment vessel with detonating charge*
5. *primers (two)*
6. *DShU-33M (reinforced detonator cable RDC-33M)*
7. *cable*
8. *pipes for lowering DShU-33M*
9. *roller for lowering the containment vessel with primers*
10. *cumulative cavity in the containment vessel*
11. *water level in the boreholes*

Figure 2.23. *Borehole charge design diagram*

The main Granulotol charge with a 22,000-kg mass was fabricated on 2 August 1997, 24 hours before the time set for triggering the charge. The containment vessel with the primers for the main charge was fabricated and lowered on 3 August, 3 hours before the blast. The charge in borehole No. 1311 was triggered on 3 August 1997 at 15:07 hours and 20.04 seconds local time.

The blast created a crater, 9.48 metres deep from the surface, with piles of earth up to 3.2 metres high. The maximum diameter of the crater at the elevation of the earth surface was 45 metres; it was 55 metres at the elevation of the piles of earth. A total of 1,250 m^3 of rock was discharged. As a result of the blast, a 10.5-m long fragment of the casing string was thrown 115 metres from the centre of the former borehole.

The crater was eradicated and levelled by backfilling the earth discharged from the borehole using a bulldozer, in line with the closure project. The borehole was finally abandoned on 20 October 1997.

Borehole No. 1381. When preparing the borehole for the experimental blast, the shaft, from the surface to an elevation of 301.0 metres was backfilled with local, natural, crushed aggregate. Then a 1-metre thick cement plug was installed with a drilling unit, with its base resting on the backfilled soil.

The main Granulotol charge with a 22,000-kg mass was fabricated on 30 August 1997, 24 hours before the time set for triggering the charge. The containment vessel with the primers for the main charge was fabricated and lowered on 31 August, 2 hours before the blast.

The borehole charge design is illustrated in *Figure 2.23*. The charge in borehole No. 1381 was triggered on 31 August 1997 at 14:08 hours and 39.179 seconds local time.

The blast produced a crater up to 3.1 metres deep from the earth surface. The maximum diameter of the crater at the elevation of the earth surface was 10 metres; 20 m^3 of rock was discharged. As a result of the blast, a 15-m long fragment of the casing string was thrown 1.5 metres from the centre of the former borehole (*Figure 2.24*).

The crater was eradicated and the area levelled (the sealing of the borehole) by way of its backfilling with local, natural earth, using a bulldozer. Based on the results of the blast, DSWA representatives decided to amend the design of the abandonment process: backfill the crater with local earth and level the sector of the former borehole. The borehole was finally abandoned on 21 November 1997.

Borehole No. 1349 When preparing the borehole for the experimental blast, the shaft, from the surface to an elevation of 551.0 metres was backfilled with local, natural, crushed aggregate. Then a 1-metre thick cement plug was installed with a drilling unit, with its base resting on the backfilled soil.

The main Granulotol charge with a 22,000-kg mass (*Figure 2.25*) was fabricated on 30 August 1997, 24 hours before the time set for triggering the charge. The containment vessel with the primers for the main charge was fabricated and lowered on 28 September, 2 hours before the blast. The design of the charge in the borehole is illustrated in *Figure 2.23*.

The charge in borehole No. 1349 was triggered on 28 September 1997 at 14:30 hours and 15.126 seconds local time.

The blast created a crater, 10 metres deep from the surface, with piles of earth up to 3.1 metres high. The maximum diameter of the crater at the elevation of the earth surface was 20 metres. The earth from the borehole was designed to be discharged in a north-westerly direction. A total of 260 m^3 of rock was discharged. As a result of the blast, fragments of the casing string from 1.5 to 11.6 metres long were thrown 40 metres from the centre of the former borehole.

The crater was eradicated and the area levelled (the sealing of the borehole) by way of its backfilling with local, natural earth, using a bulldozer. The borehole was finally abandoned on 11 November 1997.

Figure 2.24. *Borehole No. 1381 after the blas*

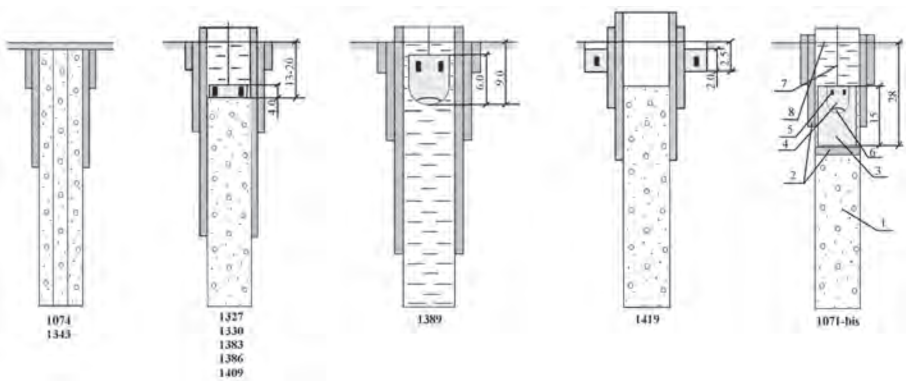
Figure 2.25. *Borehole No. 1349 Laying the explosives*

Borehole No. 1071-bis. The base of the charge was placed at an elevation of

28 metres (*Figure 2.26*). The base of the primer, fabricated from 24 kg of T-400G detonator cartridges, 16 kg of No. 6ZhV ammonite, 2,400 metres of DShE-12 detonator cable and 1,000 kg of Granulotol, was placed at a depth of 23 metres (at the opening). The primer was placed in a purpose-built containment vessel, 8.0 metres long and 1.0 metre in diameter.

The charge weighed a total of 25,040 kg of explosives. The water column over the charge was 14 metres high. The charge was detonated on 17 September 1998 at 07:19 hours and 40.551 seconds GMT.

A crater formed as a result of the blast (*Figure 2.27*) with a diameter at the upper part of the earth pile at 55 m and 18 metres deep (*Figure 2.28*). A total of more than 6,500 m^3 of rock was discharged. Fragments of rock and pieces of borehole casing were thrown over 500 metres from the epicentre of the blast. Two days later the crater was filled with ground water to a 4.0-metre elevation from the previous earth surface.



1. *gravel backfilling*
2. *concrete floor plate*
3. *main Granulotol charge*
4. *containment vessel with detonating charge*
5. *primers (two)*
6. *DShU-33M (reinforced detonator cable RDC-33M)*
7. *cable*
8. *water level in the boreholes*

Figure 2.26. *Design of charges for abandoning the test boreholes*

The crater was eradicated and the area levelled (the sealing of the borehole) by way of its backfilling with local, natural earth, using a bulldozer.

The borehole was finally abandoned on 11 November 1997.

The remaining nine test boreholes were abandoned using the methods specified in *Table 2.6*. Seven boreholes were closed using explosives.

The closure method was chosen based on the objectives of the work, the features and condition of the borehole shaft, the radioecological state of the borehole head site and underground waters.

The design of the charges is illustrated in *Figure 2.26*.

Blasts to destroy the boreholes were detonated on 13 and 14 July, 14 and 15 August 1998. On 13 August, an experimental detonation of an ammonium nitrate material was performed on the earth surface by borehole No. 1383 and, on 14 August, in borehole No. 1383 at a depth of 190 metres. On 15 August, a field experiment was conducted with 100 kg of explosives and, on 17 September, the experimental blast with 25,040 kg of explosives in borehole No. 1071-bis. A number of features of the blast are presented in *Table 2.7*.

Figure 2.27. *Fragment of the blast*

Figure 2.28. *Crater after the blast at borehole No. 1071-bis*

Table 2.6. *Test borehole closure methods*

Method number	Method description	Liquidated test borehole No.
1	Cutting drive and drill pipes, backfilling with natural material, adding scrap metal and surfacing of the sector	1074, 1343
2	Borehole backfilling with local soil, destroying drive pipes using blasting from inside the borehole with 2 tonnes of explosives and surfacing of the sector	1327, 1330, 1383, 1386, 1409
3	Cutting drive pipes by blasting, backfilling with natural material and surfacing of the sector	1389
4	Backfilling the borehole with gravel to a 20-metre elevation, destroying pipes by blasting with 2 tonnes of explosive from outside, backfilling the borehole with natural material, with the addition of scrap metal and surfacing of the sector. During the course of the work, underground water must not be allowed to spill from the borehole onto the ground surface.	1419

Almost all blasts were effective in destroying the borehole shafts. Craters formed as a result of the blasts, the features of which are presented in *Table 2.8*.

Table 2.7. *Features of the blasts to destroy boreholes*

Borehole No.	Mass of explosive charge (kg)	Depth of charge placement (m)	Blast date	Blast time (GMT)	Notes
1327	2028	20	14.07.98	05.11.35.570	
1330	2028	20	14.07.98	08.19.39.296	
1383	223	190	14.08.98	07.44.11.545	ACM demolition
	2024	14	15.08.98	02.40.59.116	
1386	2028	20	13.07.98	10.44.56.363	
1389	2024	9	15.08.98	05.05.11.156	
1409	2024	13	14.08.98	04.28.52.815	
1419	2024	2.5	14.08.98	05.39.24.970	

Table 2.8. *Crater characteristics*

Borehole number	Crater dimensions in metres across the upper part of the pile		Volume of discharged rock (m^3)	Presence of underground waters in metres from earth surface
	diameter	depth		
1327	No crater			
1330	16.0	2.5	600	No
1383	12.0	3.0	550	No
1386	19.0	4.5	1350	3.5
1389	28.0	4.5	3000	2.0
1409	18.0	5.2	1760	No
1419	11.4	3.0	400	No

The blast of 2,028 kg of explosives, placed at a depth of 20 metres in borehole No. 1327, burst the borehole casing at a depth of about 13 metres from the earth surface. In so doing, the borehole casing rose 0.7 metres above the earth surface, but no crater was formed as a result of the blast. The borehole casing was then removed using gas cutting.

The boreholes were completely abandoned, meaning sealed, by backfilling the craters with local soil that had been discharged by the blast, adding scrap metal, collected from sites adjoining the area of the boreholes. Here, the volume of the scrap metal did not exceed 5% of the backfill.

At the end of the backfilling of the crater, the sector was levelled over an area of 100 x 100 metres (*Figure 2.29*).

Temporary field roads were graded and built using a bulldozer to ensure safe transport of explosives and personnel.

Figure 2.29. *External appearance of the working area after levelling*

2.4.4. Seismological support

Given that the boreholes, destroyed using explosives, were located across a considerable territory of the Balapan Area and that extensive radiographical coverage was possible for tomographic depiction of the test site's velocity characteristics, all blasts were recorded by seismic stations of the National Nuclear Centre in collaboration with the Los Alamos National Laboratory of the University of California.

A network of 8 temporary, three-component, seismic stations were created to record seismic signals at the Balapan Area. The seismic devices were located in mine workings with a circular cross-section (bell pits) with a 900-mm diameter and 0.8-m depth. The bottom of the excavated area was filled with a 5-centimetre layer of mortar.

The temporary seismic network was fitted with seismographic stations such as REFTEK, which are equipped with short-period L4-C-3D seismic sensors. An FBA-type accelerometer was installed at the first station, located near the experimental borehole (SE).

DSWA specialists selected the location of each station at the area.

The coordinates were determined using GPS (*Table 2.9*).

Over the course of 1997 and 1998, a total of 20 blasts were conducted at the Balapan Area. The charge mass varied from 51.2 to 25,040 kg and the placement depth of the explosive charge varied from 0.0 to 630.0 metres.

Granulotol was the main explosive used for closing the boreholes. In addition ammonium nitrate explosives known as Granulite E were successfully tested at borehole No. 1383, both on the earth surface and at a depth of 190 metres.

Table 2.9. *Coordinates of temporary seismic network stations*

Station number	GPS coordinates	
	North latitude	East longitude
SE 1071-bis	49°58’54.9”	78°45’21.2”
SE 1327	49°56’06.9”	78°47’12.8”
SE 1330	49°56’58.0”	78°44’53.9”
SE 1383	49°52’17.4”	78°38’52.0”
SE 1386	49°52’51.4”	78°41’31.4”
SE 1389	49°52’39.7”	78°45’36.4”
SE 1409	50°02’22.5”	79°00’38.5”
SE 1419	50°03’50.0”	78°56’17.9”
S2	49°51’50.0”	78°52’12.4”
S3	49°56’58.0”	78°44’53.9”
S4	49°52’35.8”	78°45’49.0”
S6	49°49’18.5”	78°45’11.2”
S7	49°51’09.4”	78°59’02.8”
S8	49°58’18.8”	78°45’32.4”
S9	49°58’18.8”	78°57’31.7”

As a result of the work, 13 unused test boreholes at the Balapan Testing Area were abandoned and sealed off. Industrial explosives, permitted for application in

Kazakhstan, were used for their abandonment, while technology was developed and applied for the first time in the world for charging and blasting industrial explosives under hydrostatic pressure up to 6.0 MPa in large-diameter boreholes (over 1.0 m).

The seismic waves that the blasts caused in abandoning the boreholes were recorded by a network of purpose-built, temporary, seismic stations at the Balapan Area and by seismic stations and observatories of the National Nuclear Centre.

There was no deterioration in the environmental condition of the area, including of a radioecological nature, as a result of the closure of the test boreholes.

2.4.5. Abandonment of silo launchers at the Balapan Testing Area

In execution of the Agreement between the United States and Kazakhstan Concerning the Destruction of Silo Launchers of Intercontinental Ballistic Missiles, Emergency Response, and the Prevention of Proliferation of Weapons of Mass Destruction of 13 December 1993, the Agreement between the US Department of Defence and the Kazakh Ministry of Science on abandoning nuclear weapons infrastructure dated 3 October 1995 (allowing for the Amendment of 10 June 1996) and under the Contract DNA 001-95-C-0179 of 19 October 1995, executed between the National Nuclear Centre and the US Defence Nuclear Agency, SS-18 silo launchers within the area of the former seismic field stations were abandoned.

The seismic field stations are located in the south-east of the former Semipalatinsk Test Site, in the district of Balapanzhyr, 110 km from Kurchatov and 8 km from the Shagan River valley – in the centre of the region where underground nuclear tests were performed.

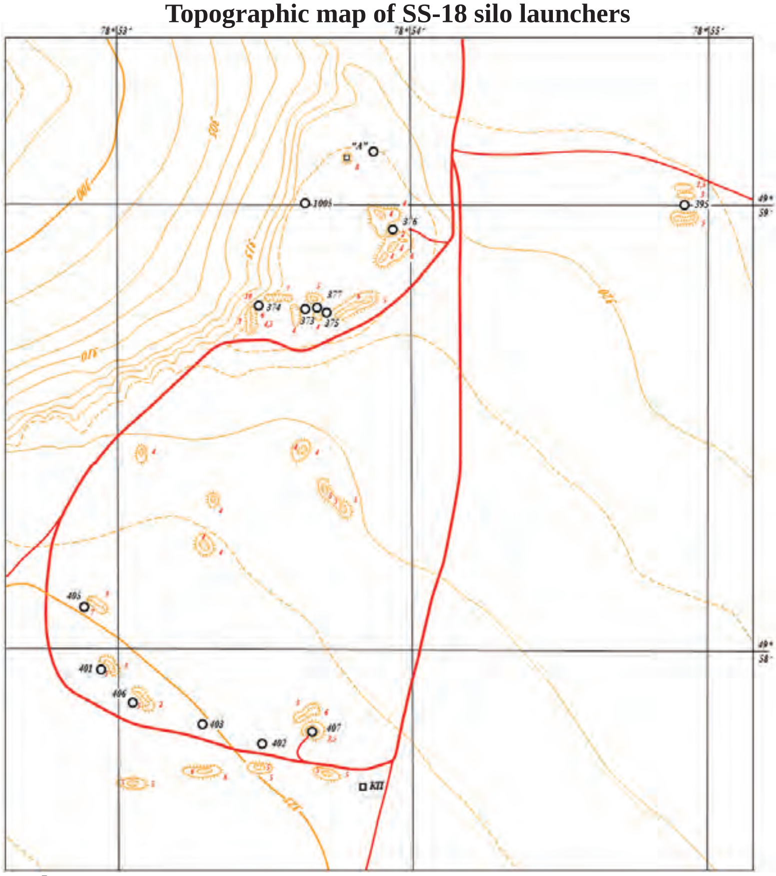
The seismic field stations cover an area of some 2 square kilometres and its area is marked by remnants of the protective enclosure made of barbed wire. The complex includes two groups of structures, each including 6 silo launchers, in turn also enclosed within security fencing (*Figure 2.30*).

Each structure, unlike a standard silo launcher area of the missile forces, where, in addition to the silo launchers, all facilities are ground-based, consists of the silo launcher itself and underground bunkers of cast-in-place, reinforced concrete, to house missile control systems, vital facilities for the control post personnel and research equipment. The bunkers and installations are connected with underground tunnels, 20 to 50 metres long. There are 5 to 10 vertical, reinforced concrete downholes around each shaft, up to 4 metres deep.

The entire area of the seismic field stations takes the form of an artificial bank of discharged earth, up to 10 metres high, inside which, at various heights from the datum level, there are shafts, bunkers, tunnels and craters up to 20 metres deep and up to 30 metres in diameter, which formed during the course of strength tests on the silo launchers after explosive work and during the detonation of the borehole heads. About 5–7 km of neglected earth roads leading to each shaft remain within the complex, along with underground steel fire water tanks.

A large proportion of the seismic field stations is contaminated with reinforced concrete and steel fragments that formed from the rupture of additional reflector and concentrating structures upon the impact of the test charges. These fragments measure from 0.05 to 2 metres in size, with individual structures weighing as much as tens of tonnes. The region housing the seismic field stations is presented in *Figure 2.31*.

Topographic map of SS-18 silo launchers



Scale 1:130,000

LEGEND

Silo launcher

Boreholes

Ground-based buildings

Relief contours

Depressions

Hillocks

Roads

Figure 2.30. *Map to illustrate silo launcher locations at seismic field stations*

There are three live boreholes in the immediate vicinity of the seismic field stations: borehole A, at a distance of 150 metres, borehole No. 1005, 200 metres away and also the Glubokaya [Deep] borehole, 450 metres away, which subsided after a collapse during a gas explosion 17 years after the testing. The entire region is in a zone of probable radioactive contamination: during preliminary exploration when preparing the installations for the blast, Russian forces at the silo launcher discovered a “spot” with a gamma-radiation dose level of 150 μR/hr and beta-radiation intensity of 90 particles/(min x cm^2). The preliminary area of this “spot” was 15 m^2 and the radioactive substance content increases with depth.

Kazakhstan has almost no information on the designation and experimental technologies pertaining to the impact on these silo launchers, the rigging and on the additional underground shaft structures.

In light of this, in 1996–1997, prior to the work commencing on abandoning the silo launchers, the National Nuclear Centre conducted a full characterisation of the silo launchers and analysed the radiation picture at the seismic field stations. It also elaborated recommendations to provide for radiation safety during the course of the work.

Approach from site 406

General view of site 401

Head of borehole 395

Remains of the cooling centre

Figure 2.31. *Views of the region housing the seismic field stations*

The silo launchers were dismantled in three main stages:

1. preliminary radiological survey of the silo launcher sites;
2. dismantling of the silo launchers and liquidation of focal points with radioactive contamination;
3. concluding radiological survey of the silo launcher sites. The radiological survey of the silo launchers included the following:

- radiation monitoring measurements in the locality (alpha- and beta-activity on the earth surface and measurements of exposure dose level) over a pre-segmented measurement grid (with 16 points for each silo launcher);

- soil sampling (144 samples were taken in the preliminary examination and 256 samples were taken in the concluding examination);
- laboratory analysis of samples for radionuclide content, including strontium, plutonium and heavy metals.

The following was established during the preliminary examination:

- silo launcher sites 401 and 406 contained remnants of building structures, the exposure dose level from which reached as much as 1.5 mR/hr, which classifies them under KPRZ-97 [the Temporary Criteria for Restricting Irradiation of the Public When Transferring Land into Business Use] as radioactive waste for burial. The background exposure dose level for this locality was 10–20 µR/hr.
- four contaminated sectors were detected on the sites of silo launchers 401 and 406:

— sector 1 – remnants of building structures (a volume of 42–50 m^3, exposure dose level up to 1.4 mR/hr and beta-active nuclide contamination of up to 2,500 particles/(min x cm^2));
— sector 2 – an area contaminated with ^{152}Eu (an area of about 100 m^2);
— sector 3 – remnants of building structures (a volume of 0.5 m^3, exposure dose level up to 40 mR/hr and beta-active nuclide contamination of up to 20 particles/(min x cm^2));
— sector 4 – remnants of building structures (a volume of 5 m^3, exposure dose level up to 40 mR/hr and beta-active nuclide contamination of up to 16 particles/(min x cm^2)).

As a result of this work, all silo launchers were fully destroyed and the relief levelled to a natural state.

After the rehabilitation work was completed and the silo launchers dismantled, the concluding radiological survey of the silo launcher areas indicated that there were no anomalous excess levels of alpha-, beta- or gamma activity in the area in question. The activity measured in the control points was recorded in the following limits:

— alpha activity – 0–1 particles/(min x cm^2);
— beta activity – 4–14 particles/(min x cm^2);
— gamma activity – 0.07–0.18 µSv/hr;
— no anomalous excess activity for all radionuclides for all silo launcher sites;
— no metal content in any samples higher than normative values.

The silo launcher sites are currently characterised by areas where the ground has subsided, most likely caused by internal cavities. These depressions take the form of circular hollows, scored with deep cracks that are circular and diametrically directed (*Figure 2.32*). Sometimes small pits of up to 50 cm in diameter and 1 metre deep are found in the centre or around the edges of the depressions. The depressions have various diameters, from several metres to several tens of metres (not usually more than 30 metres). In place of a former, unfinished silo launcher there is a circular depression, several metres deep, enclosed by the concrete wall structures of the former silo launcher (*Figure 2.33*).

The current radiation situation at the site of the silo launcher presents no danger to the environment or the general public. The content of radionuclides and metals in the soil lies within the average values for the region of silo launcher sites.

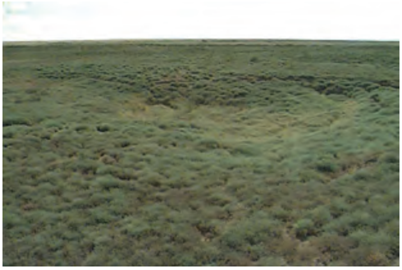


Figure 2.32. *A typical depression in the vicinity of the silo launchers*

Figure 2.33. *A circular depression in the site of an unfinished silo launcher*

2.5. Radiation examination of STS after completion of work [15]

After demilitarisation at STS, the radiation situation and its change were investigated, in order to study the impact of tunnel closure at Degelen Mountain and abandonment of boreholes and shaft-based launch installations at the Balapan Area on the radiation situation.

A radiation investigation was conducted on the near-entrance sites of 181 tunnels at Degelen Mountain, along with a study of the route taken by water flows from the tunnels and main streams of the mountain range. Several expeditions were devoted to studying the impact of tunnel abandonment on the flora and fauna of Degelen Mountain.

In 1999, radiometrical field measurements were taken of radiation parameters in the near-entrance sites: exposure dose levels and the density of surface contamination of alpha- and beta-emitters. Soil samples were taken in points with the highest contamination and then analysed to ascertain the radionuclide composition.

The radiation examination of the near-entrance sites was performed over an area of 8,000 m^2, using the chart presented in *Figure 2.34*.

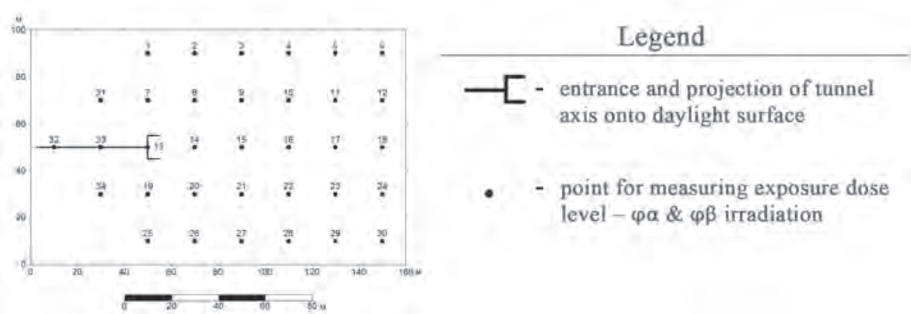
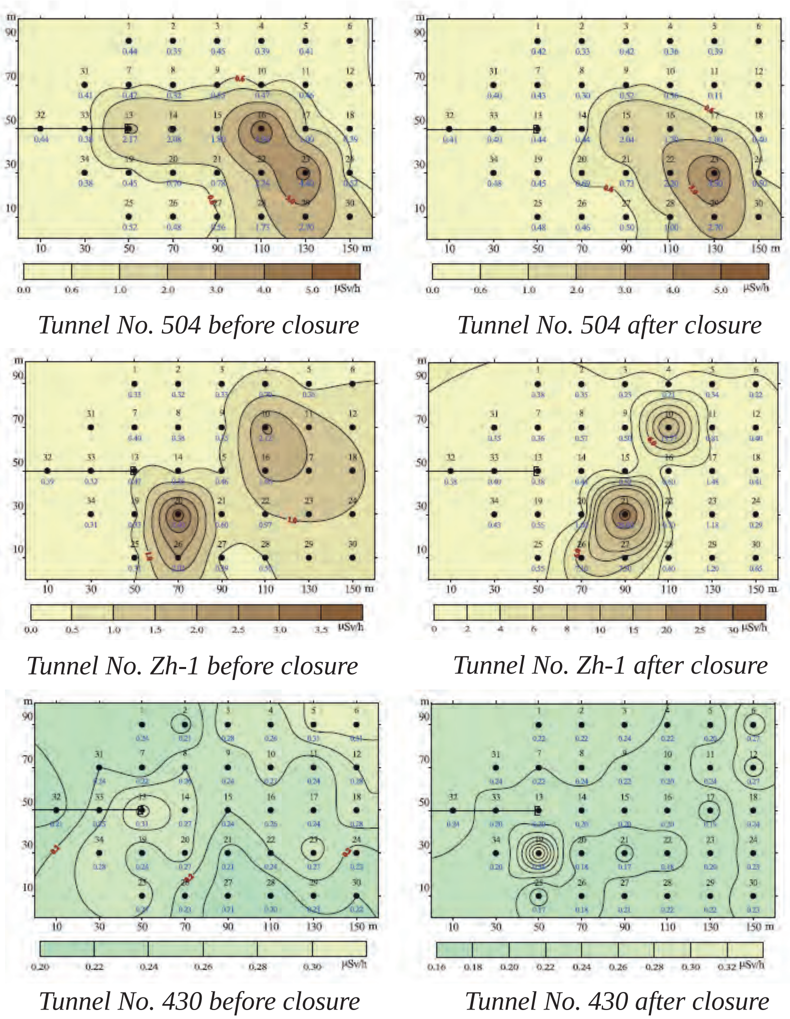


Figure 2.34. *Examination chart of near-entrance sites of tunnels*

By way of an example, *Figure 2.35* presents charts with values of the exposure dose level for certain, characteristic tunnels: No. 504, Zh-1 and 430.

To assess the impact of the abandonment of military infrastructure on the environment at Degelen Mountain, the results of field measurements were processed according to average values, specified for all measurement points in the near-entrance sections. This helped restrict the impact of separate, uncharacteristic points with maximum radiation parameter values, on the nature of the contamination of the entire sector in question.



Tunnel No. 504 before closure *Tunnel No. 504 after closure*

Tunnel No. Zh-1 before closure *Tunnel No. Zh-1 after closure*

Tunnel No. 430 before closure *Tunnel No. 430 after closure*

Figure 2.35. *Change in exposure dose level at the near-entrance sections of the tunnels as a result of their closure*

The degree of radioactive contamination of the tunnels' near-entrance sites was assessed according to the value of the exposure dose level, the most indicative radiation parameter.

Figure 2.36 presents a bar chart that describes the impact of tunnel abandonment on the natural environment according to weighted-average values for 181 tunnels.

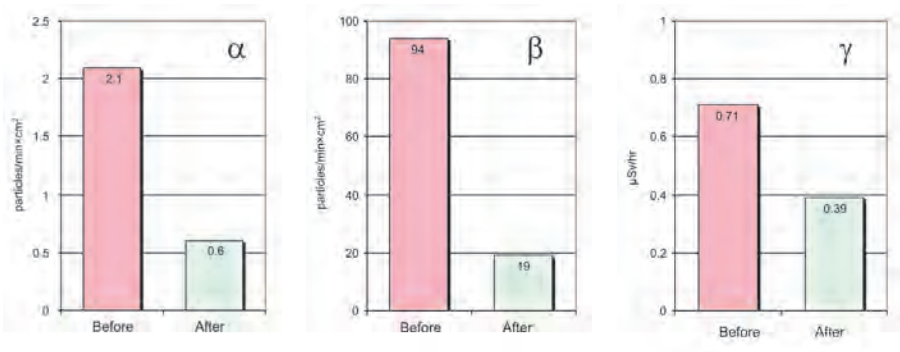


Figure 2.36. *Radiation parameters before and after tunnel closure*

The bar chart illustrates very clearly the improvement in the radiation situation at the tunnel near-entrance sites on Degelen Mountain.

The head sites of 13 boreholes and 12 dismantled, shaft-based launch installations at the Balapan Testing Area were subjected to radiation examination, involving the area measurement of radiation parameters (exposure dose level, surface contamination with alpha- and beta-emitters) and sampling from the natural environment according to set arrangements for laboratory analysis, in order to determine the isotope composition of radioactive contamination.

The impact of the abandonment work was assessed by comparing the radiation parameter values before and after the closure of the tunnels, boreholes and silo launchers. Particular attention was given to studying the impact of the hydrological regimen on the environment of Degelen Mountain.

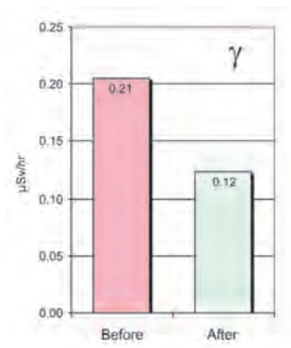
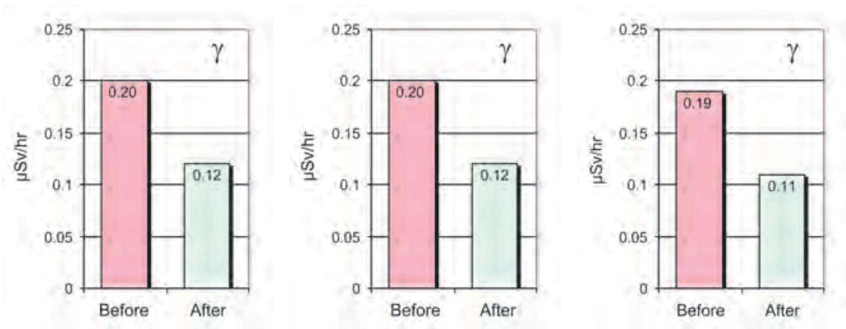


Figure 2.37. *Change in exposure dose level after the abandonment work*

Analysis of field data, taken before and after abandonment of the unused boreholes, indicated that the values of radioactive parameters at the borehole head sites were not in excess of norms, adopted in Kazakhstan. At the same time radiological monitoring showed that the abandonment efforts brought about a reduction in gamma radiation, as plain to see in the bar chart, formed using average-weighted values of exposure dose level for all boreholes in question (*Figure 2.37*).

The results of field radiometry, obtained before and after abandonment of the silo launchers, illustrated that the exposure dose levels in the studied areas were not in excess of the permissible norm of 0.6 μSv/hr. The density of surface contamination by alpha- and beta-emitters was also within established norms. Moreover, as a result of the abandonment work, gamma radiation fell at all borehole head sites, which is plain to see in the bar chart (*Figure 2.38*), formed using average-weighted values of exposure dose level for two areas housing silo launchers and for one standalone silo launcher.



a – area 1 *b – area 2* *c – silo launcher No. 395*

Figure 2.38. *Change in exposure dose level before and after silo launcher abandonment*

Based on analysis of the results from examination of the near-entrance areas of the tunnels at the Degelen Testing Area and the head sites of boreholes and silo launchers at the Balapan Testing Area, and their comparison with results of previous studies, the following conclusions can be reached:

1. As a whole, abandonment of the tunnels led to an improved radiation situation on Degelen Mountain. By backfilling the tunnel entrances, the radiation values dropped significantly. At the same time, the radiation values at the majority of tunnels exceed the level of global contamination for the middle latitudes of the Northern Hemisphere.
2. Abandonment of the boreholes and silo launchers did not generally alter the radiation situation at the Balapan Testing Area as no nuclear blasts were performed at the abandoned sites. The level of radioactive contamination at the head sites of silo launchers and boreholes does not exceed background values.
3. Without doubt, the backfilling of tunnel entrances and head sites of boreholes and silo launchers had a positive effect on the natural relief.
4. The cessation of industrial activity at Degelen Mountain led to an increase in numbers of certain animal populations and an expansion of their habitat. A number of species of animals and birds in the Red List of Kazakhstan have been sighted in the mountain range.

5. Access to the tunnel cavities, both for humans and animals, has been rendered impossible.
6. Underground nuclear tests led to a degradation of the vegetative cover of Degelen Mountain, which was observed at the start and during the backfilling of the tunnel entrances. A year later, however, there was evidence of restored vegetation of varying intensity, depending upon the composition of the backfill material and the volume of precipitation. The diversity of the species of this vegetation and the vegetation of adjacent areas is noteworthy. It is not out of the question that herbs, characteristic for the adjacent areas, will appear at the near-entrance sites, but this would need a longer recovery period to confirm. Monitoring of flora did not reveal any changes in vegetation at a genetic level.

Thus, the abandonment work performed at the Balapan and Degelen testing areas between 1995 and 1998 had a positive effect on the state of the environment. That said, the research shows that abandonment of the tunnels with water ingress at Degelen Mountain, where the aqueous system renders a significant impact on the environment, did not fully inhibit the migration of radionuclides from the tunnel cavities.

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14. Materials from summary report under Contract DSWA01-98-C-0064
15. Materials from summary report under Contract DTRA01-99-C-0023

CHAPTER 3. REDUCING PROLIFERATION RISKS

3.1. Collaborative efforts of Kazakhstan and Russia

After the cessation of tests at the former Semipalatinsk Test Site, facilities still remained that contained sensitive information on the nuclear testing technology. Such facilities include the Kolba containment vessels, individual tunnels at Degelen Mountain, areas containing dispersed nuclear waste and other special process equipment for tests and recording hardware. Economic activity within the test site, including unauthorised activity, considerably raised the likelihood of access to sensitive information and could have led to breaches in observance of provisions of the Nuclear Weapons Non-proliferation Treaty and to a threat of radiation-based and nuclear terrorism [1].

Negotiations on demilitarisation of the test site on the level of the governments of Kazakhstan and Russia began on 25 December 1993 in Alma-Ata, where Chairman of the Government of the Russian Federation Viktor Chernomyrdin and Prime Minister of the Republic of Kazakhstan Sergey Tereshchenko met and agreed that, over January and February 1994, they would review issues related to *eradication of the consequences of nuclear weapons testing at the Semipalatinsk Test Site* and draw up solutions.

To this end, pursuant to Instruction No. ASh-P8-00315 of the Government of the Russian Federation of 18 January 1994, the heads of the Russian Ministry of Defence were obligated to hold talks with the leaders of Kazakhstan on matters that determine the specific involvement of both Russia and Kazakhstan in implementation of the Programme to Assess the Consequences of Nuclear Testing at the Semipalatinsk Test Site [2].

To address these issues, the Russian Federation presented its own suggestions, the essence of which involved the following:

- to entrust all coordination of the actions of Russian ministries and departments when holding talks on this problem to the Russian Ministry of Cooperation with Member States of the Commonwealth of Independent States (Minsotrudnichestvo) and the Russian Ministry of Foreign Affairs;
- the concept of the talks should obviate any possible future claims from the Kazakhstani side as regards biased approaches to assessing the consequences of nuclear tests, and it should take into account that the Programme should be financed predominantly by the Kazakh side;
- the Programme of works must be signed by both parties on an intergovernmental level and shall contain a clause on the need to resolve the critical problem of dismantling or destruction of the nuclear device, located since 1991 in the end box of Tunnel No. 108-K. The Russian side shall finance the work on resolution of this problem.

It is noteworthy that both parties were extremely keen on the successful implementation of this Programme.

Further bilateral cooperation progressed under various treaties and agreements, such as:

- the 12 October 1998 Treaty between the Republic of Kazakhstan and the Russian

Federation on Economic Cooperation for 1998–2007, containing the Economic Cooperation Programme of the Republic of Kazakhstan and the Russian Federation for 1998–2007 (EC Programme);

- the 26 June 1992 Agreement between Member States of the Commonwealth of Independent States on the main principles of collaboration in the peaceful use of atomic energy (the 92 Agreement);
- the 23 September 1993 Agreement between the Government of the Russian Federation and the Government of the Republic of Kazakhstan on cooperation in peaceful use of atomic energy (the 93 Agreement);
- the Prospective Plan for Developing Cooperation between CIS Member States in the Peaceful Use of Atomic Energy, ratified by the Council of Heads of Government of the CIS dated 27 January 1997 (the Prospective Plan);
- the 28 March 1997 Agreement between the Government of the Russian Federation and the Government of the Republic of Kazakhstan on the Kolba containment vessels and special process equipment at the former Semipalatinsk Test Site (the Kolba Agreement). The Agreement stipulated a package of works with five tested (containing nuclear waste) and one untested Kolba containment vessel and other special process equipment at the former STS. Procedures were determined for implementing security measures and ensuring radiation and environmental safety during the course of the work.

A Steering Group (SG) was formed to implement the 28 March 1997 Agreement between the Government of the Russian Federation and the Government of the Republic of Kazakhstan on the Kolba containment vessels and special process equipment at the former Semipalatinsk Test Site (the Kolba Agreement). Technical experts from both parties to the Kolba Agreement were engaged to work in the SG. A special group of scientific and technical experts drew up recommendations to address sensitive issues as part of the SG. The mechanism for using the SG tool was first successfully deployed when working on destroying the last nuclear device, located in Tunnel No. 108-K at Degelen Mountain, and it was used in further joint work on mitigating proliferation risks at STS [3].

The parties to the Kolba Agreement collaborated, allowing for the approved and ratified Agreed List of Carriers of Sensitive Information when working at the former STS. The list was drawn up based on the Findings of the working group of experts from Russia. This list contains 29 items.

Between 1997 and 2000, as part of work on implementing the Agreement, specialists from Rosatom (Russian Federal Nuclear Centre – All-Russian Scientific Research Institute of Experimental Physics [VNIIEF] and All-Russian Scientific Research Institute of Technical Physics [VNIITF]) and the NNC worked on all 29 items of the List of Carriers of Sensitive Information.

The Russian side financed work on a number of facilities in the List (VNIIEF and VNIITF). The following was achieved as a result:

- the permanent shutdown of five tested Kolba containment vessels at two sites of Degelen Mountain and the area *RBSh*;
- the destruction of the structure and permanent shutdown of the untested Kolba containment vessel at the area *RBSh*;

- destruction of the special process equipment containing nuclear waste in boreholes at the Aktan-Berli Area [A-B];
- dismantling and permanent shutdown of the activated special process equipment at the Aktan-Berli Area;

Figure 3.1. *Working meeting of the trilateral session of the Steering Group*

- dismantling and dekitting of twenty-six hardware complexes, designed to record physical parameters during underground nuclear tests and the repatriation to Russia of the six most significant hardware complexes. At the same the SG needed to continue working to find new carriers of sensitive information at the former STS. Information was received from Russia on new sites during trilateral operations (Kazakhstan–Russia–USA). In so doing, taking into account the effect of the Non-proliferation Treaty, the information was presented to the USA for decision making. The USA financed the work under the CTR Programme and the corresponding supplements to the executive agreements under the umbrella agreement of 13 December 1993 between Kazakhstan and the United States on destroying the silo launcher installations for intercontinental ballistic missiles, eradicating the consequences of emergencies and preventing proliferation of nuclear weapons (the Silo Launcher Agreement). Representatives from the US Department of Defence occasionally took part in the Steering Group meetings to assist in coordinating work, conducted on a trilateral basis and pursuant to the approved decisions of the Steering Group session and subsequent trilateral arrangements. The arrangements agreed upon on a trilateral level were documented in the form of minutes of trilateral meetings of technical experts and were recorded in SG minutes. All minutes of the Steering Group were signed by SG members and ratified by the official representatives of the Kolba Agreement parties. The

Kolba Agreement remains in effect. There is a working mechanism of the Russia-Kazakhstan Steering Group, which includes representatives of the ministries and departments of both parties. It is proposed that the effect of the Agreement be expanded to encompass issues, associated with collaboration between Kazakhstan and Russia on STS.

The Kazakhstan-Russia Steering Group reviews all issues that present a potential hazard of the proliferation of sensitive information linked with the work performed at STS (including international projects with a third party within STS).

Joint Kazakh-Russian projects were determined according to the special List of sensitive sites that are subject to abandonment (permanent shutdown). The programme of works that fall under the List has been developed in light of new assignments, associated with the need to prevent the proliferation of nuclear waste (non-proliferation and anti-terror modes).

The territory of STS has a combination of problems, associated with the non-proliferation of weapons of mass destruction (WMD), the eradication of the consequences of nuclear tests and the prospects of developing atomic energy (the reactor research base of NNC, located at STS, the prospects of developing the scientific production complex at Kurchatov – nuclear fuel, Tokamak etc) [4].

3.1.1. Abandonment of the last nuclear charge in Tunnel No. 108-K

On 28 March 1994, the Kazakh Government and the Russian Government executed the Agreement on dismantling the nuclear device in Tunnel No. 108-K, which was signed by the heads of the respective governments, Sergey Tereshchenko and Viktor Chernomyrdin.

Work began at the Degelen Testing Area and continued there for an entire year on uncovering Tunnel No. 108-K and driving a bypass shaft to the end box, where a purpose-built nuclear device had been located for a considerable time in complicated and unregulated conditions.

It is noteworthy that the closure of the test site and the disbandment of the military units disrupted the traditional preparations, provision and performance of labour-intensive survey work there. Therefore, matters pertaining to the dismantling of the nuclear device at site No. 108-K were addressed by forming a dedicated expedition team from VNIITF specialists, who had to operate autonomously, with the support of NNC and its main divisions, such as the Atomic Energy Institute (Director Yuri Cherepnin) and the Radiation Safety and Ecology Institute (Director Samat Smagulov). The most complex mining work was performed with specialists from the Degelen small industrial business (Director Alexander Klimov).

Herman Zyryanov was appointed head of the expedition team and Boris Andrusenko was appointed operations manager. Both hail from the Russian Federal Nuclear Centre – All-Russian Scientific and Research Institute for Technical Physics (VNIITF) [3].

The operation was named *Uncovering of the structure and its destruction* and was elaborated in a very short time by VNIPIpromtekhnologiya specialists, headed by Evgeniy Kozlov. This operation provided for the breaking up of the thick plugging system in the tunnel, dismantling the complex physical vacuum installation and following the bypass shaft to penetrate the end box and reach the nuclear device. As the warranty service life of this purpose-built device was short, in accordance with the technical conditions, and as it had been under the impact of non-nominal, complex factors for almost four years, including the flooding of the end box with water, it was only natural that extreme care should be taken when performing the work.

The operation for destroying the purpose-built device was presented for expert review by the Russian Atomic Energy Ministry (Minatom) to environmental organisations in Kazakhstan, to assess its radioecological danger for a considerable period of time. Furthermore, the Interdepartmental Expert Commission on Assessing Radiation and Environmental Hazards of Non-nuclear Experiments (MVEK-NE), made up of independent experts representing the Russian Atomic Energy Ministry, the Russian Health Ministry, the Russian State Committee for Environment Protection (Goskomekologiya), the Russian Federal Service for Hydrometeorology and Environmental Monitoring (Rosgidromet) and the Russian Ministry of Defence, presented its positive conclusion on this operation. The co-chairs of the commission, representing each of the above departments, are A.M. Matushchenko, V.A. Logachev, A.B. Ivanov and G. A. Krasilov.

A Steering Group was formed to coordinate efforts on destroying the nuclear device; it included specialists from various organisations and departments of the Russian Federation and the Republic of Kazakhstan.

Alexander Shcherbin (VNIITF) was appointed Chairman of the Steering Group. The Russian Federation was represented on the SG by G.P. Zyryanov, A.M. Matushchenko and K.V. Kharitonov (Minatom), O.V. Komkov (the Russian Ministry of Defence), V.N. Fedorov (the Russian Ministry of Foreign Affairs), V.V. Kuznetsov (Russian Ministry of Internal Affairs) and V.D. Fomichev (Gosatomnadzor of Russia [State Atomic Energy Supervision Authority]). The Republic of Kazakhstan was represented by T.M. Zhantikin and S.V. Krechetov (the Atomic Energy Agency), S.G. Smagulov and Sh.T. Tukhvatulin (NNC), Yu.N. Leontiev (the Kazakh Ministry of Defence), Yu.R. Abdukadyrov and B.B. Sadykov (the Kazakh Ministry of Internal Affairs), V.I. Pichulskiy (Gosgortekhnadzor of Kazakhstan), S.P. Shevtsov (the Kazakh Ministry of the Environment and Bioresources) and M.A. Tuleshev (Main Regional Administration of the Kazakh Finance Ministry). V.G. Smirnov was appointed Executive Secretary of the Steering Group. A number of highly qualified specialists also contributed significantly to the work of the Steering Group. They include Yu.I. Vashchinkin, A.A. Grigoryan, S.V. Demyanovskiy, Yu.I. Kuznetsov, V.N. Khlopunov, N.S. Shcherbatyuk, V.V. Ganja, R.A. Aitmaganbekov and A.M. Klimov [3].

During the course of the work under the operation, seven sessions of the SG were held, where critical decisions were taken on destruction of the nuclear device in Tunnel No. 108-K and coordination of collaboration both on intergovernmental and local levels.

It is noteworthy that during preparation of the intergovernmental agreement in 1992–1994, the Russian party warned on several occasions about the destruction of the nuclear explosive device, lying in the end box for about four years at a humidity of over 80%, if there were any doubts as to the safety of its dismantling. The agreement stipulated the destruction of the device by detonating a pressure charge of chemical explosives with complete avoidance of nuclear energy release, which was ensured through the corresponding control measures.

Tunnellers were among the first to start work at Tunnel No. 108-K. When they were drilling the bypass channel to reach the end box, VNIITF specialists in Snezhinsk were ascertaining the possible state of units and assemblies of the nuclear device which had been standing for a long time in uncontrolled conditions and which was designed to be used to study the effect of high-level radiation on specimens of military and space equipment. By the time the work had started, it was already clear that during the closure period the tunnel had been flooded by underground waters, possibly on numerous occasions. The results of design, analytical and experimental research into determining the state of active materials and explosives in the nuclear device indicated that there were several hazard factors, which could have become apparent during the dismantling of the nuclear device.

After discussion of all possible solutions to the problem, the Scientific and Technical Council of VNIITF spoke up unequivocally in favour of destroying the nuclear device at the place of its installation. The specialist commission, headed by the director of this nuclear centre Professor V.Z. Nechai and appointed by order of the Minister for Atomic Energy V.N. Mikhailov, having inspected the end box and the containment vessel bearing the nuclear device, adopted the final decision to destroy the nuclear explosive device without uncovering and isolating the containment vessel with it from the physical installation.

On 31 May 1995, the nuclear device was destroyed in the end box using a purpose-built pressure charge with chemical explosive and without the release of nuclear energy.

The destruction of the device was recorded by three, independent remote control methods. The design conditions of the deployment, the time and the completeness of detonation of the explosive in the system were recorded unequivocally.

To ensure the reliable localisation of harmful and radioactive products in the zone of device destruction, new technologies, developed by specialists from VNIPIpromtekhnologii of the Russian Atomic Energy Ministry were applied in the plugging system, based on the use of cement-bentonite solutions.

Based on the results of radiation control, performed during the first five days after destruction of the nuclear device, it was found that the observed parameters of the radiation situation, both inside the tunnel and at the entrance, were at the level of the natural background.

All work conducted at Tunnel No. 108-K was completed in full accordance with the obligations, both of Russia as regards the moratorium on nuclear testing and of Kazakhstan upon its accession to the Nuclear Weapons Non-proliferation Treaty. The joint work of the two countries, once part of a united USSR, on the destruction of the nuclear device, generated considerable international interest, which is illustrated in the fact that the ambassadors of the USA and Japan in Kazakhstan visited Tunnel No. 108-K the day after the VNIITF expedition team left the site and, using their own dosimeters, they personally assured themselves of the complete ecological cleanness of the work.

The practice of rapid resolution of issues that arose during performance of the intergovernmental agreement through the Steering Group, consisting of specialists from different ministries and departments, involved in implementation of the *Uncovering of the structure and its destruction* project, proved very useful. Moreover, during abandonment of the nuclear device in Tunnel No. 108-K, a model for collaboration and cooperation of nations was trialled during the addressing of this complicated scientific and technical assignment, a model which was later to be used to address other problems.

The group of specialists from Russia and Kazakhstan were awarded a prize from the Russian Government in 1995 for Science and Technology, for their successful fulfilment of the intergovernmental agreement. These specialists include: from VNIIEF – B. Andrusenko, A. Klimov, Yu. Kuznetsov, A. Muzyrya, Yu. Polovinkin,. B. Rybin, V. Smirnov, Kh. Suleimanov, V. Filin, A. Shcherbina; from VNIPIpromtekhnologii – A. Grigoryan and E. Kozlov; from the Russian Atomic Energy Ministry – K. Kharitonov; from the Radiation Safety and Ecology Institute, NNC – S. Smagulov; from the Kazakh Atomic Energy Agency – T. Zhantikin. Moreover, G. Zyryanov and A. Matushchenko were awarded a Diploma by Kazakh President Nursultan Nazarbayev.

The work was an example of the specific and constructive efforts of both parties within the non-nuclear state, where a nuclear test site once stood and where all conditions pertaining to the non-proliferation of sensitive information had to be strictly implemented.

3.1.2. Permanent shutdown of Kolba containment vessels

The Kolba containment vessels are classed as so-called *super-containers*, designed to transport and store highly-hazardous cargoes, including explosives, highly toxic and radioactive substances, with complete localisation in sealed conditions of the products of an unauthorised explosive blast with a maximum force of up to 50 kg of TNT. The containment vessels are secured on transport support facilities, but they can be removed from them if needed.

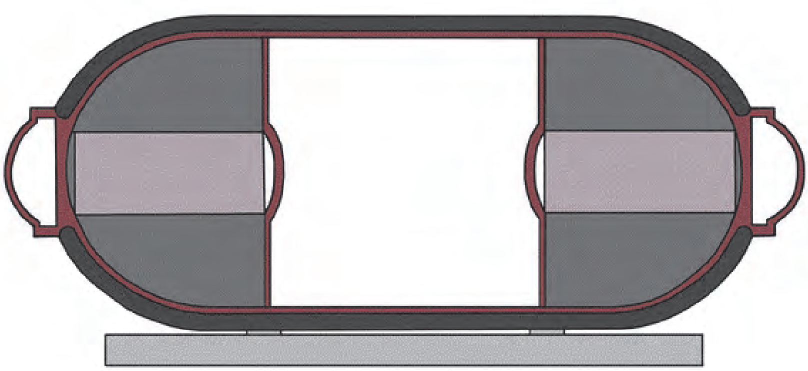


Figure 3.2. *Model Kolba containment vessel*

The design, development, scientific research and experimental design work on the containment vessels was conducted by specialists from the All-Russian Scientific and Research Institute for Experimental Physics (VNIIEF), whose representatives are directly involved in the permanent shutdown of the sites.

The entire steel surface is enclosed in a fibreglass and epoxy-resin layer (*Figure 3.2*).

There are three spent Kolba containment vessels at the former STS, in two ground-based facilities at the sites *RBSh* and K-85. Tests were performed in two containment vessels using radioactive substances; they contain nuclear waste and they pose a radiation hazard and a proliferation threat. One containment vessel, the so-called *Clean* vessel, was blast-tested with explosives in 1999. Three other containment vessels are located at the 200ASM site. In all STS contains six containment vessels.

In 1997–2000, NNC and VNIIEF worked on the permanent shutdown of containment vessels as part of abandonment of the nuclear test site infrastructure. The containment vessels at the sites *RBSh* and K-85 were embedded in concrete directly in ground-based concrete structures and these structures themselves were then bunded with earth. In 1998 three spent Kolba containment vessels were shut down at Tunnel No. 200ASM at Degelen Mountain, involving the hermetic sealing of the containment vessels and the formation of concrete plugs with subsequent tunnel closure with a concrete plug.

Key project objectives:

- reduction of the informative value of nuclear test sites;
- abandonment of nuclear test infrastructure;
- preventing unauthorised access to the Kolba facilities.

The solution chosen for shutting down the tested Kolba containment vessels is based on the vessel's ability to maintain long-term, sealed containment after its modification by VNIIEF specialists.

3.1.2.1. Permanent shutdown of the tested Kolba containment vessel at site K-85

Site K-85 is located in the southern part of Degelen Mountain. The tested Kolba containment vessel is installed on a rail platform in an embedded concrete structure (a special structure), at the borehole head site, some 160 m from the tunnel entrance (*Figure 3.3*).

The permanent shutdown work was comprised of three stages:

1. Opening the containment of the K-85 concrete structure and providing access to the Kolba containment vessel;
2. Preparation of the containment vessel for long-term storage;
3. Concrete casing of the entire structure in which the Kolba containment vessel is housed (*Figure 3.4*).

Figure 3.3. *View of the special structure, housing the Kolba containment vessel*

Figure 3.4. *Concrete casing of the entire structure in which the Kolba containment vessel is housed*

3.1.2.2. Permanent shutdown of the tested Kolba containment vessels at site *RBSh*

A reinforced concrete *settling basin* structure, bunded in earth, located about 90 km from Kurchatov, within the former STS, was used as the site for the permanent shutdown of the tested Kolba containment vessels at site *RBSh* (*Figure 3.5*). The two tested Kolba containment vessels were shut down in two stages. At the first stage, the Kolba containment vessel, tested during the Kolba Explosive Attestation experiment, was shut down. At the second stage, the Kolba containment vessel currently in the *settling basin* facility was shut down.

Permanent shutdown of the Kolba containment vessel, tested during the Kolba Explosive Attestation experiment. After performance of the Kolba Explosive Attestation experiment and regulated work by VNIIEF on examining the condition of this containment vessel, the vessel was shut down in the following sequence:

- construction of the engineering platform near the *settling basin* facility;
- opening the concrete wall, masking the entrance to the *settling basin*;
- radiation examination of the *settling basin* and the Kolba containment vessel currently housed in it;
- moving the Kolba containment vessel, tested during the Kolba Explosive Attestation experiment, to the *settling basin*;
- equipping work stations at the neck of the moved Kolba containment vessel;
- performance of regulated work by VNIIEF on hermetically sealing the necks of the Kolba containment vessel;
- erection of formwork and backfilling with soil the containment vessel, tested during the Kolba Explosive Attestation experiment;
- closure of concrete wall B.

Permanent shutdown of the Kolba containment vessel in the *settling basin* The containment vessel was shut down in the following sequence:

- opening of concrete wall A, masking the entrance to the *settling basin*;
- moving the containment vessel inside the *settling basin* to the site of permanent shutdown;

Figure 3.5. *View of Kolba containment vessel at site RBSh*

- equipping work stations at the neck of the containment vessel;
- performance of regulated work by VNIIEF on hermetically sealing the necks of the Kolba containment vessel;
- preparations for concrete pouring and concreting the containment vessel;
- closure of concrete wall A;
- dismantling the engineering platform equipment;
- dismantling the slabs of the concrete structure by wall B;
- bunding the ends of the *settling basin* facility with earth.

The diagram showing the location of the Kolba containment vessels at site *RBSh* is given in *Figure 3.6*.

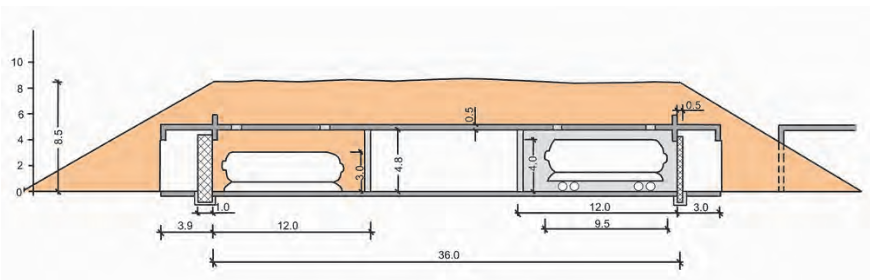


Figure 3.6. *Diagram showing the location of the Kolba containment vessels at site RBSh*

3.1.2.3. Permanent shutdown of the tested Kolba containment vessels at site 200ASM

In 1998 three spent Kolba containment vessels were shut down at Tunnel No. 200ASM at Degelen Mountain, involving the hermetic sealing of the containment vessels and the formation of concrete plugs with subsequent tunnel closure with a concrete plug (*Figure 3.7*).

The method and technology used for deactivating the Kolba containment vessels were regulated under the Technical Requirements, compiled by the Russian and Kazakh nuclear centres, the corresponding technical specifications as regards ensuring the long-term stability and hermetic sealing of the product, the strength of its housing and other norms, rules, provision and instructions.

Figure 3.7. *View of Kolba containment vessel at the 200ASM site*

Permanent shutdown of the Kolba containment vessels at the 200ASM site included the following stages:

- equipment of the near-entrance area (clearing of debris at the tunnel entrance, opening of the concrete wall, inspection of the tunnel and the equipping of work stations);
- regulated work on sealing the Kolba containment vessels in an isolated bay;
- moving the containment vessels to the tunnel;
- sealing the Kolba containment vessels in the tunnel;
- closure (liquidation) of the tunnel mouth;
- dismantling the equipment at the borehole head area and backfilling the tunnel head with rock until the natural relief of the locality is restored.

As a result of the work performed as part of the Agreement, reliable, protective barriers were erected at the facilities and areas of the former STS, excluding any unauthorised access (without industrial equipment) to the nuclear waste contained in the Kolba containment vessels.

3.1.3 Dismantling and permanent shutdown of process equipment at a number of sites of the former Semipalatinsk Test Site

Abandonment of special process equipment for a comprehensive reduction of the informative value of sites of the former Semipalatinsk Test Site, as stipulated under the 27 March 1997 Agreement between the Government of the Russian Federation and the Government of the Republic of Kazakhstan on the Kolba containment vessels and special process equipment at the former Semipalatinsk Test Site.

Boreholes with the special process equipment are located at the Aktan-Berli Area, which is found to the south-west of Area G, 20 km in the direction of the Kainar settlement and 115 km from Kurchatov. The site covers an area of about 0.25 square kilometres.

The special process equipment takes the form of containment vessel fragments (one vessel in each borehole) with remnants of explosives and radioactive waste, each with a total activity level of up to 10 curies, remaining after the 1975 experiments. In its initial state, the experimental assembly consisted of 3 kg of explosives and 100 g of plutonium.

Prior to the experiment, the special process equipment took the form of an assembly, including an explosive cartridge, enclosed in a sealed aluminium shell with a heat-insulated, polystyrene layer. The cartridge was triggered using electric detonators based on brisant explosives.

The special process equipment was placed in the borehole to conduct the experiments. As it was planned to conduct the work in a short period of time, no necessary measures were taken to ensure the long-term storage of the special process equipment.

The greatest hazard was presented by the formation of a layer of water around the explosive charge containing Trotyl, with the possibility of an alkali reaction. The interaction of the explosive in an alkali environment leads to the gradual decay of colloxylin with the formation of new substances with unknown explosive properties.

A preliminary conclusion was made based on all available data that, in the event of a worst-case scenario, a hazard could arise directly when handling the special process equipment, so work on its dismantling should be excluded.

Given the potential hazard of a combination of radioactive waste and explosives, the relatively shallow location and the possibility of unauthorised access, a decision was made to abandon the special process equipment using an industrial explosive charge. Industrial explosive charges to detonate the containment vessels were placed in the process boreholes, which were drilled in the immediate vicinity of the special boreholes (the distance between the axes at the bottom of the boreholes was no more than 700 mm).

A 40 kg detonating charge of explosive (10 kg of No. 6ZhV ammonite cartridges and 30 kg of Granulotol) was placed in a process borehole, near the location of the containment vessel (special process equipment model) in a special borehole. The charge was placed in a containment vessel of a specialised design, measuring 280 mm in diameter. The charge was detonated from three strings of DShE-12, connected to two electric detonators on the surface.

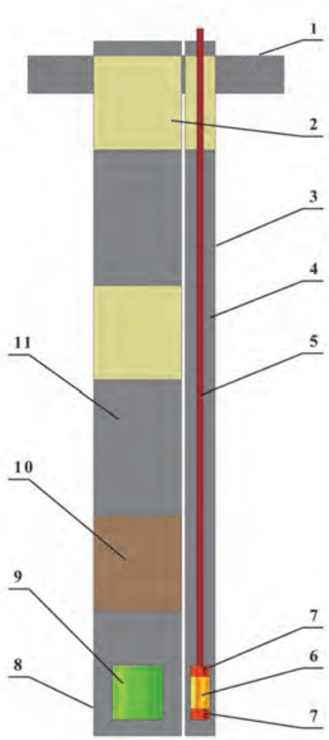
After the charge was placed in it, the process borehole was backfilled with sand, moistened with water, and filled with a sand and cement mixture to a depth of 2 metres from the daylight surface, after which the head was closed and bolted with a metal lid.

The detonator cables in the special and process boreholes were covered with a double layer of insulation tape or placed in polythene (rubber-textile) sleeves before the charges were placed.

The process flow diagram of special process equipment abandonment is presented in *Figure 3.8*.

At distances of up to 7.5 m relative to the borehole casing, 4 investigation holes each with a diameter of 135 mm and a depth of up to 5 metres more than the respective placement depth of the special process equipment were drilled in orthogonal elevations to monitor abandonment of the special process equipment. Seismic survey work was performed before and after abandonment of the special process equipment.

In 1999, Russian and Kazakh specialists, working under the Agreement, rendered the special process equipment in two boreholes safe (detonating explosive charges and destroying the respective items) and shut them down (*Figure 3.9*).



1. *concrete slab (3 x 3 x 1 m)*
2. *sand-cement ramming to a 2.0 m depth*
3. *process borehole 0300 mm*
4. *sand ramming*
5. *three strings of DShE-12*
6. *Granulotol*
7. *intermediate detonators from No. 6ZhV ammonite cartridges*
8. *special borehole 0900 mm*
9. *special containment vessel*
10. *sand and gravel ramming*
11. *sand ramming*

Figure 3.8. *Process flow diagram of special process equipment abandonment*

Figure 3.9. *Permanent shutdown of sites 19/75 and TOP*

3.2. Collaborative efforts of Kazakhstan, Russia and the USA

In the year 2000, as part of implementation of the trilateral Agreement (Russia – Kazakhstan – USA), work began at sites of the former STS to prevent any unauthorised access and for additional protection of nuclear waste at the testing areas and tunnels of Degelen Mountain. The aim of this work was to eradicate the threat of proliferation and terrorism. In May 2000, the eleventh session of the Steering Group decided to use the SG mechanism to coordinate this work. The American side financed this work [4].

Between 2000 and 2012, specialists from the Russian Atomic Energy Ministry

(VNIIEF and VNIITF), NNC and the DTRA of the US Department of Defence completed work at 46 sites of the former STS (including 15 items on the List of Carriers of Sensitive Information), specifically referring to the following:

- erection of reinforced concrete structures at sites in the Aktan-Berli Area, bunded in earth and covering the test boreholes containing nuclear waste;
- erection of additional concrete protection at the sites with Kolba containment vessels, filling the internal cavities of four test containment vessels containing nuclear waste and one untested containment vessel with a binding material of cement-sand and magnetite (cement-sand solution with 50% addition of Fe3O4) solutions;
- extraction and repatriation to the Russian Federation of activated special process equipment from two sites on Degelen Mountain;
- erection of additional concrete and reinforced concrete protective barriers at forty-two sites on Degelen Mountain, the filling of the internal cavities of boxes with nuclear waste at these sites with a binding material of cement-sand and magnetite solutions.

Additional protective barriers were erected and the boxes with nuclear waste were filled at sites on Degelen Mountain using so-called *horizontal* and *vertical* technologies. *Horizontal* technology was used to open up the tunnel entrance and restore the mine working up to the box with nuclear waste, fill the cavity of the box with a binding solution, erect concrete or reinforced concrete barriers, collapse the crown of the tunnel and conceal it beneath the surrounding mountain landscape. *Vertical* technology was used to fill the cavity of the box with binding material and erect concrete protective barriers across boreholes, drilled vertically from the surface of the mountain range. A similar *vertical* method was used to fill the internal cavities of the Kolba containment vessels with binding material.

Horizontal technology was used for work at 19 sites of Degelen Mountain, while *vertical* technology was used at 20 sites. At 2 sites work was performed simultaneously using both *horizontal* and *vertical* technologies. During this work, additional protective barriers were erected at the sites using a total volume of about 40,000 m^3 of material (concrete, rock and special solutions), which is the equivalent of erecting more than 4 km of additional protection (an average of 100 metres per tunnel at the site). Between 2000 and 2012 a total of some 90,000 cubic metres of additional barrier structures were erected at STS sites under the Agreement [4].

Prior to and after completion of the work on additional protection of nuclear waste, specialists from the Khlopin Radium Institute conducted independent radioecological surveys of the area. The results of these surveys indicated that after completion of the work, the environmental situation improved at all tunnels and areas of the former STS.

In addition to work on erecting additional protection for nuclear waste at sites of Degelen Mountain, NNC eradicated possible attempts at unauthorised access to the tunnels by backfilling existing access points into the tunnel cavity. Between 2008 and 2011, access points were abandoned at 73 sites. The American side financed this work.

In the main the work under the Agreement between 1997 and 2012 was performed by federal nuclear centres VNIIEF and VNIITF from the Russian side and by NNC from the Kazakh side. Independent radioecological monitoring was performed by the Khlopin Radium Institute.

VNIIEF and other organisations of the Russian Federation State Atomic Energy Corporation were involved in destroying sensitive information and eradicating the threat of nuclear waste proliferation from the former STS, working alongside other institutions and organisations of NNC (the Radiation Safety and Ecology Institute, the Geophysical Research Institute, the Atomic Energy Institute and the enterprises Baikal and Kazakh State Scientific Production Centre for Explosive Work) and contracted organisations from Russia and Kazakhstan (VNIIEF TANIK, Degelen and Vostokavtoprom).

From the year 2000, representatives of a third party, the DTRA of the US Department of Defence, were involved in work at areas and sites of the former STS.

As a result of the work performed as part of the Agreement, reliable, protective barriers were erected at the facilities and areas of the former STS, excluding any unauthorised access (without industrial equipment) to the nuclear waste and sensitive information at the nuclear test sites.

3.2.1. Prevention of access to nuclear waste at the Aktan-Berli Area [5–7]

3.2.1.1. Operation Groundhog

Operation Groundhog was implemented between 12 August 2000 and 31 October 2004, to prevent access to nuclear waste at a separate sector of STS.

The main types of work performed:

- erection of temporary protective measures;
- erection of a permanent physical barrier;
- enhancing security (*Figure 3.10*).

In September and October 2000, specialists from three countries (the USA, Russia and Kazakhstan) performed the following work in several stages.

Stage 1. A preliminary survey of the area was conducted, determining its dimensions and borders; a detailed topographic map was compiled on a scale of 1:500 and 158 test boreholes were found using characteristic indications and tied into the topographic plan, including 35 boreholes with a significant nuclear waste content.

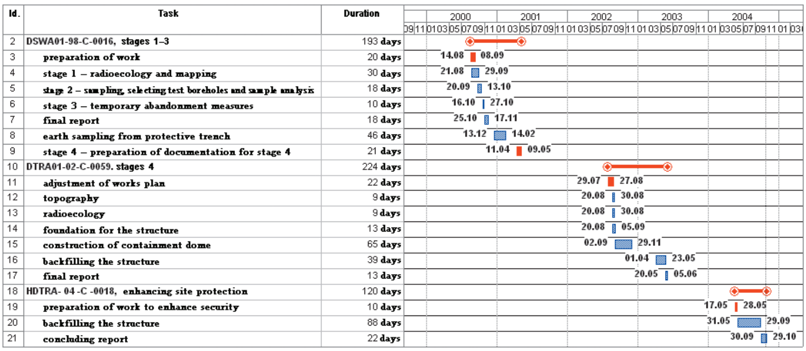


Figure 3.10. *Schedule of individual main types of work under Operation Groundhog*

Test boreholes had previously been backfilled and were not marked on the locality by any means. The area was surveyed and characteristic indications of boreholes sought to determine the location of the experimental boreholes.

The following indicative signs were used to detect individual boreholes:

- outlets of cable lines;
- traces of unauthorised activity (such as exposed earth and remnants of cables, extracted from boreholes);
- increased levels of radiation contamination.

A test borehole was deemed to have been detected if a cable outlet was uncovered.

Stage 2. The presence of significant quantities of nuclear waste was confirmed in samples, taken from three test boreholes during the drilling of special boreholes (*Figure 3.11*).

During the course of the work, the presence of nuclear waste was confirmed in a cross-section of the test boreholes in question (*Figure 3.12*).

Figure 3.11. *Drilling special boreholes at the Aktan-Berli Area*

Figure 3.12. *Laboratory studies*

Stage 3. Temporary measures were implemented to prevent unauthorised access to the boreholes containing nuclear waste. Given the presence of superficial radiation contamination, revealed within the working area during stages 1 and 2, the sector with the test boreholes and contaminated sectors was backfilled with a layer of clean soil and a protective trench was constructed and fencing erected around the area (*Figure 3.13*).

Stage 4. The objective of the work during this stage was the safe construction of a physical barrier to prevent or stop any attempts to extract nuclear waste.

Based on analysis of the research results and proceeding from the main requirements of excluding unauthorised access for an indeterminate period and ensuring the radiation and environmental safety of the work, it was decided to build a reinforced concrete containment dome—a sarcophagus—to cover part of the test boreholes, including all 35 boreholes containing significant quantities of nuclear waste. One option was selected from several construction options for localising nuclear waste at site of discovery, which involved an insignificant embedding of the reinforced concrete containment dome (*Figure 3.14*), proceeding from the premise that in this instance no hazardous radiation and environmental earth-moving operations were required on test boreholes contaminated with nuclear waste, lying adjacent to the sector in question. The main hazard in the work for implementing this containment dome option was the minimising of its dimensions using exploratory drilling work.

Figure 3.13. *Protective structures at the Aktan-Berli Area*

The construction of the concrete containment dome was performed in the following order:

- preparation of the sector for the work;
- building the substructure;
- construction of the drainage system;
- delivery of slabs to the site;
- delivery of soil to the site;

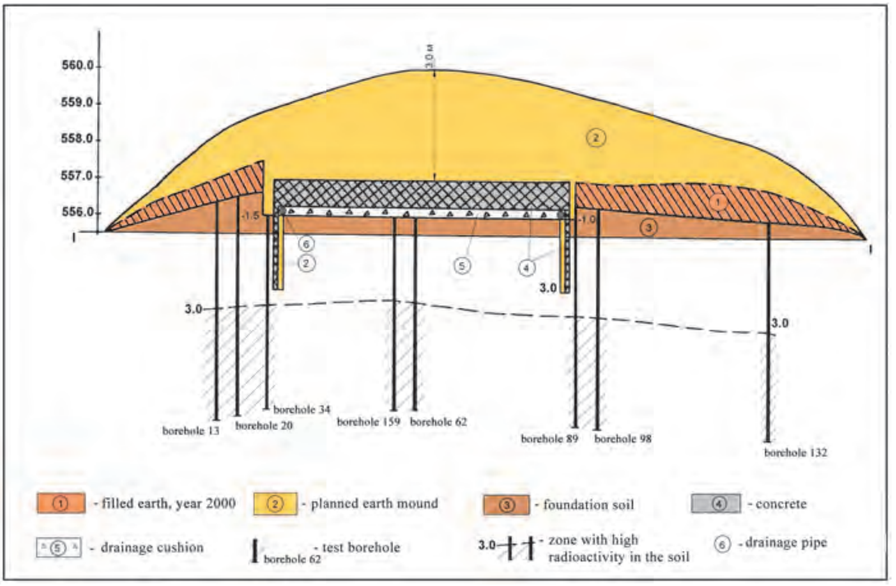


Figure 3.14. *Cross-section of the planned structure*

- laying reinforced concrete slabs into the structure;
- installation of connecting members;
- manufacture of reinforcement meshes for the cement screed;
- laying heavy-aggregate concrete into the cement screed;
- laying bitumen felt;
- backfilling of a protective layer of sand;
- building up an earth mound;
- reclamation of the sector;
- restoration of the protective trench and fencing.

Preparation of the sector for the work. Construction of the structure began with preparation of the sector to make provision for and organise the safe performance of all work on site.

To reduce the impact of radioactive contamination of individual, local sectors (*Figure 3.15*) on personnel and the spread of radionuclides to other areas by road transport, within the confines of the protective trench, these places were backfilled with soil to a thickness of up to 0.5 metres.

Temporary storage areas were installed outside the controlled area to store slabs and earth for mounds. Separate approach tracks were installed in the areas outside the working zone.

The area of the camp and the work sector were ploughed over for purposes of fire safety.

Preparation of the substructure. The surface of the work sector took the form of a levelled, evenly erected, artificial mound with a slight incline to the east, compacted during the process of constructing the mound and made of a mix of soft and semi-hard green and red clays with arenaceous and argillaceous earth of proluvial-deluvial deposits. The earth mound in the work sector varied from 0.5 to 0.9 metres thick. The base of the mound was predominantly hard red clays, covered with a thin layer of arenaceous or gruss soils, up to 0.1 m thick. When preparing the work sector for the installation of the containment dome, as-built geodetic alignment of its corners was performed.

Figure 3.15. *View of the work sector with backfilled contaminated zones*

The preparation of the substructure involved the grading and compacting (*Figure 3.16*) of the newly delivered soil, needed for levelling the bed. The area of the mound for the substructure after soil had been added to places where it was lacking and for purposes related to the technology constituted 3,700 square metres.

Figure 3.16. *Levelling and compaction of the substructure*

Construction of the drainage system. A drainage system was installed to divert possible leaks of surface water (atmospheric precipitation, melt water and so on) and also water forming as a result of the *barrage* effect beneath the structure.

Perforated pipes were assembled and laid on the levelled and prepared surface of the substructure to divert water from beneath the structure into the protective trench.

1,260 cubic metres of crushed aggregate in a grade measuring up to 200 mm was delivered from the region of the aggregate dump of Tunnel No. 208, to make the drainage system (*Figure 3.17*) and the base of the containment dome.

After completion of the drainage system installation, which simultaneously served as a cushion for laying the structure's slabs (*Figure 3.18*), a post-construction planimetric and elevational geodetic survey was conducted of the area.

Figure 3.17. Laying the crushed aggregate into the drainage system

Figure 3.18. General view of the area

Laying the slabs. Roadway slabs (*Figure 3.19*) were manufactured at the production association Semipalatinsk Reinforced Concrete LLP in Semipalatinsk. The slabs measured 6 x 2 x 0.14 metres. Each slab had an area of 12 m^2, a volume of 1.68 m^3 and weighed 4,200 kg. One slab used an average of 1.67 m^3 of concrete.

A total of 279 12 m^2 slabs were used in one row; 4 rows making a total of 1,116 slabs, to cover an area of 3,348 m^2.

Figure 3.19. *Roadway slabs*

Control specimens were tested to determine the ultimate strength of the heavy-aggregate concrete to make the slabs, 7, 14 and 28 days old, in accordance with state standard GOST 10180-90 in the specialised geotechnical laboratory of the Semipalatinsk branch of National Expert Review and Certification Centre OJSC, Semipalatinsk.

A factory-made structure of composite reinforced concrete was selected to construct the containment dome, which took the form of a structure of 4 rows of slabs (PDN-type), laid on a pre-erected cushion (mound) with a drainage system in a checkerboard pattern.

The soil in the substructure has a highly aggressive degree of corrosivity toward reinforced concrete structures, irrespective of the waterproofing grade of concrete. To reduce the corrosive impact of the soil on reinforced concrete structures, specifically the PDN-type slabs, all surfaces of the structure that come into contact with the soil were coated with two layers of hot bitumen (pursuant to the recommendations of Provision 5 of SNiP building regulations 2.03.11-85).

The slabs were delivered on a trailer from the temporary storage area to the place they were laid and put in place using a truck-mounted crane. The first row of slabs was laid on the substructure, aligned with the survey tool. The substructure was graded by filling in fine gravel using a loader (*Figure 3.20*).

Figure 3.20. *Laying the first row of slabs*

The slabs were joined in each row using arc welding to specially embedded inserts (8 inserts per slab) and between the lifting loops, located on the corners and sides of the slabs (*Figure 3.21*).

Figure 3.21. *Joining slabs in a row*

The rows of slabs were connected together using fine-aggregate concrete up to 20 mm thick all over the area of the row. When laying the mortar between the rows of slabs (*Figure 3.22*), the entire space between the slabs of the previous row was filled with this same mortar.

Figure 3.22. *Laying fine-aggregate concrete between rows of slabs*

The formulation and the components for manufacturing one cubic metre of fine-aggregate concrete was issued by the Semipalatinsk branch of National Expert Review and Certification Centre OJSC and approved by a DTRA representative.

The concrete, manufactured according to this formulation and under normal hardening conditions at 28 days old corresponds to strength class B20, strength grade M250 and placeability grade P3.

The first slab was laid in the structure on 14 September 2002 and the last, the 1,116th, was laid on 4 November. An average of 22–23 slabs were laid in a shift. A total of 30.7 cubic metres of fine-aggregate concrete were laid in the structure.

An overview of the construction after laying 2 rows is presented in *Figure 3.23*.

Figure 3.23. *View of the second row of slabs*

The mean thickness (height) of the reinforced concrete containment dome was 0.62 m, with a maximum of 0.67 m and a minimum of 0.60 m. The height of the layer of fine-aggregate concrete varies on average over the rows from 1 to 2 cm.

Installation of binding elements. Binding elements were erected for the entire thickness of four rows of slabs and the mortar between them, to secure the containment dome design to the cast-in-place structure. Two anchor holes were made in each slab of the fourth, top row, each 0.7 m deep.

A 0.75-m long rod of reinforcement metal, 28 mm in diameter was inserted into each borehole. The aperture was filled with fine-aggregate M250-grade mortar, the same as that used to lay between the rows of slabs.

Fragments of the work on installing the connecting members are presented in *Figure 3.24*.

The reinforcement metal of the connecting members in the superstructure are arc welded to the reinforcement metal of the cement screed.

Figure 3.24. *Installation of connecting members*

Figure 3.25. *View of the surface of the fourth row*

Cement screed. A cement screed from cast-in-place reinforced concrete is applied to the surface of the fourth row of reinforced concrete slabs (*Figure 3.25*).

To ensure the work was completed on schedule and given the current circumstances (a lack of slabs for laying the fourth row, favourable weather conditions), simultaneously with the laying of slabs and installation of connecting members, the reinforcement metal mesh was assembled and the concrete of the cement screed was laid (*Figure 3.26*).

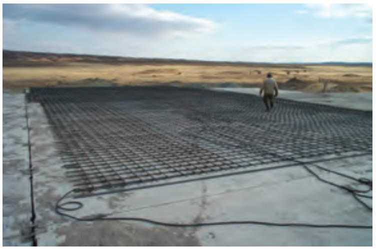
Figure 3.26. *Reinforcement metal mesh and laying concrete in the cement screed*

Reinforcement metal mesh. Welded reinforcement metal mesh is the main type of reinforcement for the cement screed of the containment dome. The mesh is made in a single row of reinforcement steel rod of class A-III hot-rolled steel with a die-rolled section of 16 mm in diameter from grade 35GS steel.

The reinforcement meshes were made on site, meaning on the upper row of the slabs (*Figure 3.27*). The reinforcement metal of the cement screed was arc welded to the reinforcement metal connecting members of the superstructure.

Laying heavy-aggregate concrete. The concrete pouring of the cement screed was performed after the reinforcement mesh was placed on a separate section of the containment dome. Given the weather conditions, the concrete was laid in two stages, when the air temperature was above zero. From 2 to 7 November 2002, when the temperature was above zero, the concrete was laid over an area of 612 m^2 with the remainder after 7 April 2003, taking into account that no concrete was laid between 14 and 19 April because of the unstable weather and the poor state of the access roads.

Before the concrete pouring work was allowed to continue, a DCMA representative inspected and accepted the previously completed screed (*Figure 3.28*).



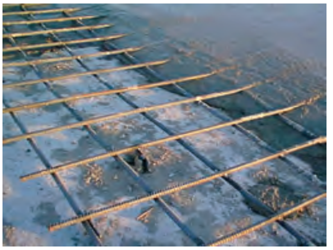


Figure 3.27. *Laying the reinforcement metal mesh*

The ready-mix concrete for this element of the containment dome structure was laid in a horizontal layer up to 10 cm thick (*Figure 3.29*).

No movement or any work was done on the setting concrete that could have deteriorated its quality.

Figure 3.28. *Inspection of the screed condition*

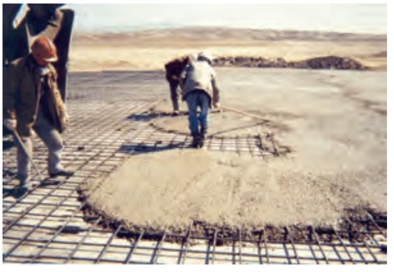


Figure 3.29. *Laying the concrete*

Laying bitumen felt. Work began from 12 April 2003 on covering the cement screed with two layers of bitumen felt. This work proceeded at the same time as the cement screed was being applied (*Figure 3.30*).

The bitumen felt was laid at least five days after the screed was put in place. Over this period the concrete in the cement screed dried and reached the required degree of strength, over 1.5 MPa (or 15 kg/cm^2), under which the necessary work could proceed on the laid concrete.

The bitumen felt was laid at any air temperature (*Figure 3.30*) but only at times of no atmospheric precipitation.

Figure 3.30. *Preparing the section for laying bitumen felt*

Figure 3.31. *Laying bitumen felt*

Figure 3.32. *Protective sand layer*

The surface of the cement screed was first primed with a bitumen solution and then the 2 layers of RKM-350B bitumen felt were applied (*Figure 3.31*).

Construction of the earth mound The bitumen felt was covered with a mix of sand and gravel to a thickness of up to 100 mm, with maximum grain size of up to

20 mm. The purpose of this was to protect the felt from tearing when building up the earth mound from macrofragmental soil (*Figure 3.32*).

Construction of the earth mound. Macrofragmental soil from the aggregate dumps of tunnels 158, 160 and 208 at Degelen Mountain, brought by truck to the temporary storage area at the working area, was used to construct the earth mound (the cover for the containment dome).

The soil from the temporary store was loaded by digger into trucks and delivered to the containment dome (*Figure 3.33*). The earth mound was built up over the erected containment dome to the rated elevation points with the earth spread in layers by bulldozer. The soil was compacted by the trucks and bulldozer as it was laid and levelled.

Figure 3.33. *Overview of earth mound construction*

The layer of soil from the top of the cement screed to the rim of the containment dome varied from 2.37 to 4.65 metres thick and on average it measured 2.71 metres, falling to 0.0 metres at the boundary of the borehole field. The thickness of the earth mound in the centre of the containment dome varied up to 5.0 metres from the top of the cement screed.

The angle of slope of the dumped earth, going beyond the limits of the borehole field, varied from 18 to 42°. The surface of the earth mound was levelled and backfilled with fertile soil (*Figure 3.34*).

Figure 3.34. *Surface of the earth mound*

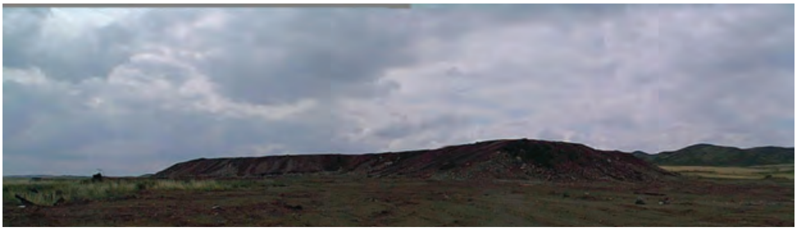


Figure 3.35. *View of the structure from the north*

The general view of the earth mound, covering the reinforced concrete containment dome, is presented in *figures 3.35* and *3.36*.

Figure 3.36. *View of the structure from the south*

Figure 3.37 shows the design layout of the structure.

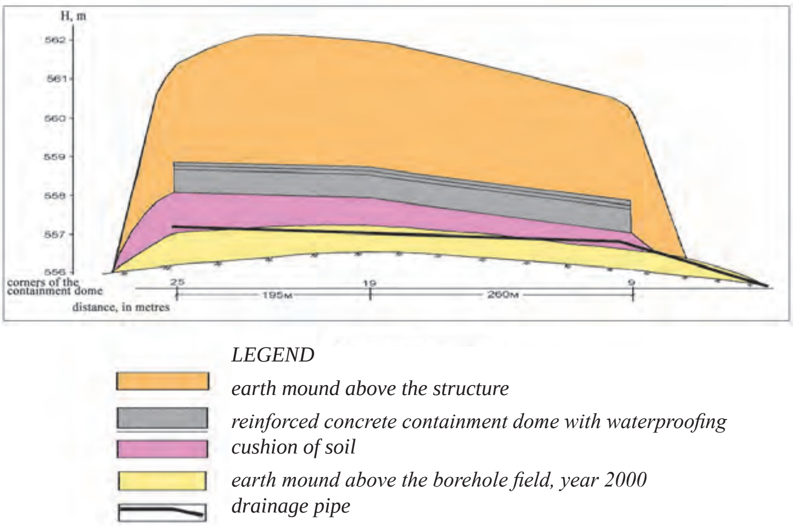


Figure 3.37. *Structural design*

Reclamation of the sector. During the course of the reclamation, some of the site's tell-tale signs (*Figure 3.38*) were removed, the soil from which was laid in the earth mound.

The site of the work was graded and clayey soil was added in separate places (*Figure 3.39*).

After completion of construction of the earth mound and the levelling of the surface, the protective trench and perimeter fencing were restored along the line of the protective trench, built in the year 2000. The trench was cleaned manually.

The work resulted in the erection of a purpose-built protective structure with the following features:

Total area of the site – 51,300 m^2

Area with altered relief – 23,000 m^2

Area of the reinforced concrete containment dome – 3,348 m^2

Area of the earth mound over the structure – 10,600 m^2
Area of the backfilled contaminated sector – 5,000 m^2
Volume of the reinforced concrete containment dome – 2,076 m^3
Length of containment dome – 78 m
Maximum width – 66 m
Minimum width – 12 m
Mean thickness (height) of the four rows of slabs – 0.62 m
Mean thickness of the earth mound from the screed surface (to the corners of the structure) – 2.9 m
Mean thickness of the earth mound from the initial relief level (to the corners of the structure) – 4.4 m
Mean thickness of the earth mound over the surface of the contaminated sector – 0.76 m
Total volume of the structure – 46,700 m^3
Volume of soil over the structure – 30,700 m^3
Total volume of the earth mound – 35,000 m^3
Volume of the closed-off trench – 4,000 m^3


before reclamation


after reclamation

Figure 3.38. *View of the site of the protective cover, before and after reclamation*

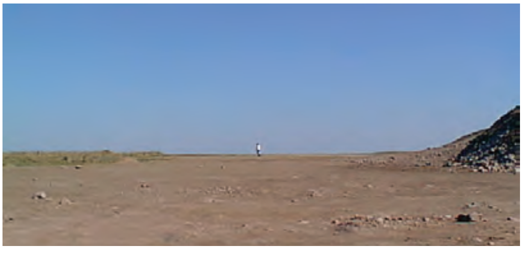


Figure 3.39. *View of the sector, adjoining the south of the structure*

3.2.1.2. Operation Blackthorn

Reinforced concrete barriers needed to be erected at 28 test boreholes, to reduce the threat of proliferation of nuclear waste from the former STS.

Work on construction of containment domes was split into five main stages:
Stage 1 – pre-construction work;
Stage 2 – preparation of foundation pits;

Stage 3 – erection of reinforced concrete containment domes;

Stage 4 – backfilling the structures and levelling the area;

Stage 5 – concluding work.

Stage 1. Work on the first stage involved the following tasks:

- inspection of the area;
- radioecological survey of the site;
- topographical survey of the surface of the site in a scale of 1:500;
- confirmation of the presence of nuclear waste;
- assembly of a field camp at the site;
- construction of an access road to the work site;
- preparation of concrete and mortar facilities for the work;
- delivery of materials to erect containment domes at the work site;

Inspection of the area. During inspection of the area, a search was performed to locate experimental boreholes and to identify them by type. The work was performed jointly by representatives of VNIIITF, DTRA and the US Department of Defence.

The location of four, separate, type-1 boreholes was established as well as 24 type-2 boreholes, concentrated over an area measuring 40 x 50 metres (*Figure 3.40*).

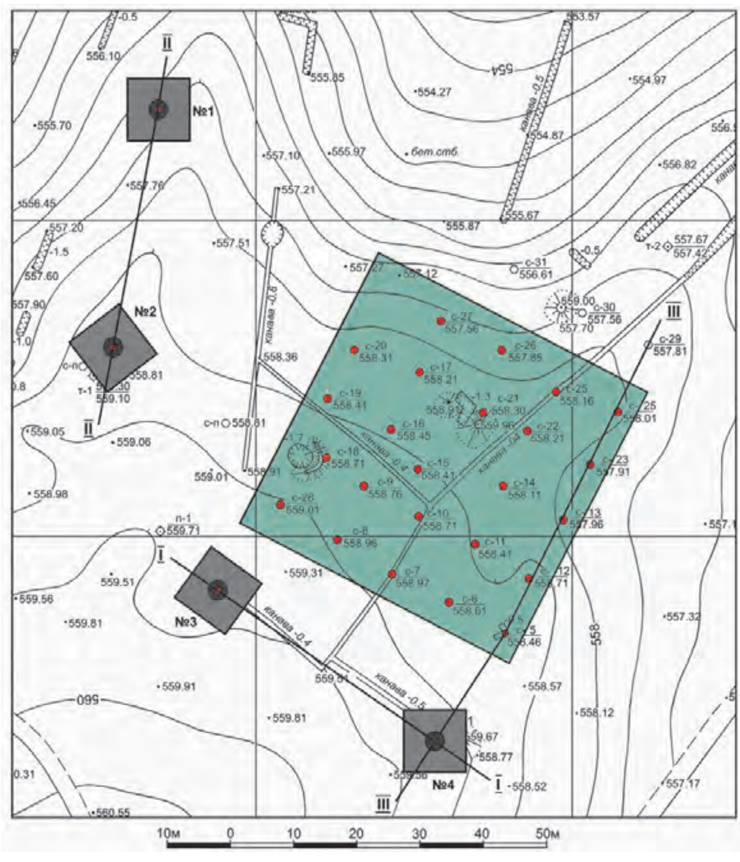


__Figure 3.40.__ Map displaying the location of boreholes at the work site

A separate containment dome was erected over type-1 boreholes, the design of which consists of two principal parts: a safety ring and cast-in-place reinforced concrete slab (*Figure 3.41*).

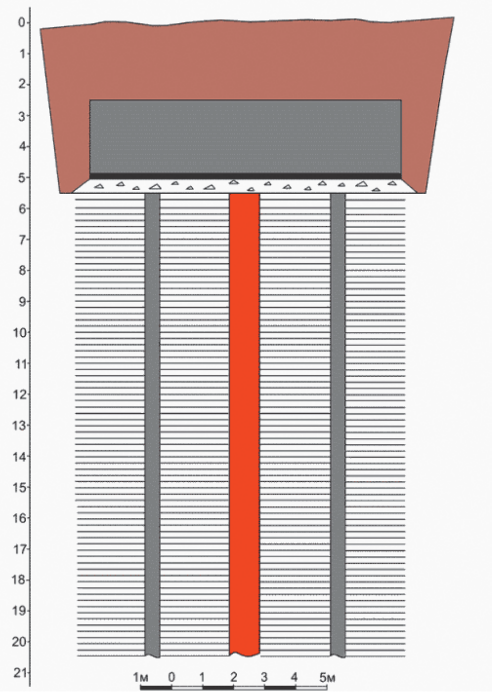


Figure 3.41. *Design of a type-1 borehole*

The substructure of the containment domes is located at an elevation of -5.5 metres from the earth surface. Special boreholes, measuring 500 mm in diameter and 21 metres deep pass from this elevation point over a radius of at least three metres from the centre of the test borehole. Reinforcement steels were installed in the boreholes and concrete poured in and compacted, making a reinforced concrete pillar. A series of 28 reinforced concrete pillars around each test borehole was what made up the safety ring. After the boreholes had been drilled and poured, a layer of ungraded gravel or crushed aggregate of up to 0.5 m thick was laid on the substructure.

The cast-in-place slab was made from a combination of cast-in-place concrete and assembled reinforced concrete slabs. The works plan stipulated the design of a single row of pre-cast concrete, onto which the cast-in-place reinforced concrete was laid. The structure is at least 2.6 metres thick. The roadway slabs were 0.14 metres thick, while the cast-in-place concrete was 2.46 metres thick.

The cast-in-place slab measured 10 x 10 metres, where the centres were shifted relative to the centre of the test borehole and the sides of the structure were oriented differently for each borehole.

After erection of the cast-in-place slab, water was removed from the surface of the structure and the structure was backfilled with soil.

At the concluding stage, the surface was levelled with the addition of a fertile soil cover.

The design of the containment dome of type-2 boreholes takes the form of a cast-in-place structure (*Figure 3.42*).

Shingle or ungraded, crushed aggregate was laid in a 0.5-m-thick layer onto the substructure of the foundation pit at -3.5 m, to serve as a drainage system for the structure and as a damping cushion (Neogene clays swell under additional moisture). roadway slabs were laid in a single layer on the cushion and a 0.7 m-thick layer of concrete poured on. The cast-in-place slab measured 48 x 48 metres, enabling 24 boreholes to be covered.

After erection of the cast-in-place slab, water was removed from the surface of the structure and the structure was backfilled with soil, pre-selected from foundation pits with additional compacting.

At the concluding stage the surface was levelled with the addition of a fertile soil cover.

The surface of the earth mound was levelled to the natural slope of the relief. **Radioecological survey of the site.** The results of the survey indicated a lack of ^{241}Am across the area. The obtained values of ^{137}Cs were not above the level of global fallout, standing at 34.7 Bq/kg.

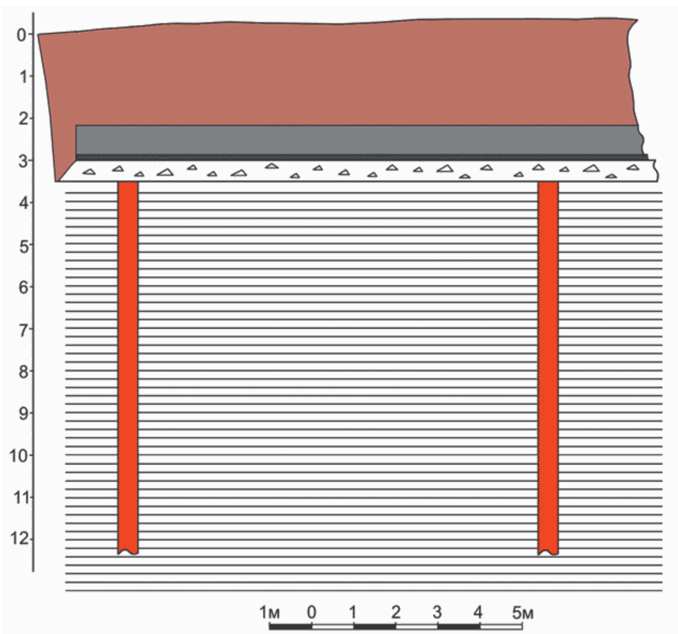


Figure 3.42. *Design of a type-2 borehole*

The exposure dose levels across the area under study were on a level of the natural radiation background, between 0.13 and 0.15 µSv/hr, which is within established norms (*Figure 3.43*). Exposure dose levels down to depths of the substructures of the containment domes (4 and 6 metres) were also on a level of the natural radiation background, as were the exposure dose levels to a depth of 26 metres.

The work formed the basis for the decision to provide radiation safety for the personnel, prevent the spread of possible radioactive contamination beyond the area and provide radioecological support for further work at the area.

Given the nature of the work, with earth-moving operations to a depth of 5.5 metres and drilling work to a depth of 26 metres in the immediate vicinity of test boreholes, and given the fact that the area had been poorly studied in terms of radioecological depth, all the work was afforded radioecological support, especially during earth-moving operations.

Linked with the possible advent of contaminating materials at individual sectors of the surface and proceeding from performance-related considerations (for control and account of working personnel), for the period of the work, a buffer zone was established around the working area – a territory with special rules governing radiation control and access.

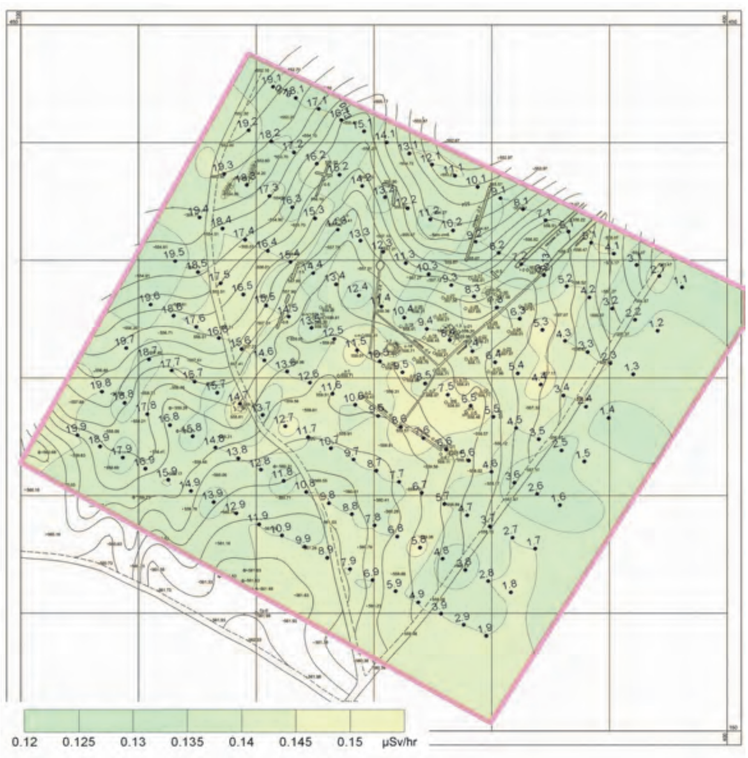


Figure 3.43. *Map of exposure dose levels within the area*

Checking for nuclear waste. The study results confirmed the presence of nuclear waste in borehole No. 1 at a depth of 22–24 metres and in borehole No. 3, at a depth of over 22.5 metres. The presence of alpha particles at the bottom of the borehole also confirms that there is nuclear waste in boreholes 1 and 3.

After extracting the counter from borehole No. 3-3, alpha contamination was discovered on the surface of equipment and the initial 3-metre section of cable (*Figure 3.44*). The contamination level was up to 20 particles/(min x cm^2) on the counter and 9–12 particles/(min x cm^2) on the cable.

After extracting the counter from borehole No. 1-1, alpha contamination was discovered on the surface of equipment and the initial section of cable. The contamination level was 6–12 particles/(min x cm^2).

The equipment and the sector around the measuring boreholes were decontaminated.

Stage 2. Work on the second stage involved the following tasks:

- excavation of foundation pits and liquidation of concrete plugs on the boreholes;
- cutting and removal of the borehole casing from the foundation pit;
- grading the surface of the working area;
- topographical survey of the foundation pits.

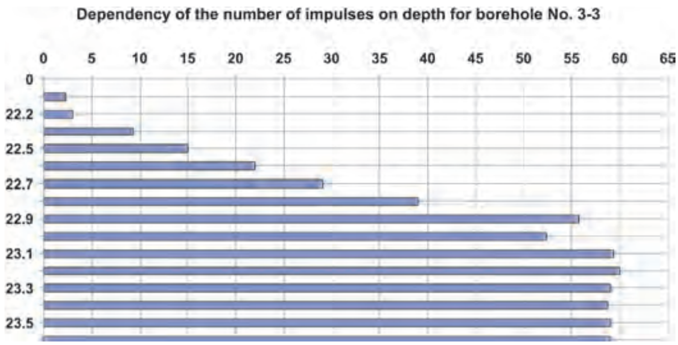


Figure 3.44. *Dependency of the number of impulses on depth for borehole No. 3-3*

Figure 3.45. *Destruction of concrete plug on borehole No. 1*

Destruction of concrete plugs on the boreholes. Preliminary work was performed on boreholes 1 and 2 to destroy concrete plugs measuring 4 x 4 x 2.4 metres, with the subsequent digging of the foundation pits. The concrete plug at the head of borehole No. 1 was destroyed using a 40 kg blast of chemical explosive (*Figure 3.45*).

Remnants of concrete from the borehole heads were removed from the foundation pits.

Cutting and removal of the borehole casing. At the end of the earth-moving operations in each foundation pit, at the elevation point of -5.5 metres, the drill casing of the test boreholes with concrete in the annular space was undercut and temporarily removed from the foundation pit to the surface (*Figure 3.46*).

Figure 3.46. *Removal of borehole casing*

Grading of the surface. After pipes were removed, the bottom of the foundation pits was graded to be able to drill special safety boreholes (*Figure 3.47*).

Figure 3.47. *Grading the surface of a foundation pit*

Topographical survey of the foundation pits. After the completion of all pre-construction work, a detailed topographical survey was conducted on the foundation pits (*Figure 3.48*).

Stage 3. The sequence of work when constructing the containment domes:

- erection of the safety ring;
- preparation of the substructure of the containment dome;
- construction of the containment dome from cast-in-place reinforced concrete.

Safety ring. The requirements established that 28 boreholes needed to be covered around every test borehole and that the distance between the walls of two boreholes must not exceed 0.2 metres.

A layout was drawn up of the location of special boreholes from the centre of the borehole (*Figure 3.49*).

Drilling of special boreholes. A LBU-50 auger drilling rig was used for the drilling with DR-type two-blade drill bits.

The special boreholes, given the requirement to create the safety ring with a gap between the concrete pillars of no more than 0.2 metres, needed to be drilled almost vertically. To ensure the verticality of the special boreholes and also given the nature of the tool string (the auger column with a 500 mm diameter and up to 22 metres long with separate segments of the column secured by a reducing coupling), particular attention was devoted to the installation and alignment of the drilling rig at

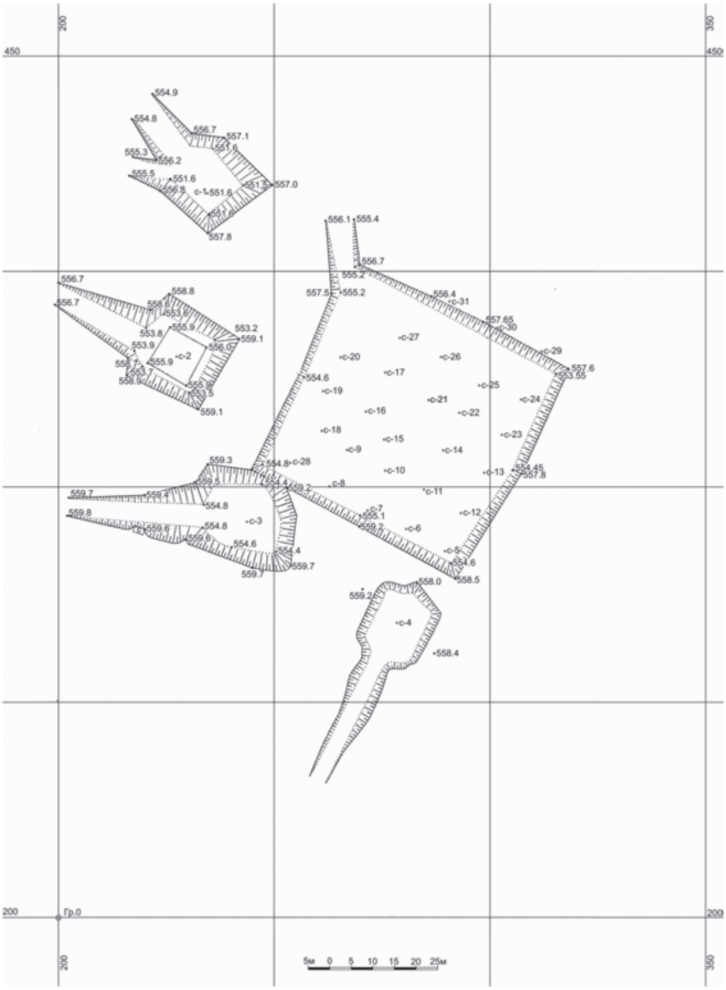


Figure 3.48. *Topographical survey of the foundation pits*

Figure 3.49. *Laying out the location of the special boreholes*

each borehole and to their spudding-in. The spudding-in (driving the upper part of the borehole to set the necessary drilling angle) was performed using a special pitching borer, a bit in the form of a feather (*Figure 3.50*).

To ensure the verticality of the boreholes, the drilling was performed at minimum speed and feeding.

A total of 112 boreholes were drilled, covering a total of 2,350 linear metres.

The entire borehole drilling process was performed with dosimetric monitoring.

Removal of soil from foundation pits. The volume of a single drilled borehole was 4.1 m^3. The volume of excavated rock, allowing for the dislodgement factor, taken as 1.3, was 5.3 m^3 from each borehole. The total volume of soil extracted from one foundation pit was about 150 m^3.

Figure 3.50. *Drilling special boreholes*

After drilling, the boreholes have to be filled with mortar. In light of this and also given the limited dimensions of the substructure of the foundation pit, the soil extracted from the boreholes was stored on the sides of the foundation pits. The soil was removed from the foundation pit using a loader or truck-mounted crane with bucket (*Figure 3.51*).

Figure 3.51. *Removal of soil from the foundation pit*

Manufacture and installation of reinforcement mesh for boreholes. The mesh was manufactured from 16-mm diameter reinforcement steel. An element of the reinforcement mesh consisted of four longitudinal bearing wires, 10–11 metres long, interconnected by arc welding to pieces of reinforcement steel.

Every 2 or 3 metres, rings were fitted on the element to secure the structure and to ensure the meshes would not catch the borehole walls during fitting. The maximum diameter of an element of the mesh (around the ring) was 0.45 metres.

The elements of the reinforcement meshes were delivered to the foundation pits. Using a truck-mounted crane, mesh sections up to 10 metres long were lowered into the borehole and connected with one another by arc welding (*Figure 3.52*).

Figure 3.52. *Manufacture and installation of reinforcement mesh*

Casing of boreholes. Once the reinforcement was fitted, the boreholes were cased in mortar with compaction. The concrete was fed from a mixer directly into the borehole along a conveying culvert (*Figure 3.53*).

Figure 3.53. *Concrete casing of boreholes*

The safety rings on type-1 boreholes were fitted between 15 August and 23 September 2004, when the air temperature was above zero.

The series of the resulting 28 reinforced concrete pillars around each test borehole was what made up the safety ring.

Preparation of the containment dome substructure. Once work was complete on building the foundation pits at the site of type-1 and type-2 test boreholes and after the fitting of safety rings around the four type-1 test boreholes, the substructure of the containment domes was then prepared:

- burial of the borehole casing at sectors of type-1 boreholes;
- laying a crushed aggregate cushion as the substructure for the containment dome;
- laying slabs.

Within the substructure of the containment dome for type-1 boreholes, measuring 10 x 10 metres, a trench was dug up to 1.2 metres deep using a digger. The cut parts of the borehole casing were then placed into this trench, which was then backfilled with soil (*Figure 3.54*).

Figure 3.54. *Burial of borehole casing in the foundation pit*

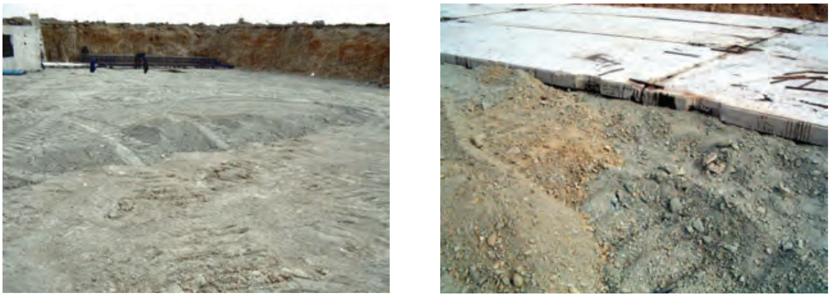


Figure 3.55. *Creating the crushed aggregate cushion*

Crushed aggregate cushion. Rubbly soil from a quarry was laid in a layer up to 0.5 metres thick on the surface of the foundation pit bottom (*Figure 3.55*) to facilitate drainage of the ground water that forms during operation. The soil simultaneously served as a damping cushion to cancel out any unevenness in the lifting of separate parts of the structures as a result of possible swelling of clayey soil, lying in the substructure (the swelling pressure for these clayey soils can reach as much as 2–3 kg per square centimetre).

Laying, preparing and joining slabs. Roadway slabs were laid in a single row all across the area of the containment domes, onto the levelled crushed aggregate cushion. The slabs measured 6 x 2 x 0.14 metres. Each slab had an area of 12 square metres.

The slabs, laid in a single row, form a technological element of the containment dome design and are predominantly intended to create optimum conditions for manufacturing the reinforcement meshes, for erection and manufacture of the formwork.

The soil in the substructure is highly corrosive toward reinforced concrete structures, irrespective of the waterproofing grade of the concrete. To reduce the corrosive impact, all reinforced concrete structures, specifically the PDN-type slabs and all surfaces of the structure that come into contact with the soil, were coated with two layers of hot bitumen.

The slabs were joined using arc welding to specially embedded inserts and between the lifting loops, located on the corners and sides of the slabs (*Figure 3.56*).

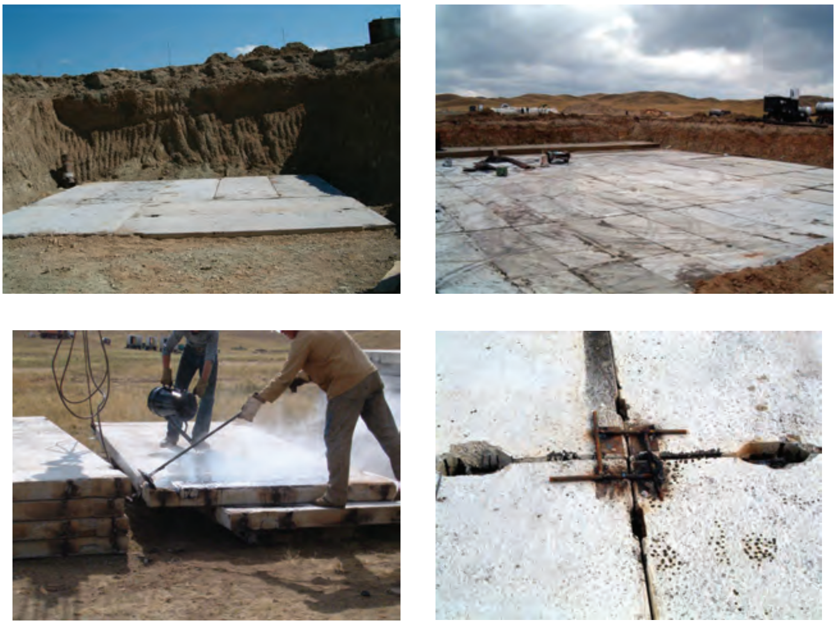


Figure 3.56. *Laying, preparing and joining slabs*

8 slabs were laid on each sector of type-1 boreholes (a total of 32 slabs), while 192 slabs were laid in the substructure of type-2 boreholes. In all, 224 roadway slabs were laid in the substructures of cast-in-place reinforced concrete containment domes.

The building of the containment domes from cast-in-place reinforced concrete included the following:

- manufacture of the reinforcement metal mesh;
- manufacture of the formwork;
- laying the concrete.

The welded meshes are the main form of reinforcement for the reinforced concrete. The elements of the reinforcement meshes were prepared at the site where the concrete was laid, on the slabs.

Manufacture of meshes from the elements. The elements of the reinforcement meshes were brought to the site of their installation, joined together using reinforcement steel and secured by arc welding. The cells in the mesh measured 20 x 20 x 25 cm (*Figure 3.57*).

Figure 3.57. *Manufacture of the reinforcement metal mesh*

The fabricated meshes were accepted for use by way of an external inspection, measurement and verification of the weld efficiency. The quality of the weld seams was checked through an external inspection.

Manufacture of formwork and pouring concrete into cast-in-place structures. The installed reinforcement mesh was enclosed in formwork, made on-site from wooden boards, to hold the mortar in the required volume. The board was 40–50 mm thick. The formwork was removed after the concrete had set (*Figure 3.58, a*).

Provision was made for the use of heavy-aggregate concrete of average density, strength class B22.5 and compressive strength grade M300 to erect the containment domes.

The Building Materials and Structures Test Centre of the Semipalatinsk branch of National Expert Review and Certification Centre OJSC (Accreditation Certificate No. KK658000.06.10.00532, valid until 5 December 2004) developed the formulation and component composition to make 1 m^3 of concrete of the requisite grade, from the components presented for laboratory research.

The concrete was gauged on a temporary batching and mixing unit. The concrete was delivered and fed to the sites for laying using KamAZ-551 ABS-5 mixer trucks.

The mortar was laid in the containment dome under boreholes 5–28 direct from the mixer, which approached the pouring site over the roadway slabs.

a) *b)*

Figure 3.58. *Formwork enclosure (a) and concrete laying (b)*

The ready-mix concrete for the containment domes over type-1 boreholes was fed over a concrete culvert, 159 mm in diameter from ground level. The concrete was laid across the entire area of the containment dome in one go, within the installed formwork (*Figure 3.58, b*).

The ready-mix concrete was laid, just as the reinforcement mesh was erected for the reinforced concrete into the containment dome over type-2 boreholes, over 3.0 metre wide pour structures. To reduce the time required for the concrete pouring, the pour structures were prepared for the pouring in the form of separate sections, located at right angles to one another.

After the concrete was laid (or after a section of the foundation pit) to the design elevation, its surface was graded (*Figure 3.59*).

Care is taken of the laid concrete in the event of high or minus ambient air temperatures at the moment the mortar is setting (about 5 hours after laying) to provide for the required hardening conditions. The climatic working conditions meant that no special measures had to be taken to care for the concrete.

The first mixer of the ready-mix concrete was laid into the containment dome over borehole No. 4 on 26 August 2004; the last was laid into the containment dome over boreholes 5–28 on 29 October 2004.

Brief description of the structures. The thickness of the erected reinforced concrete containment domes corresponds with the requirements of the Statement of Work. The mean thickness of the cast-in-place part of the containment domes over type-1 boreholes is 2.5 metres; allowing for the thickness of the slab (0.14 metres), the total thickness of the reinforced concrete containment dome was 2.64 metres.

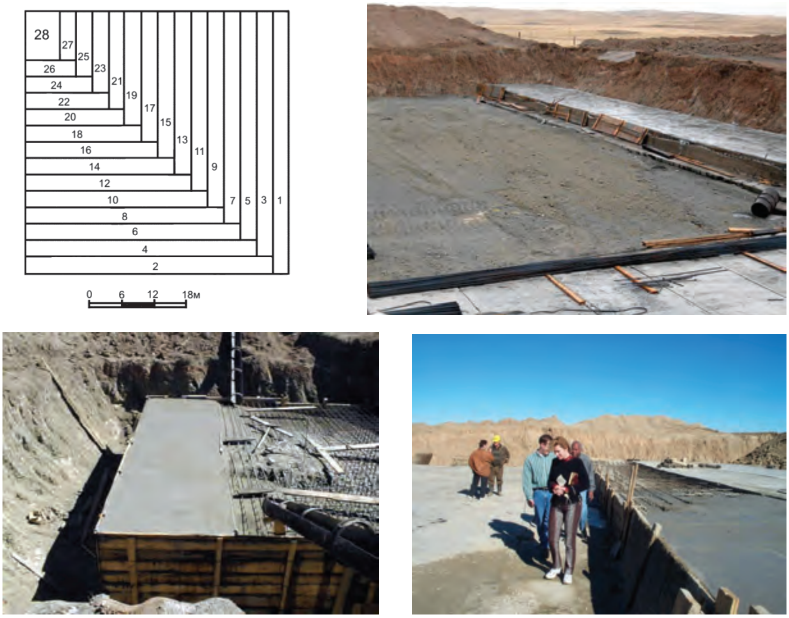


__Figure 3.59.__ Laying concrete by sections and its grading

The mean thickness of the cast-in-place part of the containment dome over type-2 boreholes is 0.69 metres; allowing for the thickness of the slab, the thickness of the reinforced concrete containment dome was 0.83 metres (*Figure 3.60*).

A total of 3,079.3 m^3 of ready-mix concrete was laid under the operation, including 2,613.5 m^3 for the erection of the cast-in-place containment domes.

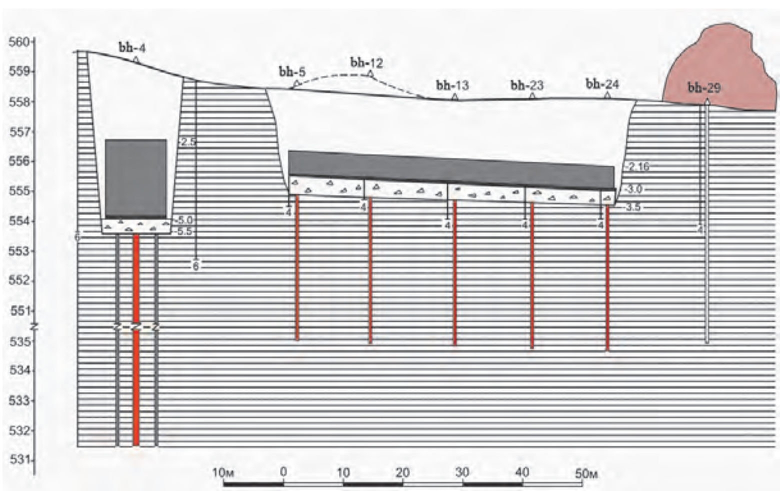


__Figure 3.60.__ Configuration drawing of containment domes

Stage 4. The fourth stage involved the waterproofing of the structure (*Figure*

3.61), the backfilling of the foundation pits over type-1 boreholes and the filling-in to the design level of the foundation pit over type-2 boreholes (a mound was erected over the entire containment dome with a thickness of 0.5 metres and more).

Stage 5. Work on the fifth and final stage involved the following tasks:

- dismantling of the field camp (*Figure 3.62*);
- topographical survey of the area's surface;
- radioecological survey of the area's surface.


Figure 3.61. *Preparing the foundation pits for backfilling*


Figure 3.62. *Dismantling of the field camp*

As a result of the work under operations Groundhog and Blackthorn, the majority of the test boreholes, including all those with significant quantities of nuclear waste, were reliably sealed with a reinforced concrete containment dome. In this way, the operation's main objective was achieved with the construction of a physical barrier, to prevent or stop any attempts to extract nuclear waste at the Aktan-Berli Area and to destroy evidence of tests here that could point to the location of the area.

The work performed led to a fall in contamination of the Aktan-Berli Area to the level of the natural background.

The measures to prevent unauthorised access to the nuclear waste promoted a general improvement in the environmental state at one of the sectors of STS.

To summarise the above, it is noteworthy that, during Operation Groundhog, the efforts of three parties, for the first time, eradicated the threat of proliferation and terrorism, with the specific example of the Aktan-Berli Area, at a qualitatively new level. The experience gained from jointly overcoming various difficulties and finding compromise solutions helped resolve tasks of an even more complex nature in the future on a trilateral basis (Russia, Kazakhstan and the USA).

3.2.2. Enhancing the safety and security of two spent Kolba containment vessels, containing nuclear waste (Operation Matchbox) [5–7]

Ensuring the non-proliferation of fissionable materials from sites at the former Semipalatinsk Test Site required an enhancement of safety and security at sites that had already been abandoned.

The objective of this operation was to enhance security of two spent Kolba containment vessel containing nuclear waste, remaining after nuclear tests.

The Statement of Work and the Works Plan stipulated the creation of a multilevel system for securing the nuclear waste in the spent containment vessels, which did not involve the extraction and transport of these vessels. The solutions devised by specialists from VNIIEF, VNIIEF TANIK, NNC and DTRA were based on the use of the protective properties of existing structures and containment vessels.

Performance of the stipulated measures enabled the following:

- the practically complete exclusion of the possible extraction of nuclear waste from the containment vessel;
- enhancing the mechanical strength of the containment vessel;
- making the containment vessel non-transportable owing to the significant increase in its mass.

Work on enhancing the security of two spent Kolba containment vessels holding nuclear waste remaining after nuclear tests was performed in line with the Works Plan to Backfill Containment Vessels at the Operation Matchbox Site, coordinated by Russian and American specialists, the Detail Design for Backfilling Containment Vessels at the Operation Matchbox Site and the Kolba Detail Design for the Additional Construction of a Safety Barrier under Operation Matchbox at sites *RBSh* and K-85 of the former STS.

The work was split into five main stages:

- pre-construction work;
- a model experiment with the backfilling of a *clean* containment vessel at site *RBSh*, both inside and out, with recovery of the structure's cover;
- backfilling of the spent containment vessel at site *RBSh* with recovery of the structure's cover, erection of an earth mound and dismantling of tell-tale signs;
- backfilling of the spent containment vessel at the K-85 site with recovery of the structure's cover, erection of an earth mound and dismantling of tell-tale signs.
- post-construction work.

Stage 1. The first stage included preparation of the working area for the work to begin. The structure was opened to ensure access to the Kolba containment vessels (*Figure 3.63*).

Stage 2. The main objective of the model experiment was to debug the technology for safe opening of the containment vessel on a *clean* vessel, to backfill it with a solution and then to use this technology on the spent containment vessels.

The types of work and their sequence were dictated by the assumed technique for filling the containment vessels and the predicted radiation situation during the opening and filling of the vessels, which was performed by VNIIEF specialists.

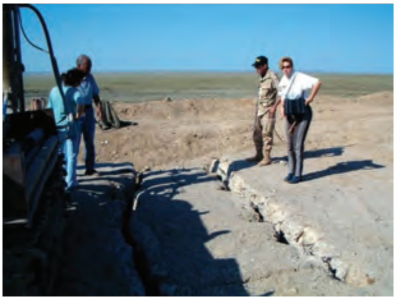
 

Figure 3.63. *Opening of the structure*

The solution for a quality enhancement of the protection of nuclear waste involved the cavity of the spent containment vessels being filled with an aqueous solution of a cement and sand mix. Not only did this achieve the binding of the nuclear waste in a strong, set solution, but it also almost completely excluded the possibility of the containment vessels being transported, given the mass of the structure had increased by several orders of magnitude. This significantly reduced proliferation and terrorism risks, diminishing them to a qualitatively new, low level.

Implementing this solution meant having to design a special means that would exclude the outlet of nuclear waste because of the rise in pressure in the containment vessel's cavity as it is filled with the sand-cement solution. During debugging of a safe and reliable means of filling the containment vessel with the cement solution, a reliable design for the oil seal was selected and an optimum cutting tool found for boring the multiple layers of the containment vessel's shell.

During the debugging of the technology (*Figure 3.64*) the following sequence of operations for filling the containment vessels was adopted, which needed to ensure the safe performance of the Statement of Work for the operation:

- the protective layer before the steel shell is removed in the central area of the containment vessel;
- connecting nozzles are fitted onto exposed sections of the shell to secure ball valves, to install the cement-pouring unit and to fit a filter;
- the body of the containment vessel is opened using the so-called *oil seal* method;
- a filtering element based on Petryanov cloth is fitted onto one of the connecting nozzles;
- the internal volume of the containment vessel is filled with binding material.

Stage 3. Work was first performed on a *clean* containment vessel, into which 24.8 m^3 of solution was pumped (*Figure 3.65, a*).

The vessel filling process was recorded on video. Two days after the pouring, the sand-cement solution had hardened and had almost no water on the surface.

At the concluding stage, the containment vessel was placed for permanent storage into a structure and the structure was then concreted and the concrete cover was restored. The concreting was performed direct from mixers from the top of the structure. The cover of the structure was also filled with concrete to the elevation of its upper part (*Figure 3.65, b*).

Figure 3.64. *Model experiments*

a) *b)*

Figure 3.65. *Filling the containment vessel with solution (a) and restoring the concrete cover (b)*

Thereafter, similar work was performed on a *dirty* containment vessel.

Work on encasement of items, used during the opening and cementing of the containment vessels (ball valves, filter items etc) and which had become contaminated during the course of the work, the top of the structure, presumably in the central part, was opened to a depth of 0.4 metres. The opening measured 1 x 2 metres. A sump was made to the protective layer of the containment vessel, 0.8 metres deep and measuring 0.8 x 0.4 metres, to ascertain the location of the central part of the containment vessel.

A 1-metre long steel feed tube was installed and secured on the protective layer (using a plate and fixing bolts). Once the tube was secured, the sump was filled with concrete. At the other end of the sump hole, at a distance of 1.2 metres from the feed tube for borehole No. 2 (injection borehole), a feed tube was installed for borehole No. 1 (for gas blowoff). A borehole was made in the sump using a 127-mm drill bit, into which a steel tube with a 112 mm diameter was inserted. The annular space was cemented with mortar (*Figure 3.66*).

After the cement had hardened, the mortar was drilled out in the feed tube using a drill bit, 105 mm in diameter and which could not drill through the metal of the casing.

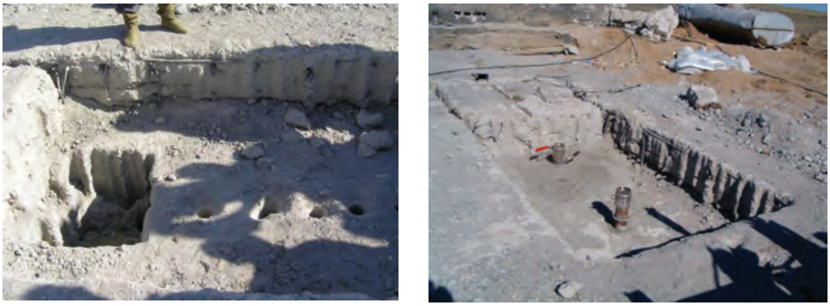


Figure 3.66. *Opening of the structure's ceiling*

There was a certain degree of risk involved in the direct opening of the containment vessel. In light of this, the drilling personnel were given final instructions on what to do when opening the containment vessel, the design of the drilling assembly was perfected and tested, the assembly was stabilised with a limiter welded to the support frame, the necessary tools were prepared (wrenches, connecting nozzles and bore bit), a flag was fitted to determine the wind direction and duties were assigned among the staff (*Figure 3.67*).

The number of personnel at the working area and working on the opening was limited to seven. Personnel were dressed in personal protective equipment. The remaining staff, working on the operation, were removed to a safe area.

Figure 3.67. *Preparation for opening the containment vessel*

The plastic protective layer of the containment vessel was drilled through the feed tube with oil being added through the oil seal, acting as a plastic tank, joined with the core feed tube by a connecting nozzle with a ball valve, 20 mm in diameter. Oil consumption in the tank was monitored during the drilling process. The containment vessel was opened—the drilling of the steel casing—within 7 minutes. There was no sharp drop in the level of oil in the tank, but it was plain to see the formation of air bubbles in the oil, evidence the opening of the steel casing.

After the drilling assembly had collapsed into the borehole up until the pre-secured limiter on the support frame of the drill unit, the core equipment was disconnected from the drill unit and thrown into the containment vessel (*Figure 3.68*).

Figure 3.68. *Drilling operations*

Contaminated air was released from the containment vessel through an oil seal. A 20 mm ball valve regulated the rate of gas release based on the quantity of bubbles that formed in the oil tank. Throughout the period of gas release from the containment vessel (90 minutes) constant radiation monitoring was performed on the state of the gases passing through the oil seal into the atmosphere around the work site. Once the release of the gas had stopped (when no more bubbles formed and all the oil had left the tank), the 20 mm ball valve was closed, the oil seal assembly was removed and the filter unit connected in its place (*Figure 3.69*).

Figure 3.69. *Release of contaminated air from the containment vessel*

The radiation situation at the work site after the containment vessel for borehole No. 2 had been opened remained unchanged and it was decided that the requisite number of personnel could be involved in subsequent operations as regards filling the containment vessel with solution, provided that constant dosimetric control was performed.

The Kolba was filled with concrete through injection pumps, fitted on the top of the structure. A KamAZ- or KrAZ-mounted ABS-5 mixer brought the ready mix and unloaded it into the receiving tank of the injection pump (*Figure 3.70*).

Figure 3.70. *Filling the Kolba with concrete*

During the filling of the containment vessel with the sand-cement solution, specialists from VNIIEF TANIK periodically monitored the state of the gaseous environment in the containment vessel and the replacement of the filter element (*Figure 3.71*).

Figure 3.71. *Monitoring the state of the gaseous environment and replacement of the filter element*

At the concluding stage, the opened part of the structure's ceiling was filled in to its initial level. Seals and ball valves with plugs fitted were not dismantled, but filled with concrete mortar. After completion of work on permanent shutdown of the containment vessel (filling with mortar), the exposure dose level of gamma radiation in this zone did not exceed the values of the natural background which, for this locality, stood at 0.1–0.15 µSv/hr (*Figure 3.72*).

The external dose rate of the personnel over the entire course of the work on the spent containment vessel stood at 0.3–0.8 µSv, which is considerably lower than maximum permissible values.

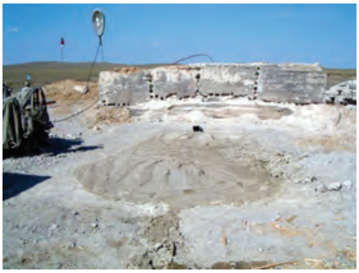


Figure 3.72. *Permanent shutdown of the containment vessel*

Stage 4. The structure with the containment vessel, conventionally designated as K-85, is located 150 metres from the entrance to the tunnel with the same name, in the southern part of Degelen Mountain (*Figure 3.73, a*). The containment vessel, located in the structure at Area K-85, was initially shut down in 2000, when it was concreted directly in a concrete structure on ground level. An earth mound was erected over the structure (*Figure 3.73, b*).

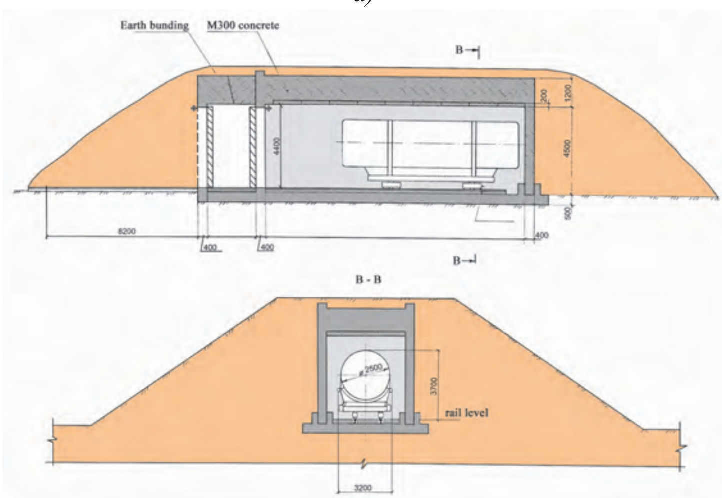
The filling of the containment vessel at site K-85 was identical to that performed at area *RBSh*.

Features of the working techniques applied at site K-85. The permanent shutdown of the Kolba containment vessel at site K-85 was conducted based on the debugged and proven technology from site *RBSh*. At the same time there were a number of somewhat significant differences. If the process holes for filling the containment vessel and bleeding the gaseous environment from the cavity on site *RBSh* were located in the upper part of the containment vessel (to determine the highest point in the containment vessel, part of its surface was cleaned of concrete), there was a 2.0–2.1 metre thick layer of reinforced concrete between the vessel surface and the top of the concrete structure, so it was not possible to determine precisely where the uppermost point of the containment vessel actually was. As a consequence, it was not possible to mark out the holes for fitting the casing of the holes or to drill the vessel housing at its highest points. At the same time the hole for filling the containment vessel proved to be below the hole for bleeding the air from the vessel. This was confirmed by the fact that only ~12.5 m^3 (~3.5 ABS-5 mixers) of cement-sand mix could be poured through the process hole to fill the containment vessel, filling 60–70 % of the cavity's volume.

The process for filling the cavity with a further ~6.5 m (~1.5 mixers) was executed through an open connecting nozzle of the first hole with simultaneous bleeding of the gas-aerosol mix through it, now without purification on a filter. Here, the risk of contaminating the air and surfaces in the area of the work with radioactive nuclear waste was reduced to a minimum as, by this time, the predominant mass of the nuclear waste in the cavity had already been localised by the cement-sand solution and its concentration in the gas-aerosol stream was significantly reduced.

The design of the filter was not as successful as that used at site *RBSh*. The filtration area was smaller, so its life cycle was very small. In addition, it created considerable resistance to the gaseous mix being bled, especially in conditions of high humidity in the cavity of the containment vessel.

a)



b)

Figure 3.73. *Kolba containment vessel at site K-85*

When filling the internal cavity of the spent containment vessels with a binding material, the formation of an air lock led to the discharge of cement mixture from the nozzle, through which the mortar was being poured. This resulted in slight radioactive contamination of the sector adjacent to the connecting nozzles designed for bleeding air and pouring in the mortar. The maximum exposure dose level in the contaminated sector was 0.29 μSv/hr, the flux density of α-particles was 3 particles/(min x cm^2) and of β-particles it was 41 particles/(min x cm^2).

Figure 3.74 shows the process of filling the containment vessel with mortar, with dosimetric support.

Stage 5. The concluding, post-construction work involved returning the structures housing the Kolba containment vessels to their initial state and eradicating all tell-tale signs.

Figure 3.74. *Filling the containment vessel with mortar and dosimetric monitoring*

When eradicating the tell-tale signs, the adjacent structure was dismantled and the area next to the structure cleared and levelled. An earth mound was erected using a bulldozer. Soil was brought in for the mound by dump trucks from a quarry, developed earlier, some 0.5 km from the area. The earth in the quarry was readied using a digger. The earth mound stood at least 1.2 metres above the top of the structure (*Figure 3.75*).

Figure 3.75. *View of the structure after completion of the work*

As a result of the work performed under Operation Matchbox at area *RBSh*, the main objective was achieved – the construction of an additional physical barrier to prevent or stop any attempts to extract nuclear waste at this area and evidence of tests was destroyed that could point to the location of the area.

The measures to prevent unauthorised access to the nuclear waste promoted a general improvement in the environmental state at one of the sectors of STS. The exposure dose level here is not higher than the background values that are indicative for this locality.

Provision was made for safe performance of all work that involved a radiation hazard. Levels of radiation on personnel were within values, regulated under radiation safety norms. No internal radiation of personnel was permissible during the work.

3.2.3. Enhancing the safety and security of three spent Kolba containment vessels, containing nuclear waste (Operation Nomad) [8]

Ensuring the non-proliferation of fissionable materials from sites at the former Semipalatinsk Test Site required an enhancement of safety and security at sites that had already been abandoned.

Reducing the threat of proliferation of nuclear waste from the former STS required a strengthening of the protection of three Kolba containment vessels with nuclear waste, located at the site known as Nomad.

This site is comprised of two engineering structures, the left and the right. The left-hand structure contains three Kolba containment vessels. An overview of the site is shown in *Figure 3.76*.

The Statement of Work and the Works Plan stipulated the creation of a multilevel system for securing the nuclear waste in the spent containment vessels, which did not involve the extraction and transport of these vessels. The solutions devised by specialists from VNIIEF, VNIIEF TANIK, NNC and DTRA were based on the use of the protective properties of existing structures and containment vessels.

To strengthen the protective barriers, a method was proposed for filling the cavity of the containment vessels that had been perfected during Operation Matchbox. Russian specialists initially proposed removing the Kolba containment vessels from the tunnel to fill them with a sand-cement solution. This proposal was based on the fact that the containers were located on special transport bogies, suitable for bringing the containment vessels out of the structure and then taking them back in again. The containment vessels were hermetically sealed following the work performed in 1998, ensuring the radiation and environmental safety of the work. NNC specialists proposed a more radical approach, which involved filling the containment vessels without opening the tunnel entrance, by drilling boreholes from the outside of the engineering structure.

Figure 3.76. *View of structures at the Nomad site*

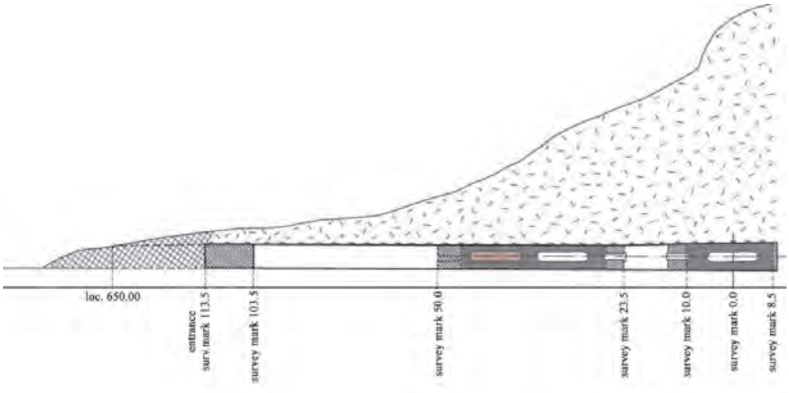
It should be mentioned that this idea was initially met with considerable scepticism. First, there was no confidence that drilling from the outside would ensure access to the required part of the containment vessel's surface, with its cylindrical shape and spherical ends. In addition, the mountain relief was so steep that a considerable volume of explosive work was needed when preparing the site to locate drilling equipment there. That said, this idea had an undoubted advantage in that there was no need to open the tunnel entrance and gain direct access to the Kolba containment vessels. The sealed nature of the containment vessels did not exclude the external, reasonably high radiation background owing to the presence of nuclear waste in their cavity. Furthermore, the matter of returning the containment vessel after its cavity was filled, while achievable, was no simple matter, as its mass thereafter would have increased several times over. Trilateral negotiations led to a compromise solution, which involved the sand-cement filling of the cavity of only one containment vessel, nearest to the entrance. The other two containers are protected only by pumping in mortar into the free volume around the boxes in which the containment vessels are located.

Objectives:

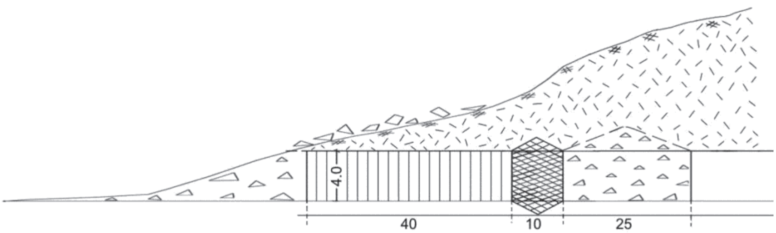
- to enhance the safety and security of the left-hand structure by pouring mortar into the box that houses containment vessel No. 1 and the chambers where spent containment vessels 2 and 3 are located, and by pouring mortar from fine-aggregate concrete into the internal cavity of containment vessel No. 3 without opening up the entrance to the engineering structure;
- to enhance the safety and security of the right-hand structure by using a combined method, involving a blast from inside the sector with the structure and the installation of a cast-in-place reinforced concrete plug.

Figure 3.77 shows the arrangement for strengthening the engineering structures.

The work began on 19 September 2005 and was completed on 30 May 2006.



a)



b)

Figure 3.77. *Arrangement for strengthening the left (a) and right (b) engineering structures*

Individual types of work were performed simultaneously on the left and right structures. The main stages and types of the work are presented in *Figure 3.78*. Throughout the period, support of the following kind was rendered to the construction work to ensure safe working, the security of personnel and works equipment and the uninterrupted supply of the requisite materials to the perform the work:

- radioecological support;
- medical support;
- maintenance of field roads;
- maintenance of the base camp and field camps;
- security for the engineering structure;
- delivery of equipment and materials to the site.

Based on the results of assessment of the radiation situation prior to the work commencing at the working areas, it was established that:

- the dose level of gamma-emitting radionuclides did not pose a hazard for the personnel;
- the exposure dose level over the greater part of the area of the inspected sites was within the norm (0.3 μSv/hr) as set by KPR-96 (Temporary Criteria for Decision Making on limiting public exposure to radiation from natural sources of ionising

radiation) and is at a level of background values, indicative for the mountain locality;

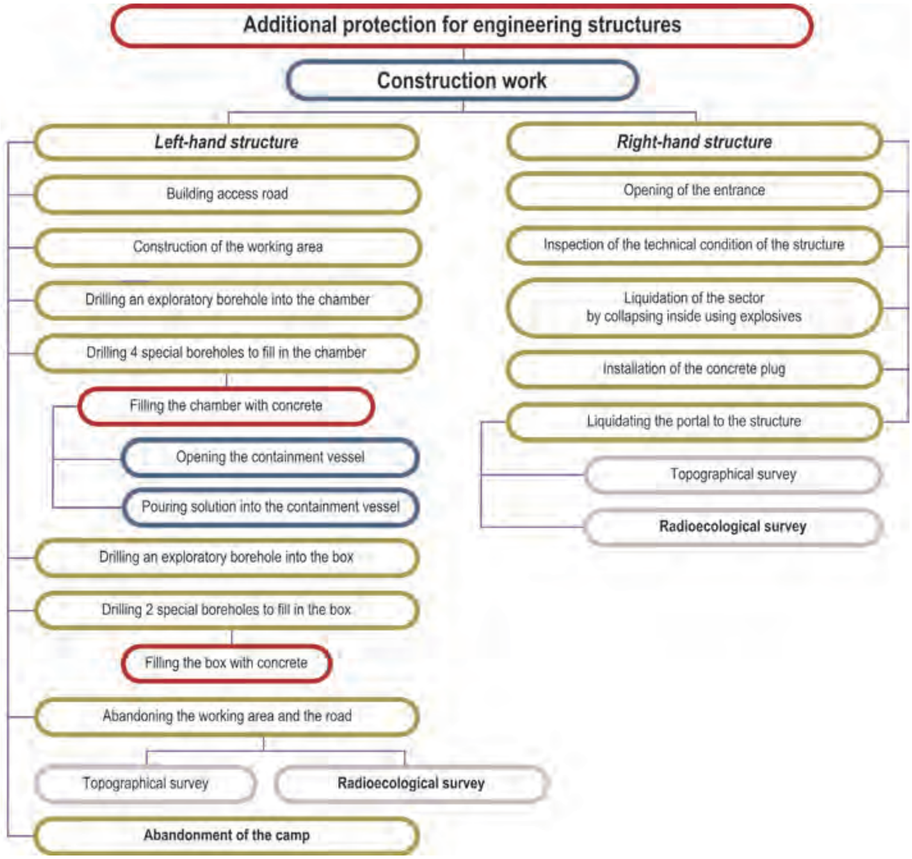


Figure 3.78. *Main stages and types of work*

- building materials—crushed aggregate from the quarry—can be used for industrial and road construction away from residential areas.

3.2.3.1. Left-hand structure

The protection of the left-hand structure was enhanced by opening up the chambers of the structure using special boreholes from the working area and then filling these chambers with a concrete mortar through these boreholes.

A temporary access road was built to erect the working area above the structure (*Figure 3.79*).

The working area consisted of two terraces, formed by crushing large fragments of rock using a number of blast cycles in blast holes and pressure charges with the subsequent backfilling of the rock fragments with crushed aggregate from a local quarry and multiple grading of the delivered earth (*Figure 3.80*).

Figure 3.79. *Access road*

Figure 3.80. *Working area over the structure*

Special boreholes, with a diameter from 105 to 250 mm, were drilled from the surface of the working area. Vertical boreholes were drilled using an URB-3AM drilling rig, while inclined boreholes, with a TEJ drilling unit (*Figure 3.81*).

The precise location of containment vessels 2 and 3 inside the chamber was unknown and the planned position of the boreholes could be altered based on the results of drilling wildcat holes.

The drilling of the first of the wildcat holes (No. 2 with a 115 mm diameter) yielded a positive result: the drilling assembly fell through into the cavity (it was the falling of the drilling assembly that determined entry into the structure). A video camera (*Figure 3.82*) helped to determine the position of the bottomhole of the first drilled borehole relative to the containment vessels. The video camera revealed that the hatch of the hermetically sealed access point in the direction of the box with containment vessel No. 1 was closed and that it was not expected that additional concrete would leak through the hole.

Figure 3.81. *Borehole drilling*

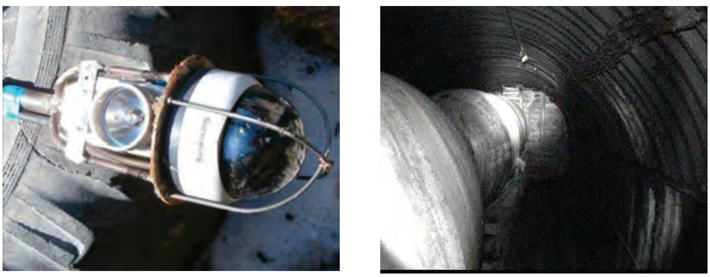


Figure 3.82. *Video recording*

According to the survey of the structure with two containment vessels, the position of the remaining special boreholes for pouring the concrete was adjusted.

Three boreholes were drilled at an incline of from 45 to 60 degrees from the vertical to open up the box with containment vessel No. 1.

Borehole No. 4, drilled from the surface at an angle of 51 degrees from the vertical, entered the box after travelling only a short distance through the concrete plug. Borehole No. 5, drilled from the surface at an angle of 60 degrees, entered the box more to the left in the rear part of containment vessel No. 1.

Video recording in the box with containment vessel No. 1 was of a poor quality, both during the survey and when pouring in the concrete, which is linked with poor light and the absorption of the light by the walls of both the mined hole and the containment vessel (*Figure 3.83*).

The cover of the containment vessel, replaced during work in 1999, had good reflective power; the number of fixing bolts can be counted on the photographs. It was the cover that served as the starting point when surveying the box.

It was revealed that the sealed access point cover, leading out from the box, was fully open and engineering steps had to be taken to prevent the mortar from leaking into the neighbouring box.

6 special boreholes were made to pour the mortar into the box with containment vessel No. 1 and the chamber with containment vessels 2 and 3 (*figures 3.84* and *3.85*).

Figure 3.83. *View of containment vessel No. 1 (a) and view of the sealed access point in the box (b)*

The proportioning of the mixture for the concrete mortar was made at the concrete and mortar facility, built at the area by the left-hand structure. The mix was delivered to the working area in ABS-92 mixer trucks. The concrete was fed into the chamber directly through a special hopper, without using any pumping equipment. Once the casing string became full to the top with concrete, the process of filling the chamber was complete (*Figure 3.86*).

Figure 3.84. *Casing the boreholes with pipes*

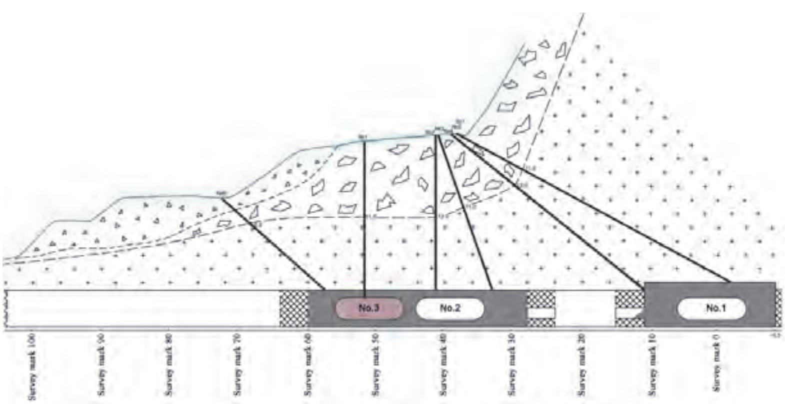


Figure 3.85. *Position of borehole bottomholes relative to the chamber and the box*

Figure 3.86. *Pouring mortar into the chamber and box*

The process of the mortar flow in the chamber was recorded on video through boreholes, through which concrete was not being fed at that time (*Figure 3.87*).

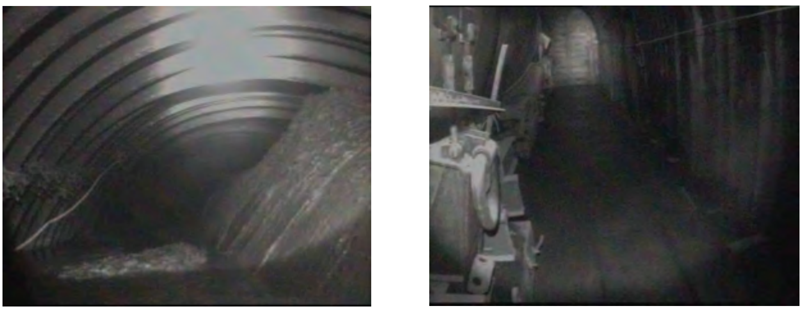


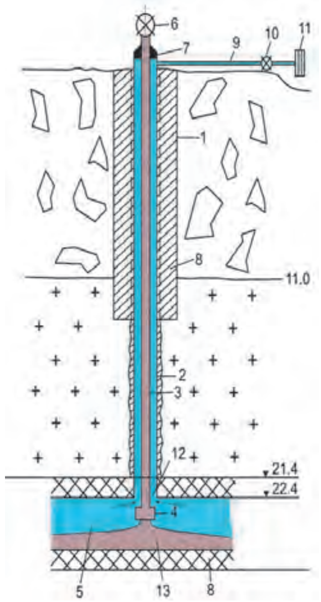
Figure 3.87. *Photographs of the pouring of concrete into the chamber*

The mortar flowed in the chamber on account of its fluidity, the composition of the concrete, determined by its formulation and, at the final stages, by the pressure caused by the column of concrete in the borehole shaft.

The mortar was poured into the box with containment vessel No. 1 over inclined, special boreholes 4 and 5, using a BUK-1 pump (*Figure 3.88*).

Figure 3.88. *Pouring the mortar into the box with containment vessel No. 1*

The filling and the flow of the concrete in the box was observed using a video camera. Once the casing string of borehole No. 4 became full to the top with concrete, the process of filling the box was complete.



1 *shaft of special borehole Ø 250 mm;*
2 *drill casing Ø 130 mm;*
3 *core tube Ø 70 mm for pumping in the sand-cement solution into the containment vessel;*
4 *4 core tube ø 108 mm with a drill bit of ø 112 mm to open the containment vessel;*
5 *containment vessel;*
6 *valve on mortar pumping pipe;*
7 *stuffing box;*
8 *mortar in the chamber with containment vessels 2 and 3;*
9 *outlet tube for gas;*
10 *valve on outlet tube; 11 filter;*
12 *gap in containment vessel housing for gas outlet;*
13 *sand-cement solution in containment vessel No. 3.*

Figure 3.89. *Diagram of opening of containment vessel No. 3*

The position of special borehole No. 1 was chosen in order to use it open containment vessel No. 3. As a result of the drilling, the bottomhole of the borehole was located directly over the axis of containment vessel No. 3, in its central part.

Given these circumstances, along with representatives of VNIIEF TANIK, it was proposed to then implement an arrangement whereby the containment vessel was filled through a single borehole, with the installation of a single channel for pouring the sand-cement solution and a separate air outlet channel for the air, forced from the containment vessel, which is connected to a filter by an outlet tube (*Figure 3.89*). This solution was recorded as an amendment to the Detail Design.

The work was performed using a mobile SKB-5 drilling assembly, mounted on an URAL-375 truck. The preparations for opening the containment vessel progressed simultaneously with laying the concrete in the box.

The shaft of the drilled borehole was cased with steel pipes, 130 mm in diameter, after which the annular space was cemented (*Figure 3.90*).

The opening of the containment vessel was one of the most hazardous in terms of radiation, as, during its performance a gas-aerosol mix of nuclear waste could be emitted, especially when there is slight surplus pressure (relative to atmospheric pressure) in the cavity of the containment vessel.

The main task here was to prevent the outlet of a considerable volume of displaced air into the zone where personnel were working, through the gap between the casing pipe and the core equipment at the moment the housing of the containment vessel was first opened.

This problem was resolved using a stuffing box. A device was screwed to the casing pipe for the outlet and filtration of gases. The filtering element was manufactured in the form of a cassette with 8 sheets of Petryanov cloth (*Figure 3.91*). The containment vessel opening operation was performed after the personnel, the equipment and appliances were ready. A hole was drilled in an oil-and-water suspension; prior to the work commencing, about 30 litres of automobile oil was poured in and then the cock opened for feeding a minimal volume of water from the tank. About 1 hour after the drilling began, the containment vessel housing was cut through. Gas flowed from the bleed system and the readings on the filter indicated the presence of radioactive contamination. Binding material was pumped into the internal volume of the containment vessel in a pressurised environment, created continuously by the column through the pumping channel and connected with the hopper. The point when the spent containment vessel had been completely filled with binding material was determined when the mix emerged from the bleed pipe.

Figure 3.90. *Cementing the borehole's annular space*

Continuous radiation control was maintained at all stages of the work with the spent containment vessels, including with the involvement of representatives from the Russian Federation (*Figure 3.92*).

When the sand-cement solution had been poured into the containment vessel, the bleed system was dismantled and the borehole head was poured with concrete.

Work on pouring mortar into the chamber with two containment vessels and the box with one containment vessel, and on pouring the sand-cement solution into the containment vessel began on 16 April and ended on 19 May 2006. The concrete was laid only when the temperature was above zero.

Figure 3.91. *Preparing the filtering element*

Figure 3.92. *Monitoring the radiation situation after opening the containment vessel*

Laboratory tests indicated that the heavy-aggregate concrete, obtained at the production site, corresponds to grade M300 in compressive strength and the requirements of the Statement of Work (on average 295.6 kgf/cm^2)

When the work was completed, all equipment and mechanisms were removed from the working area and abandonment work commenced. Additional earth was brought in on dump trucks from the quarry and the earth, brought in earlier to construct the working area, was loosened using a digger (*Figure 3.93*).

Figure 3.93. *Abandoning the working area*

3.2.3.2. Right-hand structure

Given that the left- and right-hand structures are connected with one another, work was performed on the right-hand structure to strengthen the protection of the left-hand structure.

In April to May 1998, as part of the Programme to Abandon the Nuclear Weapons Infrastructure at the Semipalatinsk Test Site, Kazakh and American specialists destroyed the mouth of the right-hand structure by detonating pressure charges of explosives above the surface of the structure with subsequent backfilling of the cut-in trench with rock before recreating the natural relief of the locality.

Over recent years there has been a rock slide from the upper part of the mountain, which closed off the near-mouth section of the right-hand structure (*Figure 3.94*).

All protective measures at the right-hand structure were erected under constant dosimetric monitoring, while the blast work to crush and break up the rock over the structure's mouth and the work within the structure was conducted in accordance with the Detail Design for Closure of the Right-hand Structure.

Figure 3.94. *Bank of rock over the entrance to the right-hand structure*

By detonating low-power pressure charges, approaches were made to the large boulders, overhanging the mountain slope above the structure's entrance. Several crushing cycles were performed, including upon the axis of the structure. The rock was crushed until the larger pieces had acquired the form of fine clumps. The rocky backfill was opened up with a bulldozer and then the rock was loaded by digger into dump trucks and taken to a dump. When clearing the rock from the trench, large fragments were discovered, which were additionally crushed using pressure charges or blasts in blast holes.

After the first frame of the structure's supports was opened up, the cut-in trench was expanded and extended (*Figure 3.95*).

In the presence of a dosimetrician and rescue workers, operatives from the Russian Federation and NNC conducted a preliminary survey of the technical state of the structure through the opened part of the entrance. The survey yielded satisfactory results (*Figure 3.96, a*).

At an elevation of 125 metres a concrete plug had been constructed with a welded metal pipe, 2.0 metres in diameter. Gas cylinders were found near the protective wall and a small aperture was found in the metal plate that covered the pipe, the dimensions of which made it impossible for a person to pass through. Because of this it can be stated with confidence that there had been no unauthorised access beyond the concrete plug (*Figure 3.96, b*).

Figure 3.95. *Opening of the structure*

a) *b)*

Figure 3.96. *The condition of the structure (a) and traces of unauthorised activity (b)*

After the preliminary survey of the structure, work continued on expanding the cut-in trench and fitting out the structure's entrance (*Figure 3.97, a*).

Upon completion of preparations for entry into the structure, a detailed survey was performed, based on the results of which the initial site of the rockfall and the concrete plug was established and the types and volume of the required work were clarified to ensure safe performance of any further work (*Figure 3.97, b*).

Given the actual state of the excavated section, a 15-metre long section was determined for collapsing the rock (the survey mark at 57 metres to the survey mark at 72 metres) and installing a 10-metre reinforced concrete plug (the survey mark at 44 metres to the survey mark at 54 metres), with a distance of three metres between them, in full accordance with the Detail Design. At the site of installation of the concrete plug in wedge form, the section of the mine working was expanded by 0.5 metres in all directions using a blast in blast holes.

The earth that was collapsed when preparing the site for placing the concrete plug was shifted with a bulldozer to the site where the face of the structure was to be buried (to the survey mark at 72 metres) as a result of a blast (*Figure 3.98*).

a) *b)*

Figure 3.97. *Installation of the near-entrance section (a) and detailed survey of the structure (b)*

The blast holes for collapsing the structure were drilled into the sides, cover and bottom of the excavated section using a Sullivan self-propelled unit.

When the blast holes had been drilled, the supply lines were dismantled at the collapse section, the blast holes were charged and detonated.

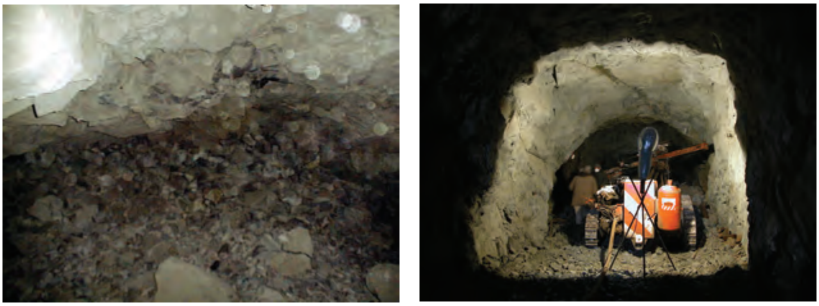


Figure 3.98. *Arrangement of the caving*

After the detonation the earth completely shrouded the entire section of the structure under a newly formed cover.

The main safety element of the structure, in line with the Statement of Work, was the 10-metre long concrete plug with wedge, which is made of heavy-aggregate concrete, conforming to M300 grade (strength class B22.5).

The proportions of the concrete mix were selected according to state standard GOST 27006, proceeding from the characteristics of the components for making concrete. Crushed natural granite was used as the coarse aggregate for the concrete mix, while a sand-gravel mix was used as the fine aggregate. These were supplied by specialist contractors. Portland cement made by SemeyCement in Semipalatinsk was used as the binding material.

Figure 3.99. *Installation of the concrete plug*

The excavated section for the concrete element was cleared of rock debris and then wooden formwork was erected for the concrete pouring. The reinforcement meshes for housing the reinforced concrete plug were made from class A-II reinforcement rod steel with a die-rolled section with a 22-mm diameter, from grade 35GS steel (similar reinforcement steel was used in work under Operation Blackthorn).

Separate elements of the reinforcement mesh were made at the near-entrance section and then conveyed to the installation site and arc-welded to the grid. The concrete mortar was fed from a mixer truck on a conveyor and into the formwork (*Figure 3.99*).

Laboratory tests indicated that the heavy-aggregate concrete, obtained at the production site, corresponds to grade M300 in compressive strength (on average 296.4 kgf/cm^2).

Figure 3.100. *View of the mouth after backfilling*

After installation of the concrete plug, the equipment and supply lines were dismantled, the entrance frame was taken down and the mouth of the structure was backfilled up to the existing relief of the locality (*Figure 3.100*).

The main operations related to closing off the right-hand structure were performed in the following time frames:

- preparation of the area: 13 September – 25 September 2005;
- opening of the structure's entrance: 25 September – 21 November 2005;
- preparation and collapsing of the structure's ceiling: 22 November – 28 November 2005;
- installation of plug: 28 November – 4 December 2005;
- closure of the structure's entrance: 4 December – 24 December 2005.
- 4,000 m^3 of rock was extracted when opening up the entrance.
- 213 m^3 of heavy-aggregate concrete was laid in the reinforced concrete plug.
- The near-entrance section was backfilled with 4,500 m^3 of rock.

3.2.3.3. Radiometrical support

The radioecological survey of the sectors of the right- and left-hand structures and the support elements of the work were performed to determine the actual radiation situation at the work sites at the start of the work, during their performance and upon their completion, based on which an administrative decision could be made on which steps needed to be taken in these conditions to reduce the impact of the radiation factor on the health of personnel and to prevent the transfer of contaminants to the environment.

Operatives from the accredited Test Centre of Radiation Safety and Ecology Institute, NNC conducted field studies using verified instrumentation, listed in the state register of Kazakhstan. Radiometric studies at the areas were performed in accordance with certified guidelines.

The following work was performed when rendering the radioecological support on the left- and right-hand structures to ensure the radiation safety of the staff:

- deployment of a permanent radiation monitoring station;
- radiation contamination monitoring of the air in the work zone;
- radiation monitoring of radiation parameters in the work sites;
- radiation monitoring of vehicles and ancillary equipment;
- radiation monitoring of residential modules and industrial premises in the field camp.

The measures that were adopted under the Works Plan and executed in reducing the radiation risk for the personnel and the environment helped prevent secondary radioactive contamination and the possible transfer by staff and equipment of radioactive products beyond the work zone. They also excluded the possible internal and external overexposure of staff.

The exposure dose level during monitoring of personnel throughout the period of the work remained at the background level, as recorded during the preliminary radioecological survey, and it varied from 0.12 to 0.17 μSv/hr. Monitoring of unprotected skin indicated that the maximum radiation intensity of α- and β-particles in the workers was not exceeded.

Radiometric studies prior to the start of the construction work and after its completion were performed according to a single technique and observation grid; they involved measurement of exposure dose level and radiation intensity of α- and β-particles at an elevation of 0.03 metres from ground level (*Figure 3.101*).

Exposure dose levels at areas, located at the near-entrance sectors of the left- and right-hand structures, varied from 0.09 to 0.44 μSv/hr and from 0.13 to 0.23 μSv/hr, respectively.

After enhancing the safety of the engineering structure, there is no radioactive contamination of the area in question; the work did not worsen the radiation condition within the working areas. The obtained results are confirmed by comparing the obtained values with the results of the preliminary survey.

3.2.4. Extraction and removal of activated, purpose-built process equipment from two tunnels at the Mayak production association (Russia) (Operation Golden Eagle) [9]

Proceeding from the positive experience from work under Operation Nomad, in the spring of 2005, the heads of Rosatom gave their consent to execution of the latest information contract between VNIIEF and the Los Alamos National Laboratory, on this occasion pertaining to the tunnel sites containing nuclear waste in a relatively accessible form.

Figure 3.101. *Radiation monitoring during performance of the work*

Agreement No. 37713-000-02-35 on Technical Assignment 026 stipulated quantitative criteria for assessing the proliferation and terrorism threats as applicable to nuclear waste as well as the elaboration of technical proposals on reducing these threats at tunnel sites of the former STS. At this stage the reports for LANL did not identify the sites, rather the sites were given conventional names, with a description of their protected nature given in general form (without specifying distances between plugs, their thicknesses and so on).

The consent of the American side for the sites not to be identified in the Russian reports ensured that a relatively large number of sites (sixteen) were covered, satisfying the chosen and approved criteria for assessing proliferation risks. A quantitative assessment of the risk was obtained for each site. As a result, all sites were split into four categories, according to the hazard posed. The Russian side proposed looking into the possibility of creating additional protective barriers to exclude access to the nuclear waste, without using industrial methods, at 16 sites that corresponded with hazard levels from 4 to 2, respectively. The fourth level is the maximum level of hazard. Three sites corresponded to this level and they were assigned the letters X, Y and Z.

On 8 September 2005, Kurchatov hosted the first bilateral working meeting between

Russia and the USA, with a second held on 17–22 April 2006, to discuss working options at the “critical” tunnels. A fundamentally new event in these consultations was our consent to repatriate to Russia the activated special process equipment and fragments thereof, remaining at site X.

Additional protective measures at sites X and Y were implemented in the order as established under Kazakh law and pursuant to the requirements of effective state standards and normative documents, including health protection of the workers and the environment over the following key stages:

Stage 1 (pre-construction work) – preparation of the area in front of the entrance; radiological and environmental surveys; excavation of soil, digging of a trench and removal of rock debris; removal of the entrance plug.

Stage 2 (construction (mining) work) – mining survey; erection of a protective cover over the engineering structure, removal of collimators, safe engineering up to the first plug, restoration of the rail tracks; installation of a life-support system, preparations for and the opening of a hole in the first plug, preparations for drilling and blasting; removal of rock, collimators and other plugs; restoration of rail tracks and the life-support system, extraction of packaging and its placement in a purpose-built container.

Stage 3 (transport) – the transporting of the container by road to Degelen Station and its dispatch by rail to Russia.

Stage 4 (concluding work) – installation of a plug and sealing of the engineering structure.

Starting from the opening of the boxes with the special process equipment and until the container was handed over at Lokot Station, all work was performed in the presence of guard patrols by Kazakh Interior Ministry troops.

3.2.4.1. Site X

The detail design for the additional protection of engineering structure X was elaborated by the Kazakh State Scientific Production Centre for Explosive Work of the National Nuclear Centre.

Experimental data and the results of practical experience in protection of spent containment vessels and enhancement of the protection of engineering facilities at previous sites were used in the design. *Figure 3.102* shows the design layout of the engineering structure.

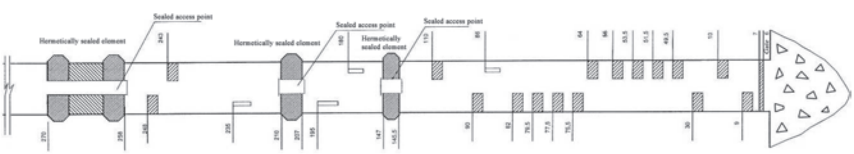
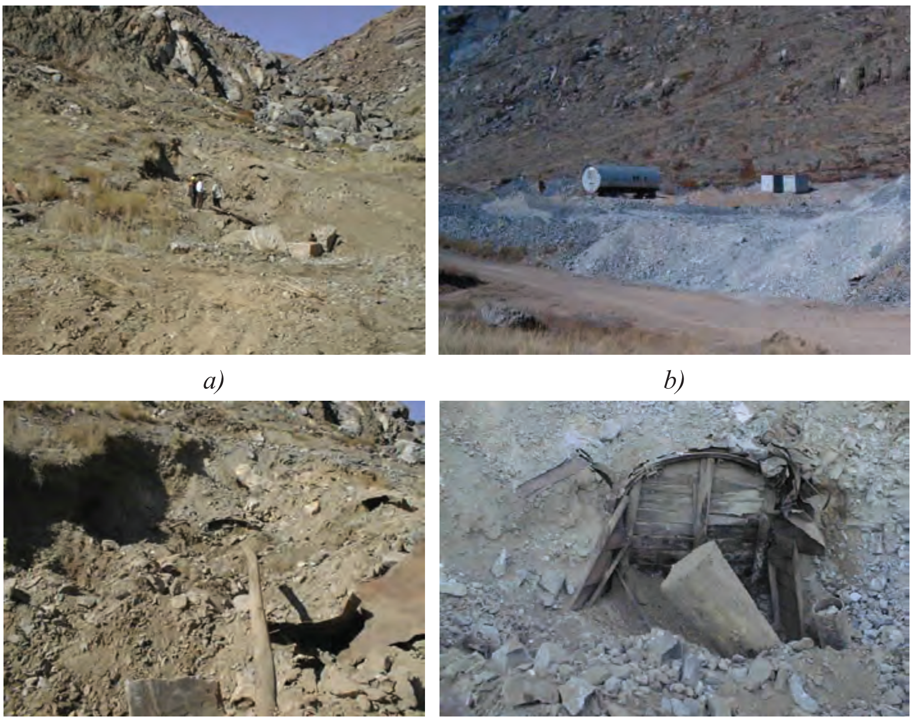


Figure 3.102. *Design layout of the engineering structure at site X*

Contracted field mining work began on 19 September 2006. After levelling the surface of the working area and the site for locating the explosives storage facility (*Figure 3.103, a, b*) and after erection of a field camp, the cut-in trench was opened up (*Figure 3.103, c*).

After dismantling the concrete safety plug, the entire section of the structure was found to be full of rock, frozen in ice. Mine rescue workers knocked a passage into the structure in the mine's upper part (*Figure 3.104*). Given the unsafe condition of the structure, work inside was stopped until specialists from the three countries had reached a joint decision. On 10 October 2006, specialists involved in the operation from the three countries, supported by operatives from the military mine rescue division of the Kazakh Ministry of Emergency Situations, surveyed the state of the structure to determine the possibility of and the procedure for recovery work (*Figure 3.105*).



a) *b)* *c)*

Figure 3.103. *View of the working area of site X (a), the location of the temporary storage facility for explosives (b) and the entrance once opened (c)*

Professor Ivan Yerofeyev, doctor of technical science and head of the Kazakh State Scientific Production Centre for Explosive Work was involved in the survey of the engineering structure. Professor Yerofeyev made a considerable contribution to abandonment of the nuclear infrastructure and non-proliferation of nuclear waste at the former Semipalatinsk Test Site. Unfortunately, this was to be his last working visit.

The following was determined as a result of the survey:

- the rock mass of site X had been fragmented by preceding blasts into large blocks of rock. There were cracks on the surface of the rock mass, through which water had leached from precipitation, resulting in the bottom, the walls and the crown of the mine, at up to 30 metres to the entrance, being covered in a layer of ice;
- the right-hand side of the mine, up to 50 m in from the entrance, had been shifted 1–1.5 metres into the mine as a result of seismic activity;
- at the 50-metre point a heap of rock began, which covered the entire section of the mine;
- localised caving, up to 1.5 metres high, was detected in the ceiling of the mine.

Figure 3.104. *View of the structure's entrance*

Figure 3.105. *Surveying the structure at site X*

The survey results confirmed that the structure at site X was in an unsafe condition.

The radiation situation at the entrance and initial part inside the structure corresponds with the natural background for this locality.

On 11 October, a technical meeting was held in Kurchatov, where representatives of Kazakhstan, Russia and the USA decided on the possible, safe restoration of a section of the structure, provided that a number of preliminary measures were implemented.

The restoration of the sector requires time, additional material expense and safety measures. To reduce downtime, the technical meeting decided that, from 14 October, work would begin on preparations for opening up the structure at site Y.

The portal to the structure at site X was provisionally sealed and placed under security (*Figure 3.106*).

Figure 3.106. *Sealed portal to site X*

Figure 3.107. *Field camp at site X*

Negotiations were held from 23 to 27 October 2006, which concluded with the signing of a modification to the contract on removing unforeseen rock heaps at site X.

Recovery work on the unsafe structure at site X commenced on 4 December 2006. A photograph of the field camp is shown in *Figure 3.107*.

The greatest problems encountered when recovering the sector involved work on the frozen mixture of rock and metal and the removal of metal items from the rock mass. This work had to be completely performed by hand; no loading machinery would be able to capture this mixture. The pipes (or rails) had to be dug out manually, cut into small pieces and loaded into cars by hand.

The most undermined part was found at the 70–90-metre interval from the entrance, from where more rock than the volume of the structure at this interval was removed, linked with considerable caving of rock from the ceiling and the sides.

In the interval from survey mark 110 to survey mark 145.5, the structure was almost half filled with a mixture of rock and metal items.

In all, from survey mark 0 to survey mark 145.5 metres in the recovered sector, 176 frames of top-drive system [SVP]-17 were installed and replaced. Views of the bottoms of a number of sections are presented below (*Figure 3.108*).

Figure 3.108. *View of bottoms of separate sections*

The earth is made of crushed rock, soldered together with ice as far as survey mark 50, then with building and metal structures and pipes. From the survey mark at 15 metres, the cross-section of the structure is almost 70% covered in rock, shifted from the right-hand side of the tunnel (*figures 3.109* and *3.110*).

After survey mark 110 the technical state of the mine improved. At this interval mostly caving of the rock from the ceiling of the structure was observed (*Figure 3.111*).

A tectonic fault was recorded at survey mark 111, which was traced from almost the entrance to the structure. Along the left-hand side of the structure, a slip plane was clear to see, while along the right-hand side there was a vertical crack over 10 cm wide. After repairs to the supports in the intervals between survey marks 129 and 139, the concrete protective plug was broken to 1.5 metres thick with a sealed access point at survey mark 145.5 (*Figure 3.112*).

Figure 3.109. *Caved rock, structures and scrap metal, to be cleared and removed*

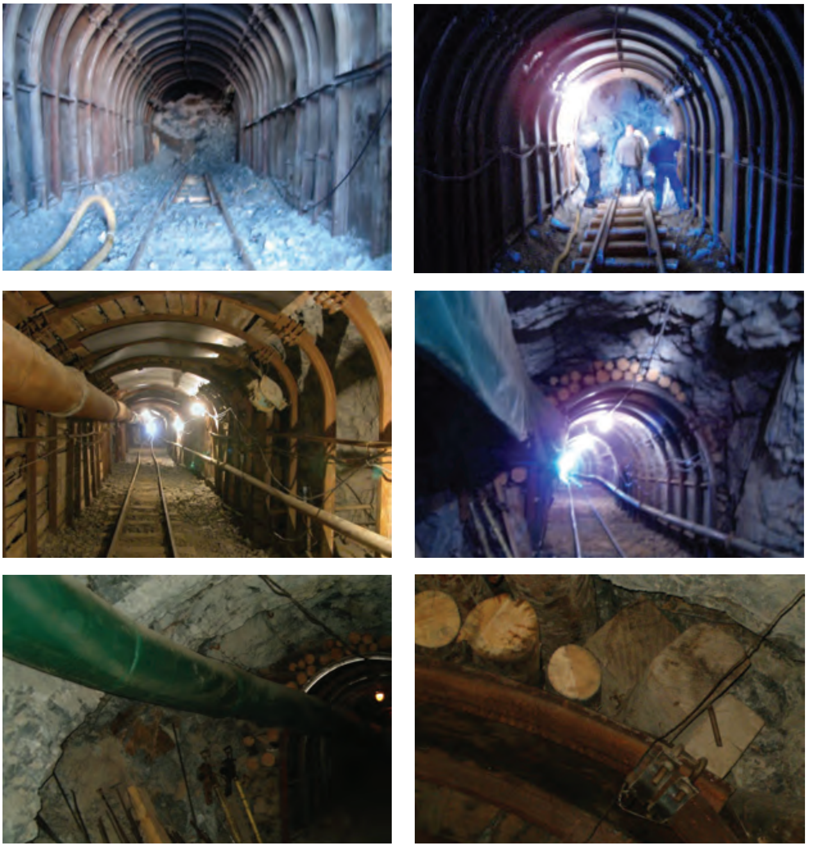


Figure 3.110. *Lining the mine working*

The survey of the sector of the structure up to mark 258, where the penultimate plug was located, indicated that this sector was in a satisfactory technical state (*Figure 3.113*).

The concrete plug at the mark at 258 metres had a sealed access point – a metal pipe about 1.0 metre in diameter, through which a passage had been made to the box with the remnants of the special process equipment (*Figure 3.114*).

Figure 3.111. *View of the sector from survey mark 110*

Figure 3.113. *The sector to survey mark 258*

Figure 3.112. *Tectonic crack on the right-hand side of the structure, with sealed access point*

Protective plug at survey mark 258

Sealed access point

View of the structure's box

Survey of the box

Figure 3.114. *Survey of the structure*

Removal of rock from the structure

Receiving bunker for rock

Rock storage site

Figure 3.115. *Extraction of rock from the structure*

After the survey a decision was made about the possibility of extracting material from the box without destroying the concrete protective plug. All the rock from the structure was taken out to a storage site away from the working area (*Figure 3.115*).

On 10 April 2007, after recovery of the sector of the structure to the survey mark at 258 metres, work at site X was suspended and continued at site Y.

Security at the site was provided from 10 April by guard forces from the military unit.

Between 10 May and 6 June, Russian specialists, accompanied by NNC specialists, searched for and collected the remnants of special process equipment in the structure's box. A package with remnants of the special process equipment from site Y, removed by Russian operatives, was placed into this same box, after which the box was sealed (*Figure 3.116*).

Figure 3.116. *Working in the box*

Once the special process equipment had been removed from the box at site X and it had been taken out on 8 June, work began on strengthening the physical protection of the structure. In the space of the sealed access point, a 12-metre long reinforcement column was installed and poured with mortar using a BUK-1 concrete spreader (*Figure 3.117*).

In an interval of 30–40 metres, two sets of wooden formwork were installed, between which a reinforcement mesh was installed through the entire volume. Using the BUK-1's pump, installed at the entrance to the structure, 98 m^3 of mortar was pumped into the plug. After construction of the concrete plug the support frame of top-drive system [SVP]-17 was dismantled in the interval of 0 to 10 metres and the structure's entrance was dissembled (*Figure 3.118*).

Equipment and materials were loaded and taken out from the near-entrance area and the explosives storage facility was abandoned. The cut-in trench and the mouth of the tunnel were backfilled with rock and the near-entrance area and the adjacent territory were levelled using a bulldozer (*Figure 3.119*). *Figure 3.120* shows the diagram of the structure after the work was completed.

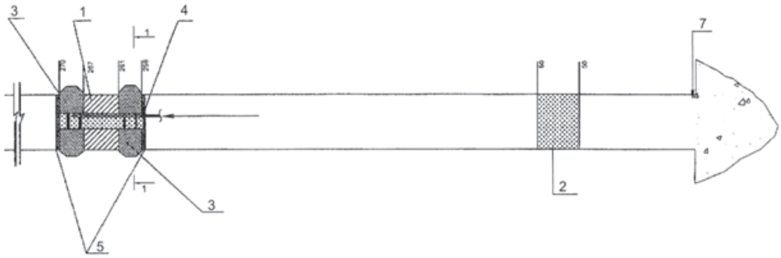


Figure 3.117. *Sealed access point abandonment diagram*

Figure 3.118. *Work on the structure*

Figure 3.119. *Photograph of the near-entrance area before and after the work*

Heavy-aggregate, average-density concrete with an intermediate strength class of B22.5 was used to backfill the boxes and construct the concrete plugs.

All the work was performed under constant radioecological monitoring to avoid possible overexposure of the personnel, radioactive contamination of equipment and facilities and contamination of the environment.

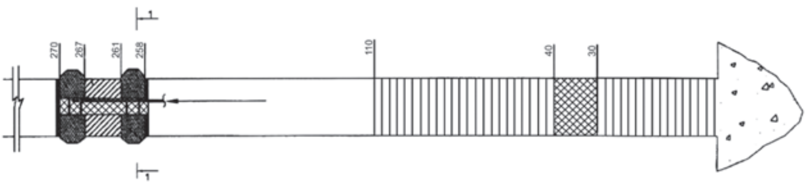


Figure 3.120. *Diagram of the structure after the work*

A decontamination station for personnel and equipment was installed and maintained in a constant state of readiness at the work site.

The work was performed by operatives of the accredited Test Centre of the of Radiation Safety and Ecology Institute, NNC.

The following types of work were performed during radiation support:

- radiation contamination monitoring of the air in the work zone;
- monitoring of radiation parameters at the work sites;
- radiation monitoring of equipment and vehicles;
- radiation monitoring of residential modules and service premises at the field camp;
- individual dosimetric monitoring of category A personnel, deployed to work with radioactive substances;
- laboratory research of samples.

Individual instances of ^{222}Rn were recorded in excess of permissible volume activity:

- 23 April 2007 – 4 x 10^4 Bq/m^3 – with measurement performed in the region of the survey mark at 270–280 metres (beyond the plug);
- 7 June 2007 – 2.7 x 10^4 Bq/m^3 – with measurement performed in the region of the survey mark at 259 metres (after extracting special process equipment from the end cavity);
- 12 June 2007 – 2.5 x 10^4 Bq/m^3 – with measurement performed in the region of the survey mark at 200 metres (after extracting special process equipment from the box);

When the concentration of radon during work using personal protective respiratory equipment exceeds permissible average annual volume activity, a restriction on the time personnel can remain in the structure is introduced.

During the work no excess was recorded in the permissible volume activity for ^{220}Rn. *Figure 3.121* displays air sampling at the work site.

Measurement of radiation parameters included measurement of exposure dose level, the flux density of α- and β-particles of the work sites, facilities and equipment during a working shift (*Figure 3.122*).

When performing radiometric surveys, the measured flux density values of α-particles did not exceed the detection limit of the instrumentation used (1 particle/(min x cm^2)). The measured flux density values of β-particles at all survey sites likewise did not exceed the detection limit of the instrumentation used (10 particles/(min x cm^2)).


Figure 3.121. *Air sampling*

Individual dosimetric monitoring is an integral part of radiation safety provision at the site. The operatives who were deployed directly in the work inside the structure were sent for individual dosimetric monitoring.


Surveying the surface of the structure's bottom


Measurement of contamination on the surface of transport facilities in the near-entrance section

Figure 3.122. *Measurement of radiation parameters*

The doses obtained during one shift (1 day) did not exceed the detection limit of the instrumentation used (0.01 mSv) which, in annual terms, is less than the permissible dose limit for category A personnel, as set by NRB-99 norms of radiation safety (20 mSv per year).

Throughout the course of the work, at the end of each shift, the surfaces of the protective clothing of the personnel working in the structure, were examined (*Figure 3.123*).

Swabs were periodically taken throughout the course of the work to monitor the radioactive contamination of working surfaces within the structure (*Figure 3.124*).

During recovery of the structure at the start and at the end of each engineering process (drilling, loading rock etc), the spectrum of γ-radiation on the surface of the bottom and walls of the structure was recorded with a gamma-spectrometer to monitor the presence of industrial radionuclides ^{241}Am and ^{137}Cs.

Figure 3.123. *Examination of personnel*

Figure 3.124. *Swab sampling*

During the period that elapsed, no cases of overexposure of personnel, working at site X, were revealed.

The measurements of radiation parameters (exposure dose level, flux density of α- and β-particles) were recorded in the same points as when performing the preliminary survey.

Results of the radiation survey indicated that the radiation parameters remained practically unchanged after the work in the working area.

The radiation parameters in the structure's working zone at site X were within the following values: exposure dose level from 0.18 to 0.36 μSv/hr; flux density of β-particles from 10 to 22 particles/(min x cm^2). Results of measurements of flux density of α-particles did not exceed the detection limit of the instrumentation used (0.2 particles/(min x cm^2)). The obtained data correspond with the results obtained during the preliminary survey.

3.2.4.2. Site Y

The engineering structure at site Y is located in a narrow, intermountain trough. A view of the area before the work (*Figure 3.125*) and the structural diagram (*Figure 3.126*) are presented below.

Figure 3.125. *Area at site Y before the work*

During a gamma survey on foot at the area of site Y, two local sectors of radioactive contamination were detected (*Figure 3.127*).

The first sector was near the backfilling of site Y, where diggers made an access hole when attempting to penetrate the cavity of the structure (*Figure 3.128*).

The maximum exposure dose level in this sector was 0.3 μSv/hr, for flux density of β-particles it was 60 particles/(min x cm^2) and for flux density of α-particles it was 12 particles/(min x cm^2).

The second sector was located on the boundary of the surveyed sector, about 40 metres from the entrance to the structure. The maximum exposure dose level recorded at this point was 23.0 μSv/hr, for flux density of β-particles it was 140 particles/(min x cm^2) and for flux density of α-particles it was 6 particles/(min x cm^2).

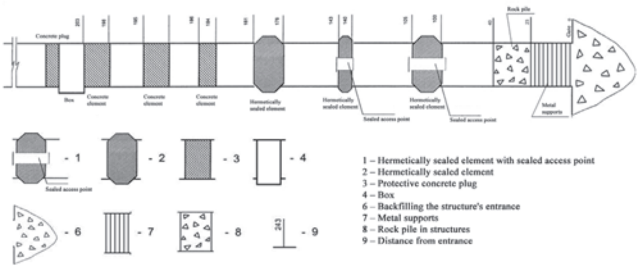


Figure 3.126. *Diagram of the structure at site Y*

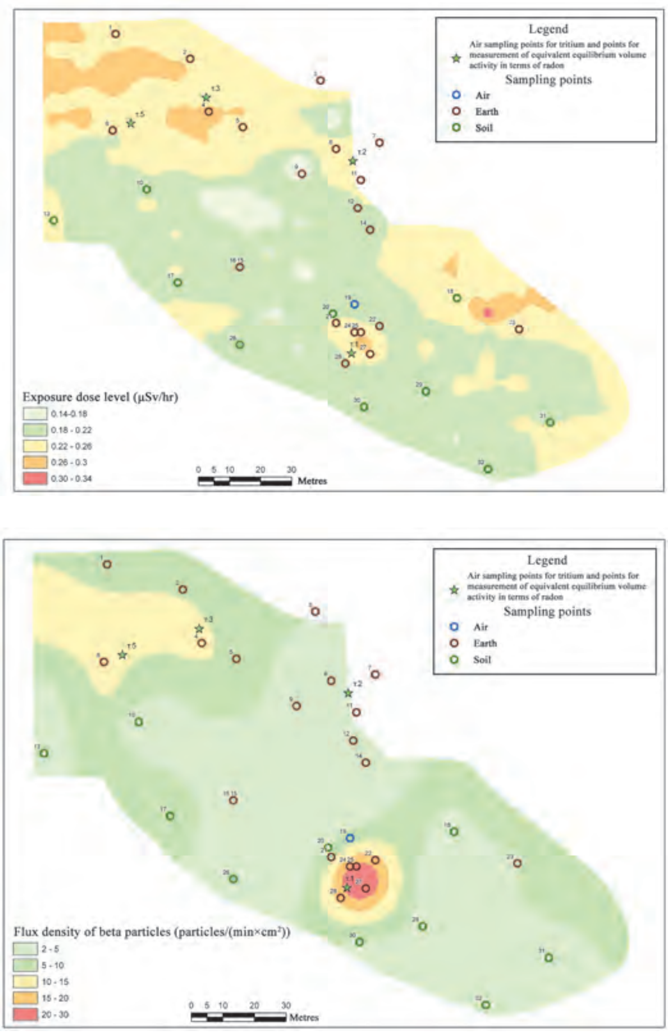


Figure 3.127. *Map of the spread of exposure dose level (a) and flux density of β-particles (b) at the area of site Y*

The radiation values in the remaining part of the area at site Y varied as follows:

- for exposure dose level – from 0.14 to ~0.3 μSv/hr;
- for flux density of β-particles – from <2 to 12 particles/(min x cm^2).


Figure 3.128. *Access hole into site Y*

Results of measurements of flux density of α-particles did not exceed the detection limit of the instrumentation used (<0.2 particles/(min x cm^2)). These values are at background level for Degelen Mountain.

According to field data from measurements, the equivalent equilibrium volume activity of radon at the site's area was below the detection limit of the device, at >4 Bq/m^3.

The construction work under the assignment included the following:

- excavation of soil from the trench and removal of rock fragments;
- removal of the plug at the entrance;
- technical survey;
- where necessary, erection of mine supports;
- recovery of railway tracks at the near-entrance area and inside the structure;
- installation of life-support systems;
- destruction and removal of five concrete safety plugs;
- opening of the box with remnants of the special process equipment;
- pouring of mortar into the box;
- installation of a safety plug, up to 40 metres from the entrance;
- backfilling of the structure's entrance;
- levelling of the area;
- concluding radiological survey of the area.

Work at site Y began on 16 October 2006 and was completed on 2 July 2007.

The schedule of the works under the assignment to strengthen the protection of two engineering structures at sites X and Y stopped and started in light of various circumstances (*Figure 3.129*). The work was performed either at one site or at the other. An abnormal situation at site X was caused by a break in the work to draw up additional design documentation and purchase additional materials. Under preliminary agreement, fragments of the special process equipment should have been removed on one set of rolling stock, linked with which it was almost simultaneously necessary to approach and open the boxes at both sites.

All work on fitting out the tunnel was done in accordance with the design documentation and unified safety regulations for explosive operations. Dosimetric and technical monitoring was performed throughout the course of the work.

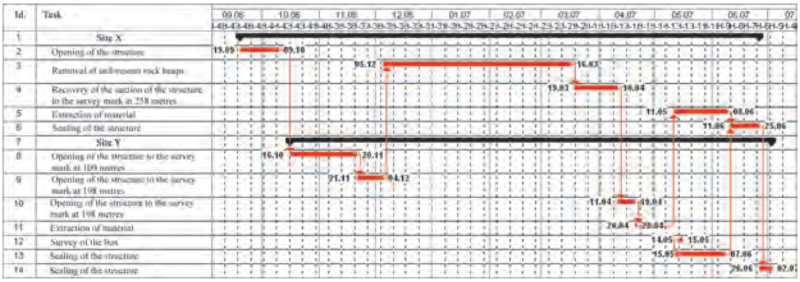


Figure 3.129. *Works schedule on abandoning structures at the sites*

After the rock had been excavated from the trench and the surface levelled, the entrance to the structure was recovered. The mine rescue team surveyed the engineering structure (*Figure 3.130*). Based on these surveys, the volume and means of conducting the recovery work in the engineering structure, the order and duration of this work and safety measures in the structure were all clarified.

After radiation monitoring, the rock was removed from the structure to a designated site within the working area (*Figure 3.131*).

At the elevation of 100–105 metres there is a hermetically sealed element with a sealed access point. The survey was performed through this sealed access point (*Figure 3.132*).

Russian specialists and operatives from the Radiation Safety and Ecology Institute examined the condition of the structure's section beyond the plug (*Figure 3.133*). Similar work was performed at all sectors after the concrete safety plugs were opened and destroyed.

The examination revealed that the radiation situation was normal beyond this plug and discovered traces of unauthorised access by scrap-metal scavengers – cut tubes and used oxygen cylinders (*Figure 3.134*).

The concrete plug at the survey mark at 100 metres was eradicated.

After recovery of the section of the structure to the 130-metre mark, work at the site was suspended and continued at site X, while this site was sealed off and manned with a security presence (*Figure 3.135*).

Work was resurrected at the site from 11 April.

Concrete safety plugs were eradicated at the survey marks at 140–143 metres with sealed access point (*Figure 3.136*) and at the survey marks at 176–178, 184–186 and 190–195 metres.

The technical and radiation situation at the recovered section from the survey mark at 100 metres to the mark at 198 metres was satisfactory.

The last plug before the box with fragments of special process equipment at the survey mark at 198 metres consisted of individual blocks of concrete (*Figure 3.137*). The radiation background by the wall of the plug at the 198-metre mark was increased.

Opening of the entrance

View of the structure's entrance
before and after development

Technical survey of the structure

Blockage of the structure upon its sealing

Figure 3.130. *Recovery of the entrance*

Figure 3.131. *Removal of rock from the pile*

Figure 3.132. *Hermetically sealed element with sealed access point at the elevation of 100 metres*

Figure 3.133. *Survey of the section of the structure beyond the elevation at 105 metres*

Figure 3.134. *Traces of unauthorised presence*

Figure 3.135. *Sealed portal to engineering structure Y*

Figure 3.136. *Hermetically sealed element with sealed access point at the survey mark at 140 metres*

Figure 3.137. *Examination of the concrete plug at the survey mark at 198 metres*

Figure 3.138. *Boreholes to sample gases and for video surveillance*

In the concrete plug at survey marks at 198–203 metres, a 105-mm-diameter borehole was drilled to a length of 5 metres to sample air from the atmosphere of the box. Then the borehole was drilled out to a diameter of 170 mm to deliver a video camera into the box and to conduct a survey (*Figure 3.138*).

No toxic gases of any kind were found in the box. The condition of the box was satisfactory in a technical sense (*Figure 3.139*), while the radiation background was considerably increased.

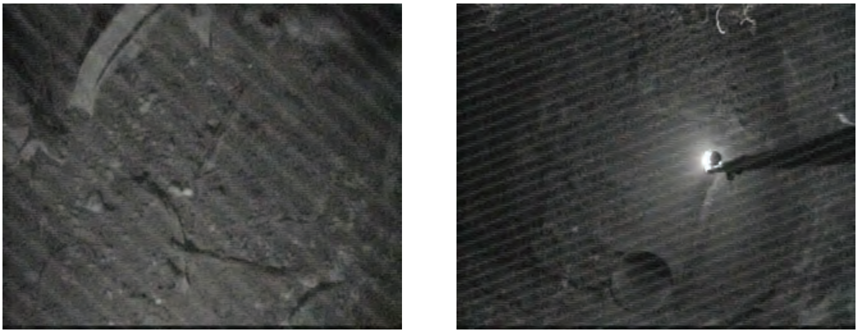


Figure 3.139. *View of the box through the video camera*

As a result of drilling and blasting, the entire concrete plug collapsed at the interval of 198–203 metres, as the concrete plug had previously been broken down (revealed during the survey of the box).

A passage was arranged into the box through the point of access (*Figure 3.140*). On 20 April, Russian specialists surveyed the box, as a result of which fragments of the activated special process equipment were detected. According to the decision, adopted to reduce possible contamination of a considerable part of the structure, the fragments were packaged into a flexible container and taken away to the engineering structure at site X.

Figure 3.140. *Box of the structure*

US representatives were informed of the operation by e-mail. On 14 May, DTRA specialists arrived in Kurchatov and, on 15 May, a joint (trilateral) survey was performed on the box in the structure at site Y (*Figure 3.141*), as a result of which the presence of the special process equipment in the opened box was confirmed, as was the correctness of the decision to take it away to structure X for temporary storage, with security provided by guards of the military unit.

Figure 3.141. *Survey of the box in the structure*

Based on the results of the survey, it was decided to pour a concrete solution into the section of the structure from the survey mark at 193 metres, as the structure's bottom was contaminated with radioactive elements after this mark.

Wooden formwork was installed at the survey mark at 193 metres to fill the box and the section of the structure. The mortar, prepared using an ABS mixer, was delivered to the pouring point by a plugging car and loaded over a transporter to the BUK spreader (*Figure 3.142*). A total of 136 m^3 of mortar was made and poured into the box.

Figure 3.142. *Concrete pouring into the box*

Figure 3.143. *Installation of the concrete safety plug at 38–48 metres*

A double set of wooden formwork was erected at the survey mark at 38–48 metres, between the walls of which a reinforcement metal mesh was installed all around the plug (*Figure 3.143*). The mortar was poured using a BUK-1 concrete spreader, located at the near-entrance area. A total of 92 m^3 of mortar was poured into the plug at the survey mark at 38–48 metres.

At the end of the work, the tunnel entrance and the near-entrance framework were dismantled and the structure's cut-in trench backfilled with rock (*Figure 3.144*). A total of 550 m^3 of rock was backfilled into the trench. A diagram of the structure after the work is presented in *Figure 3.145*.

During the concreting, the concrete was subjected to regular quality control in accordance with effective Kazakh standards.

Figure 3.144. *View of the site after closure*

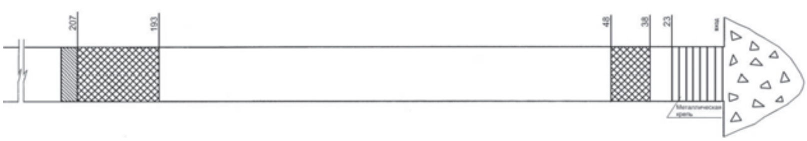


Figure 3.145. *Diagram of the structure after the work*

Laboratory tests indicated that the concrete, obtained at the production site, corresponds to class B22.5 in compressive strength (on average 294.7 kgf/cm^2).

Radioecological support was arranged for all the work, to provide for the safety of the personnel on site, including monitoring of the air and the rock taken out to the surface (*Figure 3.146*). Maximum volume activity in terms of radon and thoron were within permissible levels.

Measurement of radiation parameters included measurement of exposure dose level during the course of a shift, flux density of α- and β-particles in the work sites, facilities and equipment.

Maximum exposure dose level (10.0 μSv/hr) in the bottom was within the permissible level according to NRB-99 norms of radiation safety (11.76 mSv/hr). One exception was an exposure dose level, recorded on 10 May 2007, after the destruction of the plug in the end cavity. The exposure dose level stood at 16.0 μSv/hr, which is 1.4 times higher than the permissible level under NRB-99.

A maximum flux density of α-particles was also recorded after destroying the plug to the box, which stood at 103 particles/(min x cm^2). This is 200 times higher than the level of radioactive contamination by α-active nuclides of the surfaces of premises with a permanent presence of personnel and which hold equipment (5 particles/(min x cm^2)), as monitored under NRB-99.

After passing the survey mark at 190 metres, a spot was discovered (S = 225 cm^2), the flux density of β-particles at which reached 2 x 10^4 particles/(min x cm^2), which is ten times higher than the level of radioactive contamination by β-active nuclides of the surfaces of premises with a permanent presence of personnel and which hold equipment (2000 particles/(min x cm^2)), as monitored under NRB-99.

a) *b)*

Figure 3.146. *Measurement of equivalent equilibrium volume activity of radon and thoron in the structure (a) and sampling of air in the working zones (b)*

Subsequent work in the structure was performed with a limit on the time personnel could spend there, mandatory control of the daily exposure dose of the personnel and measures to reduce the effect of radiation factors (reducing ventilation power to reduce dust elevation, dust management with water, treating the inner surfaces of the tunnel with a cement mortar and covering radiation-contaminated ground with polythene).

After erecting the concrete plug, the flux density of α-particles reduced tenfold and did not exceed 100 particles/(min x cm^2); no excesses were recorded in terms of exposure dose level and flux density of β-particles.

On 8 May 2007, Russian specialists surveyed the box and a further survey was performed by Russian and American specialists on 15 May 2007.

The dose received during the course of the work did not exceed the permissible dose level for category A personnel, as stipulated under NRB-99.

The surfaces of protective clothing and gauntlets were inspected daily, when the personnel passed from the buffer zone to the residential zone (*Figure 3.147*).

Figure 3.147. *Examination of protective clothing*

Figure 3.148. *Inspection of the tunnel bottom using a portable gamma-spectrometer*

Figure 3.149. *Visual diagram of contamination of the near-entrance sector*

The bottom of the tunnel and equipment were periodically inspected using a portable gamma-spectrometer during the course of the work (*Figure 3.148*).

The inspection with the gamma-spectrometer recorded the presence of gamma-emitting ^{241}Am radionuclides, starting from the survey mark at 175 metres.

On 16 April 2007, samples taken in the structure recorded minimal significant specific activity (MSSA) of industrial radionuclide ^{241}Am at 45 times higher than the permissible level. In light of this, at 12.30 hours, work in the tunnel was temporarily suspended.

The following measures were implemented to prevent repeat contamination and overexposure:

- a radiological survey of the near-entrance sector was performed to designate the buffer zone;
- the buffer zone was fenced off;
- the field camp was relocated to a point outside the buffer zone;
- access to the buffer zone was permitted only through a decontamination room with dosimetric monitoring and where personnel had to change all protective clothing; if any contamination was detected, the protective clothing was sent for decontamination. If decontamination was not possible, the protective clothing was sent for burial;
- measures were taken to prevent dust elevation from the heap of extracted soil.

Once these measures were completed the work was resumed. Measurement of the surfaces of equipment revealed no radioactive contamination.

Examination with a portable gamma-spectrometer was used to determine places of contamination at the near-entrance area. These measurements showed that contamination of the working area was universal and of a mosaic nature; it was not possible to delineate the spots. A decision was made to conduct reclamation and recovery work at the near-entrance area to reduce the negative impact of the radioactive contamination on the environment.

Between 27 June 2007 and 29 June 2007, the near-entrance area and the working area at site Y were additionally backfilled with crushed aggregate (*Figure 3.149*). The reclamation work was based on operational measurements of radiation parameters, obtained during the work on entrance closure and on data from the report by Russian specialists on the preliminary survey.

The reclamation involved the backfilling of the contaminated area with crushed aggregate. Crushed aggregate from the slope opposite the tunnel entrance was used for the backfilling.

During the reclamation of the area, operational spectrometric monitoring of the crushed aggregate and the contaminated sector was performed. Evidence of the quality of the work was the lack of a ^{241}Am peak at the backfilled area. As a result, the entire area was backfilled with a layer of crushed aggregate (*Figure 3.150*). The height of the backfilling varied from 10 to 25 cm, depending upon the initial level of the radiation contamination.

Recorded measurements of exposure dose level were performed in fixed points on a grid, at an elevation of 0.03 metres from ground level. Based on the measurement results, a map of exposure dose level spread was constructed for the area under study (*Figure 3.151*). Exposure dose level fluctuated between 0.18 and 0.41 μSv/hr.

Based on the measurement results, a map of the flux density of β-particles was also constructed for the area under study (*Figure 3.152*).

Figure 3.150. *Overview of the area at site Y after completion of the work*

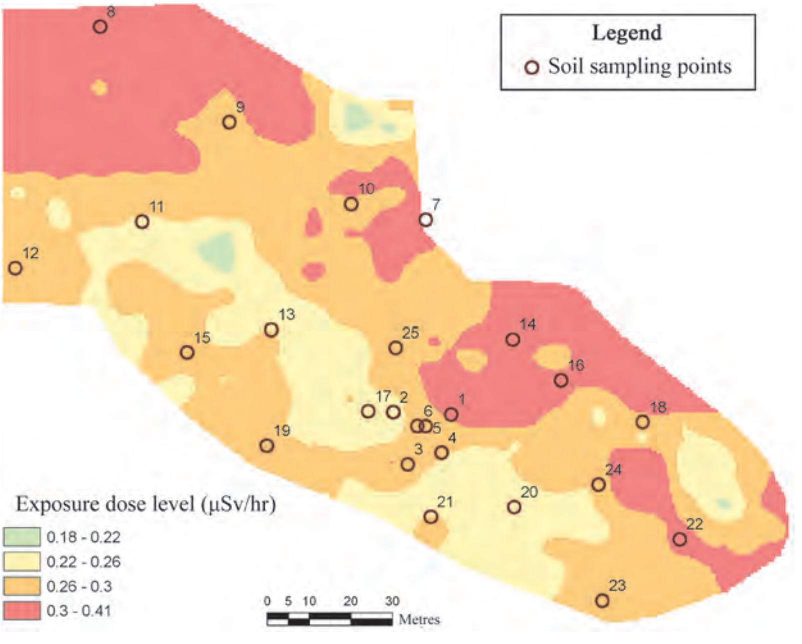


Figure 3.151. *Map of exposure dose level spread at the working area of site Y*

The measurements established that flux density of α-particles in the working area was below the detection limit of the instrumentation (0.2 particles/(min x cm^2)), while flux density of β-particles varied from 5 to 18 particles/(min x cm^2). These values are at background level for Degelen Mountain.

During a gamma survey on foot, a sector with localised radioactive contamination was detected in a depression, about 25 metres to the left of the tunnel entrance. This sector of localised radioactive contamination arose as a consequence of unauthorised business and was not connected with the work performed under the project. Nevertheless, partial reclamation work was performed on this sector, which considerably reduced the radioactive contamination but did not eradicate it completely.

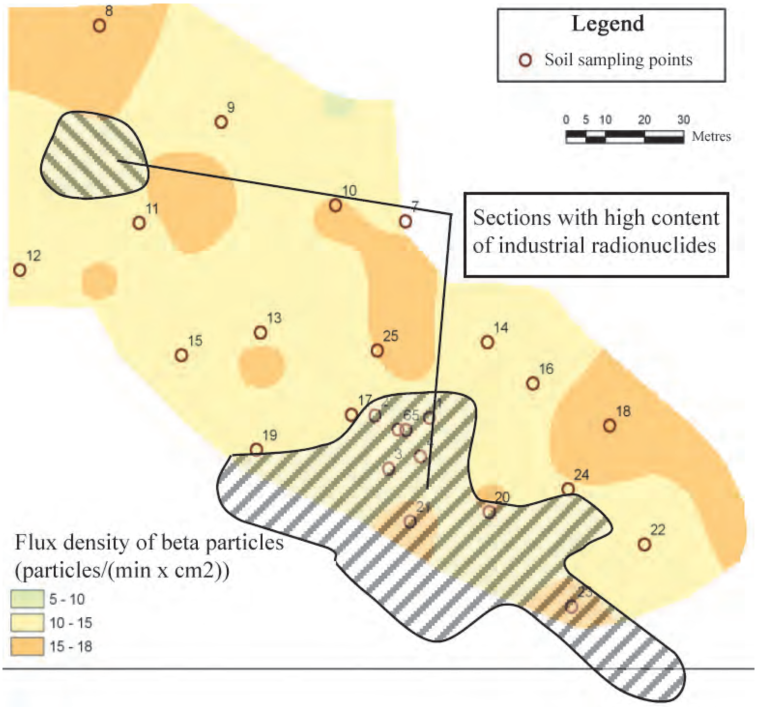


Figure 3.152. *Map of the spread of flux density of beta-particles*

The key contaminating radionuclide in the structure was ^{241}Am. Its activity in a number of samples exceeded permissible average annual volume activity, which is 0.2 Bq/m^3 for this radionuclide. The maximum value stood at 13.4 Bq/m^3, which is 67 times higher than the permissible average annual volume activity (survey mark at 150 metres). In this instance, even given that all the work was performed using personal protective respiratory equipment, which weakens the supply of radionuclides through the respiratory organs by a factor of 200, the total effective dose received by the personnel stood at 6.3 mSv, which is within the norm. Despite this, based on the results of monitoring, other personal protective equipment was used in future work, specifically an AVI gas mask for emergency response and recovery work, which reduces supply of radionuclides through inhalation by a factor of 500.

Maximum activity of plutonium in an air sample reached 36 Bq/m^3. This value is about 70 times above the permissible average annual volume activity. Given that all the work was performed using breathing apparatus, the effective annual dose was 6.5 mSv.

Upon laboratory analysis of the samples taken at site Y and calculation of the dose based on the obtained results, no excesses of the effective annual dose, as per NRB-99, were recorded.

The radioactive parameters at site Y were on the level of background values, determined for Degelen Mountain.

3.2.4.3. Transport of special process equipment fragments

The Programme for Transporting the Activated Special process Equipment in Four ASN44-566 Packages From the Engineering Structures of STS Across Kazakhstan to the Russian Federation was elaborated to facilitate the interaction of those involved in the work and to provide for safety and physical protection when transporting fragments of the special process equipment, activated as a result of nuclear activity, from the engineering structures of STS sites, during transportation in four ASN44-566 packages, placed in an NT 233 safety device.

The Programme was coordinated with a number of ministries and departments, deployed in this event, including the Chairman of the Atomic Energy Committee of the Ministry of Energy and Mineral Resources, the President of Kazakhstan Temir Zholy, the national railway company of Kazakhstan, the National Security Committee of the Republic of Kazakhstan, the Commander-in-Chief of the Interior Forces of the Kazakh Ministry of Internal Affairs, the Kazakh Ministry of Transport and Communications, the Kazakh Ministry of Emergency Situations, the Kazakh Environment Ministry, the Chief Medical Officer of the Republic of Kazakhstan, the Kazakh Foreign Ministry, the Kazakh Ministry of Finance and the Managing Director of Kazakhstan Temir Zholy for Transportation (*Figure 3.153*).

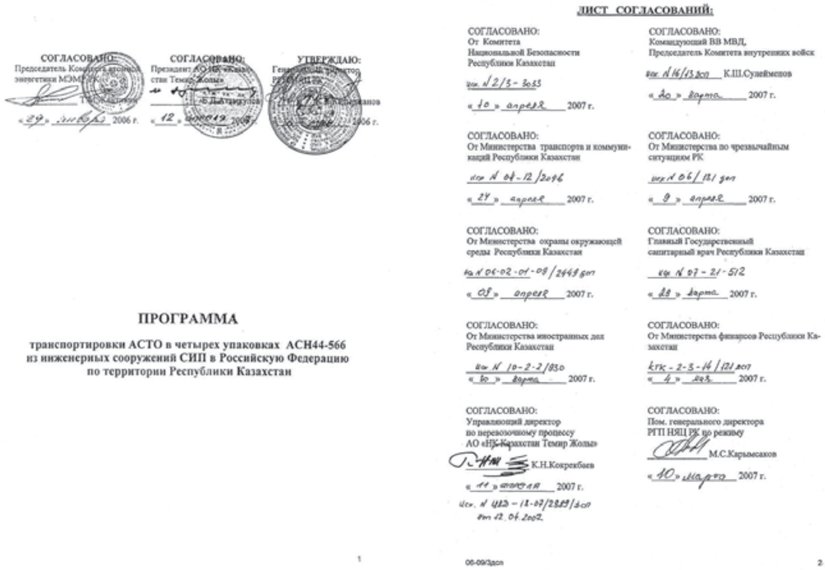
A transport control centre was created to help coordinate and manage the transportation, which included representatives of the carrier, the sender and the recipient, the Kazakh Ministry of Internal Affairs and the Kazakhstan National Security Committee. The centre is located in Kurchatov. The centre operated in real time, from the moment the cargo was loaded at Degelen Station to the moment it crossed the Kazakh border at Lokot Station and in standby mode until the cargo arrived at the recipient’s station.

The Programme for Physical Protection During Rail Transport in Kazakhstan was drawn up to provide for the physical protection during transport by rail.

The accompanying car and the cargo car arrived from Russia (the property of the recipient), completed the corresponding customs formalities and were delivered to the point of loading.

On 6 June 2007, the transport container was delivered by road from Kurchatov to the working area of site X (*Figure 3.154*).

Empty AT-400 R containers were weighed and inspected at the working site (*Figure 3.155*).



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«12» января 2006 г.

УТВЕРЖДАЮ:
Генеральный директор
2006 г.

ПРОГРАММА

транспортировки АСТО в четырех упаковках АСН44-566 из инженерных сооружений СИП в Российскую Федерацию по территории Республики Казахстан

1

ЛИСТ СОГЛАСОВАНИЙ:

СОГЛАСОВАНО:
От Комитета
Национальной Безопасности
Республики Казахстан
«10» апреля 2007 г.

СОГЛАСОВАНО:
Командующий ВВ МВД,
Председатель Комитета внутренних войск
К.Ш.Сулейменов
«20» марта 2007 г.

СОГЛАСОВАНО:
От Министерства транспорта и коммуникаций Республики Казахстан
«24» апреля 2007 г.

СОГЛАСОВАНО:
От Министерства по чрезвычайным ситуациям РК
«9» апреля 2007 г.

СОГЛАСОВАНО:
От Министерства охраны окружающей среды Республики Казахстан
«08» апреля 2007 г.

СОГЛАСОВАНО:
Главный Государственный санитарный врач Республики Казахстан
«28» марта 2007 г.

СОГЛАСОВАНО:
От Министерства иностранных дел Республики Казахстан
«30» марта 2007 г.

СОГЛАСОВАНО:
От Министерства финансов Республики Казахстан
«4» 2007 г.

СОГЛАСОВАНО:
Управляющий директор
по перевозочному процессу
АО «НК Казахстан Темир Жолы»
К.Н.Кокрекбаев
«11» 2007 г.

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Пом. генерального директора
РГП НЯЦ РК по режиму
М.С.Карымсаков
«10» марта 2007 г.

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Figure 3.153. *Cover sheet of the Programme for Transporting the Activated Special process Equipment in Four ASN44-566 Packages From the Engineering Structures of STS Across Kazakhstan to the Russian Federation, with approval sheet, endorsed and approved by: Chairman of the Atomic Energy Committee of the Kazakh Ministry of Energy and Mineral Resources T.M. Zhantikin; President of Kazakhstan Temir Zholy E.D. Atamkulov; The National Security Committee of the Republic of Kazakhstan; The Commander-in-Chief of the Armed Forces of the Internal Affairs Ministry, Chairman of the Interior Forces Committee K.Sh. Suleimenov; the Kazakh Ministry of Transport and Communications; the Kazakh Ministry for Emergency Situations; the Kazakh Environment Ministry; the Chief Medical Officer of the Republic of Kazakhstan; the Ministry of Foreign Affairs of Kazakhstan; the Kazakh Finance Ministry; Managing Director of Kazakhstan Temir Zholy for Freight Transport K.N. Kokrekbayev; Assistant to the Chief Executive of the National Nuclear Centre of Kazakhstan for Operating Regulations.*

Figure 3.154. *Transport container at the working area*

Figure 3.155. *Weighing AT-400 R containers before material was added*

On 6 June 2007, Russian specialists placed fragments of the special process equipment into the containers by the protective wall at the 258-metre mark and the containers were then taken out to the structure's entrance.

American and Russian specialists, with dosimetric monitoring performed by NNC operatives, inspected the box of site X after extracting the special process equipment and conducted the necessary radiometric measurements (*Figure 3.156*).

The AT-400 R containers were placed in the transport container, their lids closed and sealed by Russian and American specialists (*Figure 3.157*).

Once the transport container was filled and closed, the cargo was handed over at the working area to an NNC representative to transport it by road to Degelen Station and to load the container into the vehicle (*Figure 3.158*).

At this point the work in extracting the special process equipment from the structures at sites X and Y was complete. The special vehicle with the container loaded was handed over into the custody of a security detachment of the Ministry of Internal Affairs (*figures 3.159* and *3.160*).

On 6 June 2007, the container was shipped by road to a specially prepared siding at Degelen Station and, after a radiometric control survey and customs formalities, the container was loaded into a special rail car (*Figure 3.161*).

Personnel involved in surveying the box in the structure

Radiometric measurements of the containers

Figure 3.156. *Survey of the box in the structure*

Figure 3.157. *Russian and American specialists closing and sealing the containers*

Figure 3.158. *Handing over the container for transportation and loading the transport container into the special vehicle*

Figure 3.159. *Control survey of the transport container*

Figure 3.160. *Loading the transport container into the vehicle and its handover into custody*

Figure 3.161. *Loading the container into the special rail car*

All the work, from the opening of the boxes with the special process equipment and to the moment the container was handed over at Lokot Station, was performed under an armed guard of interior forces from the Kazakh Ministry of Internal Affairs. On an hourly basis, the head of the guard would report on the situation to points on the route, from the moment the train left Degelen Station and to the handover of the cargo into custody in the recipient's country.

On 6 June 2007, the special rail car crossed the Kazakh border.

3.2.4.4. Site Z

In accordance with the Works Plan, additional protection needed to be built at site Z, in the intervals between survey marks at 76–96 and 101–105 metres (from the structure's entrance).

Allowing for the relief over the box of the structure and given the experience gained in Operation Nomad, work on abandonment (strengthening the protection) of the site was conducted without opening the structure's entrance and without removing building waste and materials from the structure.

Between 1996 and 2000, work was performed at all engineering structures at Degelen Mountain to abandon nuclear test infrastructure, including the exclusion of unauthorised access to the structure. All the structures were sealed within no more than 50 metres from the entrance (erection of a concrete plug at the portal or collapse of the structure's crown), while the engineering structures themselves were concealed under the surrounding landscape.

Examination of the state of the engineering structures, performed in 2001–2005, illustrated that, at the moment of the examination, the protective barriers to about 70% of the engineering structures had been either opened or breached. In some places, traces of nuclear waste were recorded on structural metalwork that had been extracted there.

The structure at site Z was closed on 2 October 1997 by drilling and blasting from outside. The collapsed section stretched for 15 metres. The portal into the engineering structure was backfilled with fine rock and concealed under the surrounding landscape (*Figure 3.162*).

a)

b)

Figure 3.162. *View of the structure's entrance before (a) and after (b) closure*

In June 2007, representatives from Kazakhstan, Russia and the USA performed a reconnaissance survey of the site and a decision was made on the possible strengthening of the protection of the engineering structure without opening up the entrance (*Figure 3.163*).

Figure 3.163. *Surveying the area of the site*

The results obtained from the radioecological survey led to the conclusion that the radiation situation within the arranged working area at site Z before the work commenced was of a background nature for the Degelen area and did not pose a radiation hazard for the personnel. A map of the spread of exposure dose level is presented in *Figure 3.164*.

Additional protective measures at the sites were implemented in the order as established under Kazakh law and pursuant to the requirements of effective state standards and normative documents, including health protection of the workers and the environment over the following key stages:

- pre-construction work;
- construction work;
- concluding work.

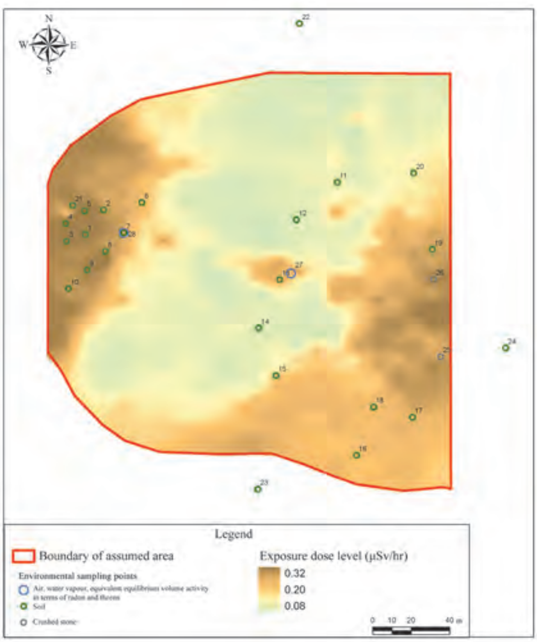


Figure 3.164. *Map of the spread of exposure dose level*

During the course of all work, the following was conducted:
- radioecological support;
- medical support;
- maintenance of the field camp;
- delivery of equipment and materials to the site.

The work was performed between September and December 2007.

In the preparatory period, NNC and participating organisations, drew up and submitted the Works Plan to the Customer. Proceeding from the aims and objectives, prior to the work a method was selected for pouring concrete mortar in the interval at the survey marks at 76–96 metres and a sand-magnetite mix in the interval at 101–105 metres, through purpose-built boreholes, drilled from the working area above the structure.

The construction work involved constructing access roads in the working area, drilling exploratory and special boreholes, pouring concrete and sand-magnetite solutions into the boxes and abandoning the working area and the roads.

A photograph of the field camp is shown in *Figure 3.165*.

Figure 3.165. *Field camp*

The access road with a turning onto the working area, located over Box No. 2, was built following the decision to open Box No. 1 with inclined boreholes.

The designed road strip was cleared from large rocks, building waste and other items in the road construction area using a bulldozer (*Figure 3.166*).

The working area over Box No. 2 had an area of 30 x 20 metres (*Figure 3.167*).

The proportioning of the components and preparation of the concrete and the sand-magnetite solutions were performed at the concrete and mortar facilities. The heap of rock from the structure was used for the construction. A storage facility was arranged in the area to store inert materials, cement and magnetite (*Figure 3.168*). Work began on drilling exploratory boreholes with a diameter of 105 mm from Box No. 2, located between the survey marks at 76 and 96 metres. The opening of the box was resolved by drilling three boreholes.

Access roads The working site

Figure 3.166. *Clearing the road strip*

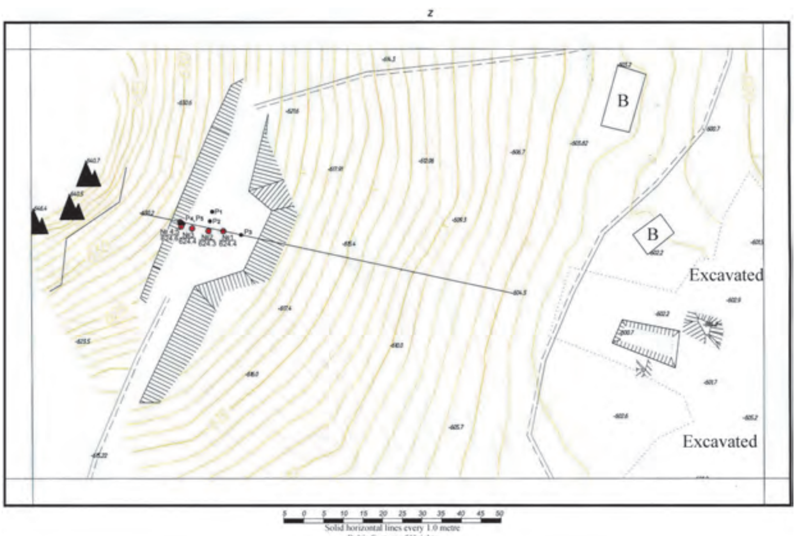


Figure 3.167. *Plan of the working area*

Figure 3.168. *Area for stockpiling the sand and gravel mix, cement and magnetite*

Video surveillance camera

View of a section of the structure on the monitor

Figure 3.169. *Using a video camera and computer equipment*

Air samples were taken through exploratory borehole p1 from the box and the level of activity was sampled and measured. The radioecological situation in the structure was determined as normal according to the measurement data.

A Sunkwans SK D106/M290 video camera was used for video surveillance inside the structure, from the surface of the working area. The footage was recorded and viewed using a computer (*Figure 3.169*).

The video surveillance helped to determine the parameters of the box – its approximate length and the distance to the protective walls. The observations revealed the presence of a sealed access point with an open hatch on the protective wall, located nearer to the entrance, and a metering tube in the protective wall, located towards Box No. 1 (*Figure 3.170*).

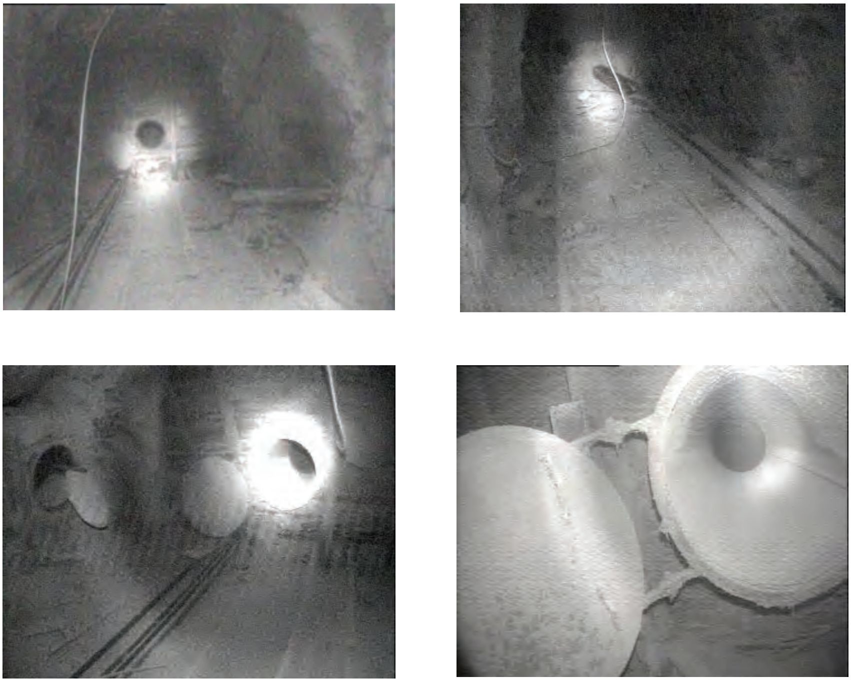


__Figure 3.170.__ View of Box No. 2

The video surveillance helped to determine the location of special boreholes for the concreting. A drilled borehole with a diameter of 105 mm entered the structure (determined by the tool string sinking and no more drill mud or air emerging onto the surface). At first, the borehole was used to measure the levels of activity. The measurement data determined the radioecological situation in the box of the structure to be higher than normal. After the video surveillance it was established that the box is about 8 metres long. Also, there were fragments of some devices visible in the box and evidence was discovered of unauthorised access into the box through a pipe in the top left corner of the protective wall (*Figure 3.171*).

A borehole with a diameter of 215 mm was drilled to pour concrete into Box No. 1. With visual observation, a soil sample was taken using the drill rig from the bottom of the structure through this borehole. Based on radiation measurement data on the soil, Russian representatives voiced doubts as to the conformity with the available information on the location of the necessary box.

Additional measurements of the swab, taken a second time from the bottom of the structure, and a detailed review of the video recordings obtained confirmed these doubts. A decision was made to continue the work on studying the section of the structure after the section that had been opened.

Under agreement with the DTRA representative, the next box of exploratory borehole p5 was opened at the work site. Measurements of levels of activity and swabs were taken from the bottom of the box of the structure through the drilled borehole. The measurements indicated increased levels of activity in this box. Video surveillance confirmed the need to pour concrete specifically into this box (*Figure 3.172*).

A borehole with a diameter of 215 mm (c5) was drilled into the box so it could be poured with mortar. This was the last special borehole at the site, after which work could continue on concreting the boxes.

Figure 3.171. *View of Box No. 1*

Figure 3.172. *Situation in Box No. 3*

The distance from the surface of the working area to the structure's cover along vertical boreholes varied from 18.4 to 18.7 metres; along inclined boreholes the distance varied from 22 to 35 metres. A sectional drawing of the sector is presented in *Figure 3.173*.

The vertical boreholes for work in Box No. 2 were drilled using an URB-3AM drill rig, mounted on a KamAZ truck (*Figure 3.174*). Inclined boreholes were bored using a TEJ drill rig, with a wide range of incline angles (*Figure 3.175*).

After all drilling and specialist work as stipulated under the programme for Box No. 3 (instead of Box No. 1), DTRA and Russian specialists began the concrete pouring of Box No. 2 and the pouring of a sand-magnetite solution into Box No. 3.

The components for the concrete were tested at the Semey branch of the Building Materials and Structures Test Centre of the National Expert Review and Certification Centre. Laboratory tests indicated that the heavy-aggregate concrete, obtained at the production site, corresponds to grade M300 in compressive strength (on average 296.7 kgf/cm^2), which meets the requirements of the Statement of Work.

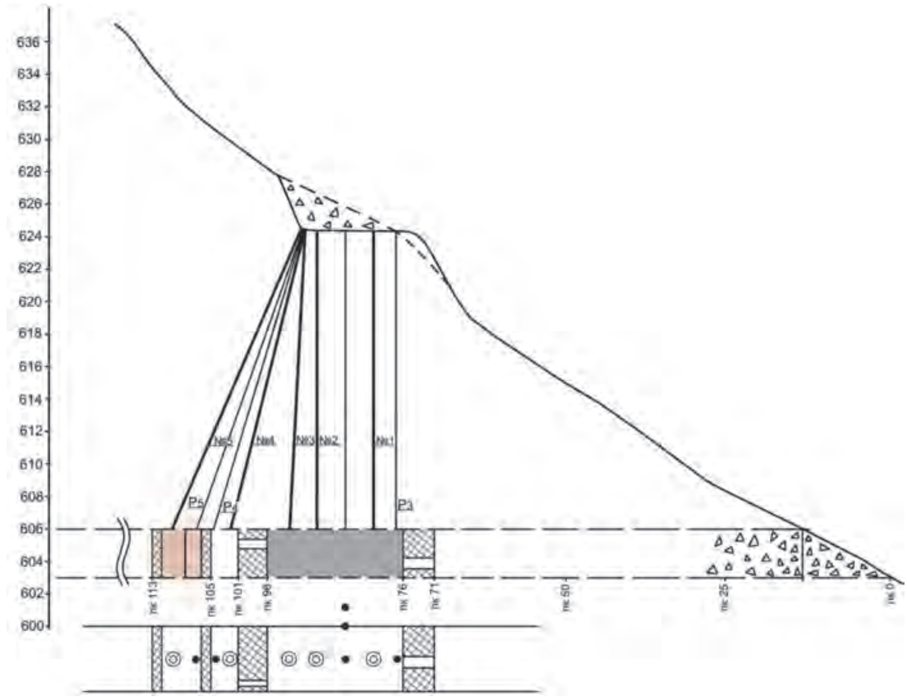


Figure 3.173. *Sectional drawing of the sector*

Figure 3.174. *The drill rig at the working area*

Drilling inclined boreholes *Heads of special boreholes*

Figure 3.175. *Creation of special boreholes*

Box No. 3 was filled with a sand-magnetite solution, containing mineral magnetite (Fe3O4), equalling at least 50% of the mass of the sand-gravel mix.

The concreting work on the surface of the working area was performed from 24 October to 7 November, predominantly when the average daily ambient temperature was above zero.

The ready concrete mix and the sand-magnetite solution were delivered to the near-entrance area in ABS-5 cement mixer trucks. The concrete mix was unloaded into the receiving funnels of the boreholes using discharge devices (*Figure 3.176*).

Figure 3.176. *Pouring solutions into the boxes*

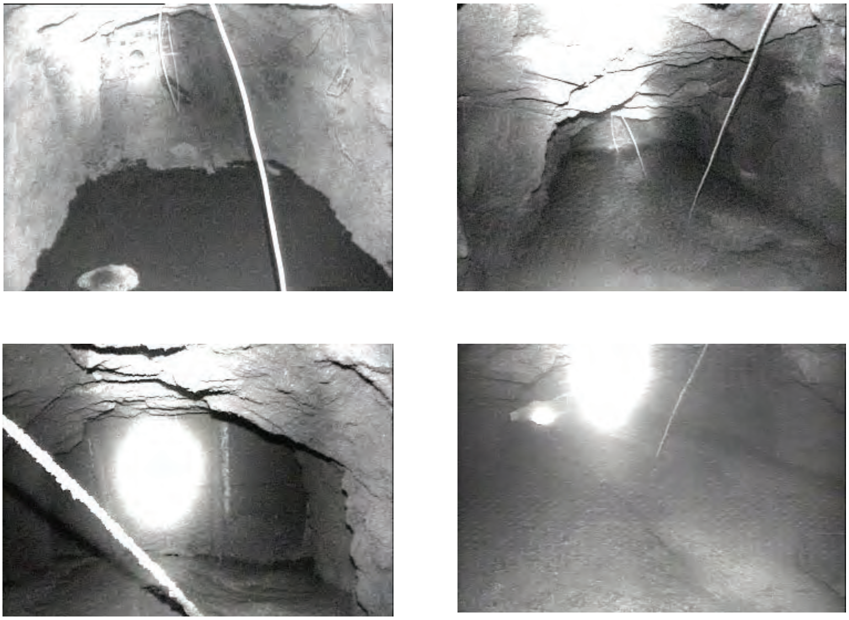


Figure 3.177. *Pouring mortar into Box No. 2*

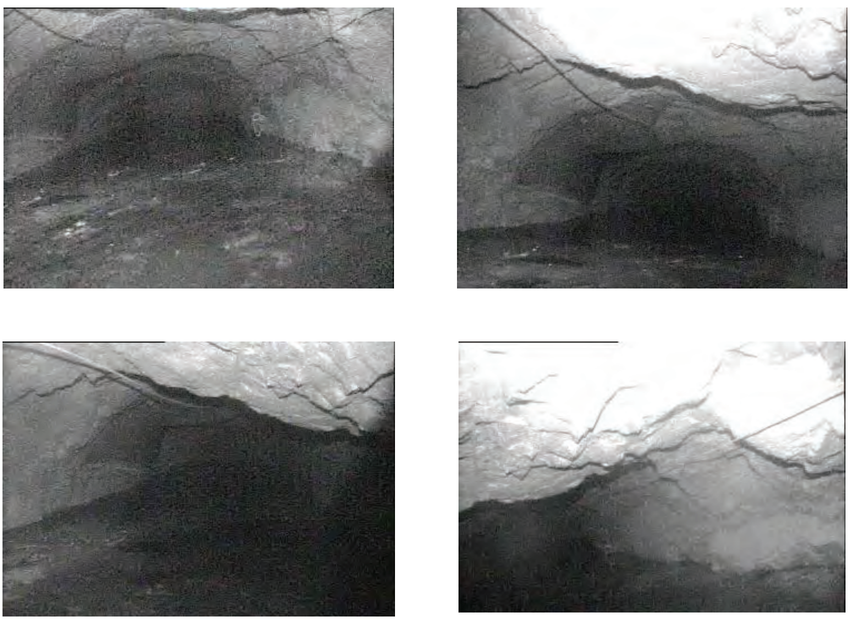


Figure 3.178. *Pouring the sand-magnetite mix into Box No. 3*

The filling process and the flow of the solution in the boxes was monitored on video through the boreholes, not used in the pouring process (*figures 3.177* and *3.178*).

The shafts of all drilled boreholes were poured with mortar to the daylight surface (*Figure 3.179*).

After completion of the work on site, reclamation work proceeded at the working area, the access roads and the camp with the concrete and mortar facilities (*Figure 3.180*). The working area and the roads were backfilled with earth with a large fertile soil content, which is particularly favourable for grassy vegetation.

All work on strengthening the protection of the structure was performed by employees of the accredited Test Centre of NNC, with dosimetric monitoring.

Upon completion of work on site, a concluding survey of site Z and its adjacent regions was performed to monitor the radiation situation at the site after the protective measures.

Radioecological studies were performed in accordance with certified guidelines.

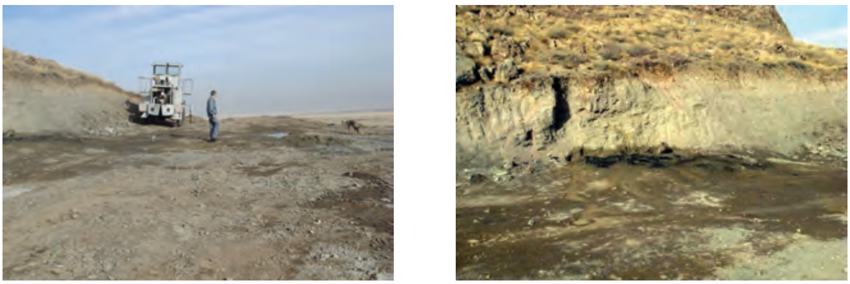


Figure 3.179. *View of the working area after abandonment of the boreholes*

Figure 3.180. *Reclamation of the area*

During radioecological support, the following types of work were performed to provide for the radiation safety of the workers and to protect the environment at site Z:

- radiation contamination monitoring of the air in the work zone;
- monitoring of radiation parameters at the work sites;
- radiation monitoring of equipment and vehicles;
- radiation monitoring of residential modules and service premises at the field camp;
- individual dosimetric monitoring of category A personnel:
- environmental sampling;
- measurements using a portable gamma-spectrometer;
- laboratory analysis of soil samples, airborne aerosols, water vapour and swabs, taken in the work zone.

Maximum equivalent equilibrium volume activity in terms of radon and thoron was within permissible levels (*Figure 3.181*).

Measurement of radiation parameters during the course of a shift included measurement of exposure dose level, flux density of α- and β-particles in the work sites, facilities and equipment.

The maximum measured exposure dose level in the working area (11.76 μSv/hr) was considerably lower than the permissible exposure dose level, while the flux density of α- and β-particles at all survey sectors was within the detection limit of the instrumentation used.

The operatives who were deployed in the work were sent for individual dosimetric monitoring. Individual exposure doses of personnel (0.04–1.39 mSv) during the set time frame were within the permissible dose level for category A personnel.

Soil and mud samples were taken during the borehole drilling to monitor the radionuclide composition (*Figure 3.182*).

As a result of the laboratory gamma-spectrometric analysis, it was established that three soil samples, taken where the work was performed, displayed a specific activity of ^{137}Cs higher than the background level of global fallout which, for this locality, stands at around 15 Bq/kg, although it was considerably lower than the minimum significant activity for personnel.

Figure 3.181. Measurement of equivalent equilibrium volume activity in terms of radon and thoron at the working area

Figure 3.182. Soil sampling

Laboratory analysis of water vapour samples was performed to determine the tritium content in the industrial and residential zones. Tritium concentrations in the ambient air of the industrial zone varied from 0.06 to 0.42 Bq/m^3 while, in the residential zone, they varied from 0.06 to 0.62 Bq/m^3. The tritium concentration in respiration air was considerably lower than maximum permissible values.

The work was regularly monitored under a contract between NNC and DTRA (*Figure 3.183*). The DTRA representative accepted the work at individual stages on site and was granted access to all aspects of the work.

Figure 3.183. *Monitoring the course of the work*

The course of the work was discussed at a Steering Group meeting on 15–18 October 2007 (*Figure 3.184*).

Thus, from September to December 2007 the protection of the engineering structure was strengthened at site Z, without opening the entrance to the structure.

Compared with the preliminary radioecological survey at site Z and the adjacent areas, the radiation parameters did not alter and remained at the level of background values, determined for Degelen Mountain.

The radiation situation at tunnel Z after the protective and reclamation measures remained at the same level as it was before the work commenced.

The radionuclide content in the studied soil remained at the same level as during the preliminary survey of the tunnel and the adjacent area.

There is no radiation hazard at the site in question.

Figure 3.184. *Steering Group meeting*

As a result of the concluding survey of the site, the safety of the work at the tunnel and the lack of any negative anthropogenic effect on the existing geosystem were confirmed.

Throughout the course of the radioecological support for the work there were no cases revealed of overexposure of personnel working at site Z and nor were there any cases of contamination of the environment, facilities or equipment.

3.2.5. Strengthening physical barriers to tunnels at Degelen Mountain [10–12]

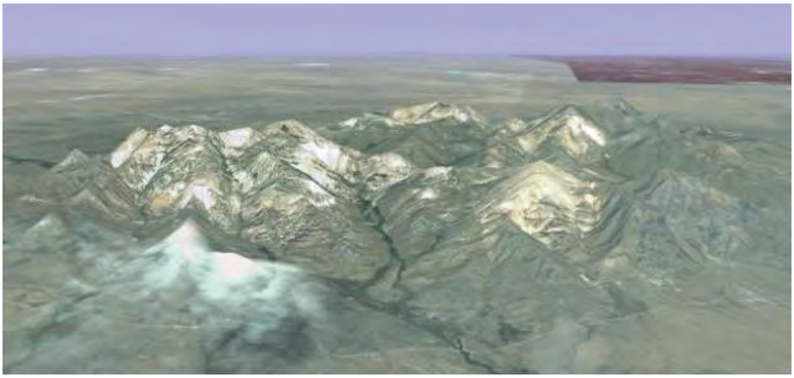


Figure 3.185. *Degelen Mountain*

The working sites are located within the former STS, within the area of Degelen Mountain, which is a dome-shaped peak with an isometric shape (*Figure 3.185*), which rises 500 metres over the surrounding area. The mountain stretches 18 km in a north-north-westerly direction and measures 10 km across.

The Degelen mountains are classed as typical middle altitude peaks with relief that is typical for the granitoid ranges of central Kazakhstan. This is mainly mural jointing with exotic elements (*Figure 3.186*), caused by wind erosion and frost weathering in conditions of a semi-arid climate. The escutcheon is formed by an alluvial bench, characteristic for any mountain range.


Figure 3.186. *Shapes of the relief*

The slopes are predominantly gently sloping with an incline up to 30° and, nearer to the peaks the angles rise to 40–45°. Sections are encountered with sheer rocky faces.

The absolute elevations of individual peaks exceed 1,000 metres. The maximum altitude of the southern spur stands at 1,070.2 metres and of the northern spur, 1,084.9 metres. The terrain relief coefficient of the locality is 3.

The relief in the region of the structures is mountainous, the soil cover is rocky, the vegetation is mountain-desert like (steppe vegetation) and there is no farmland.

There are a number of streams in the vicinity of the mountain with a more-or-less constant flow: the Uzynbulak, Karabulak and Baitles (*Table 3.1*). The largest of the surface water sources, with the most constant water flow within the mountain area is the Uzynbulak stream.

The near-entrance sections of the structures are located at elevations from 600 to 800 metres above the Baltic Sea level (*Figure 3.187*) and, structurally, they stand higher than bottomland sections of the streams. There are no waterlogged or bog areas beyond the engineering structures and no such areas are likely according to preliminary calculations.

Table 3.1. *Water flows by streams*

Water flow	Water flow in m^3 per hour	
	maximum	minimum
Uzynbulak	857	90
right tributary of Karabulak	95	4
Baitles	180	0.4

From 1961 to 1991, a total of 181 horizontal mine workings were constructed within Degelen Mountain (with a total area of 331 km^2) with 0.6 mine workings for every square kilometre (*Figure 3.188*).

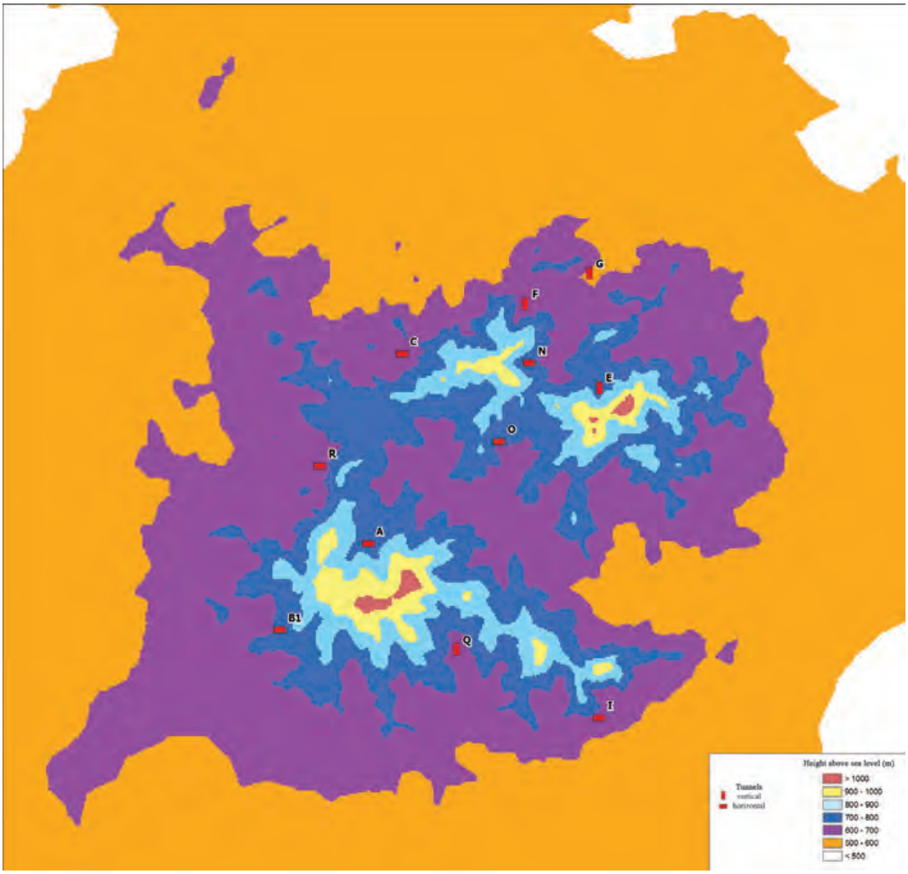


Figure 3.187. *Absolute elevations of Degelen Mountain*

As a result of the tests conducted, the relief of the mountain over many end boxes of the structures was disturbed (*Figure 3.189*).

Degelen Mountain is located in the north-east part of the Kazakh hummocky topography, within the former Semipalatinsk Test Site. In terms of its administrative and territorial division, the area is located in the East Kazakhstan Region and is characterised by an extremely low population, less than 1 person per 1 km^2.

The engineering structures at the sites at Degelen Mountain are voluminous, linear, underground structural systems (mine workings), designed for nuclear weapons testing and for the temporary presence of personnel to assemble equipment and constructions when preparing for the tests (*Figure 3.190*).

The seismic rating of the area where the sites at Degelen Mountain are located stands at 5 on the MSK-64 scale. Under multiple seismic effects from the nuclear tests, including those up to and including 5 points, it is possible that a number of the sites collapsed.

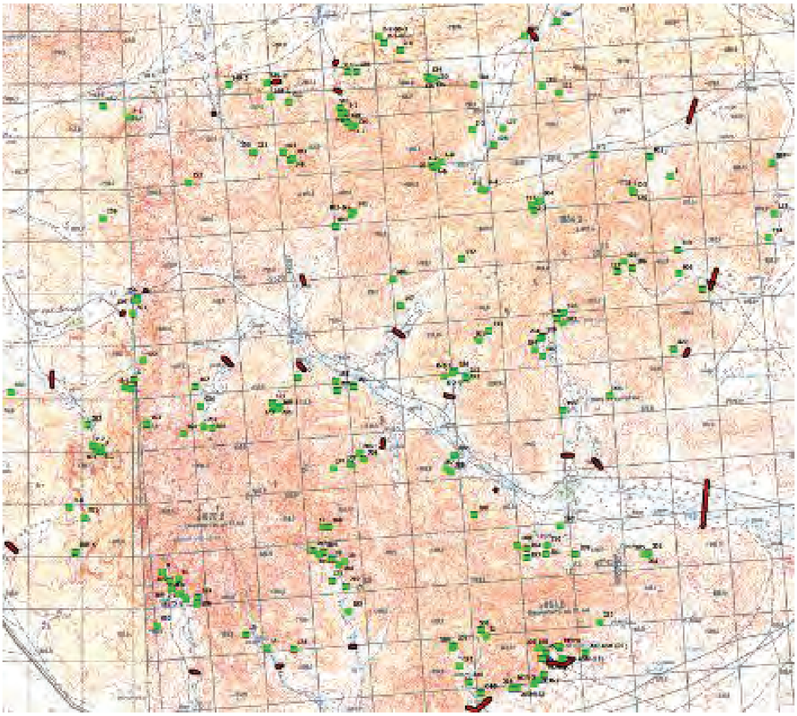


Figure 3.188. *Structure layout diagram*

No destructive natural phenomena were recorded between 1961 and 2010, including floods and tornadoes, in the locality of the sites over the period of observations.

Given the ban on civilian and military flights over the area of the former Semipalatinsk Test Site, which still remains in force, the lack of operational airfields within some 150 km of the mountain and the fall in the total intensity of air freight in the republic, the probability of an aircraft crashing onto the sites is negligible.

There are no railways, major roads or transport waterways to the sites within a radius of over 50 km from Degelen Mountain, on which liquefied gases and explosives could be used. In a similar radius there is a reliable lack of major storage facilities for fuels and lubricants, explosives, munitions and so on. There are no industrial facilities or sites, mains or other gas and oil pipelines or any other major industrial facilities within a radius of at least 150 km.

Therefore, there is practically no risk of a destructive external impact of either natural or industrial origin for the sites at Degelen Mountain.

The sites, the industrial structures, are characterised by the following indicative features:

— they are located away from residential developments;
— they are located far from sites bearing mineral deposits;
— there are no sinkhole zones;

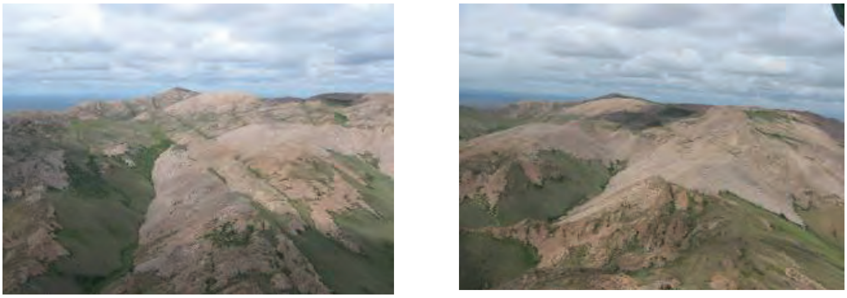


Figure 3.189. *Mountain relief over the epicentres of blasts (view from a helicopter)*

Figure 3.190. *Model of an engineering structure*

- there are no zones liable to landslides, mud flows, avalanches or other hazardous geological processes;
- there are no bog areas;
- they are in zones of underground water seepage;
- they are located away from sanitary protective buffer zones of underground and surface sources of potable and domestic water supply, water purification facilities and water mains;
- they are located predominantly away from watersheds;
- they are located away from land, covered or planned for coverage by forests, woodland parks and other green spaces that provide protective and sanitation-hygiene functions and which are locations for public leisure;
- the ground water in the valleys of the mountain range is unsuitable for drinking or process water supply in terms of its mineralisation;
- a level of ground waters nearer than four metres from the bottom of the structure;
- the geological layers are aquifers and have a hydraulic connection with the underlying aquifers;
- the mountain has tectonic faults and zones of intensive natural and industrial

fractures, with a distance to the seismic-risk fault of more than 40 kilometres;
- the mountain is distinguished by low sensitivity to faulting, subsidence and sinking;
- after industrial intervention, the geomorphological situation has stabilised;
- the rock that makes up the mountain is solid and very dense;
- the rock in the foundation is permeable;
- the locality has slopes that are mostly with gradients of over five percent;
- the distance to the nearest water intake of underground and ground waters, or from the surface water source is more than 40 kilometres away;
- the actual use of the land brings no significant economic benefit and potential use of the land likewise has no acknowledged value;
- there are no sites of cultural or national importance within more than 40 kilometres;
- the locality has no tourism value and is seldom visited by residents of neighbouring towns.

There is no centralised water supply at the sites. Potable water, where needed, is supplied by road tanker from the Baikal Area, where there is a water post.

There is no centralised provision of electricity. Where needed, the sites are supplied with electricity from diesel electric power stations.

Communication between the site and the city of Kurchatov is possible using a satellite.

There are no places near the sites that are used as either permanent or temporary places of residence. The nearest population centre is 50 km from the work site (*Figure 3.191*) and it has a population of fewer than 1,000 people. The principal occupation of the rural population is animal breeding.

Major industrial centres are 100–200 kilometres from the borders of the test site.

The Baikal reactor complex is also located 52 km away.

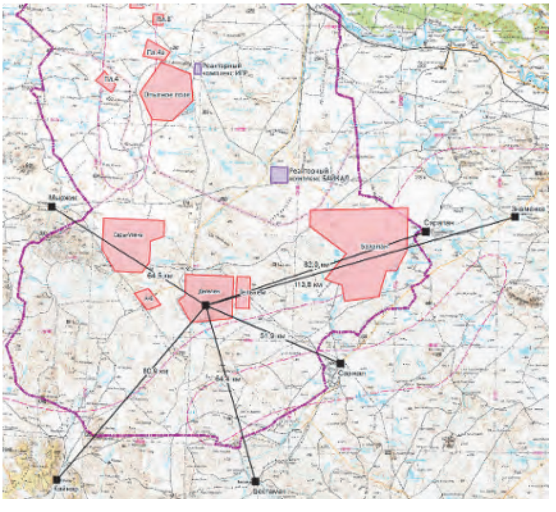


Figure 3.191. *Nearest population centres*

There is no danger of harming third persons, given the considerably remote location of the nearest population centres and industrial sites.

Starting in 2008, the work was performed under framework agreement (contract) HDTRA 1-08-G-0001 dated 3 March 2008, executed for a five-year term. The financing of the work was sourced under separate assignment-orders. Three assignment-orders were signed in total, including addenda (modifications).

3.2.5.1. Work at sites D1, D3 and D5

Under the first assignment-order in 2008, additional protection was implemented at the three sites (D1, D3 and D5).

The principal methods for implementing this work during the course of trilateral technical meetings involved vertical and horizontal workings. Information based on the examples of the sites D1, D3 and D5 is presented below.

The main aim of the work on the additional protection for the engineering structures at the sites was to prevent or render ineffective any attempts to extract and proliferate nuclear waste or other nuclear technologies. This is achieved by installing additional protective barriers in the engineering structures:

— the end box is filled with a sand-magnetite solution;
— at separate intervals in the structure additional protective barriers are built from concrete or reinforced concrete.

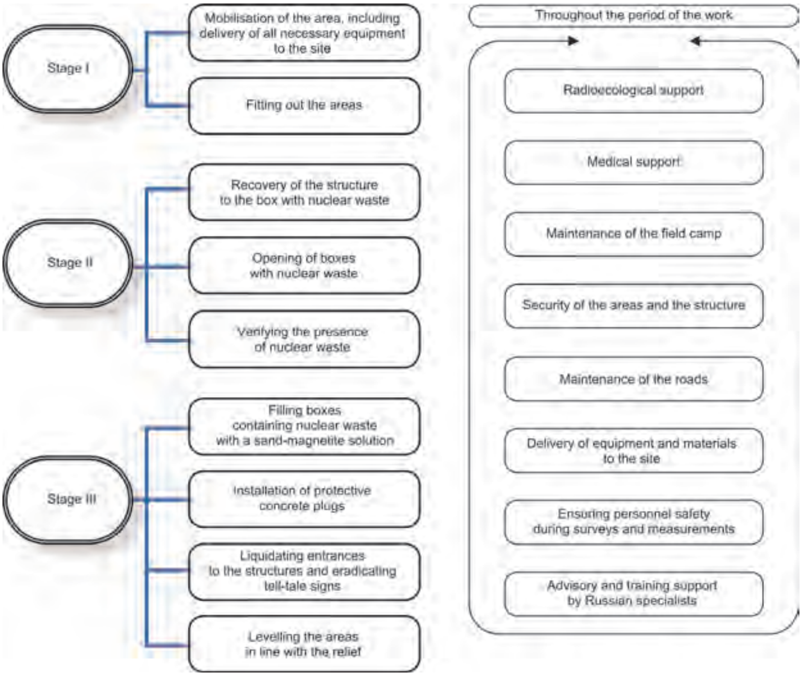


Figure 3.192. *Process flow diagram of the erection of additional protection for an engineering structure*

Protective barriers for an engineering structure shall be taken to mean artificial constructions, erected in the course of preparations for testing and abandonment of entrances, that are made from concrete, reinforced concrete, heaps of crushed aggregate and piles of rock, formed upon the liquidation of the near-entrance sections of structures upon blasting inside or from the surface of the structures, and also which are created in the course of work on additional protection for the engineering structures.

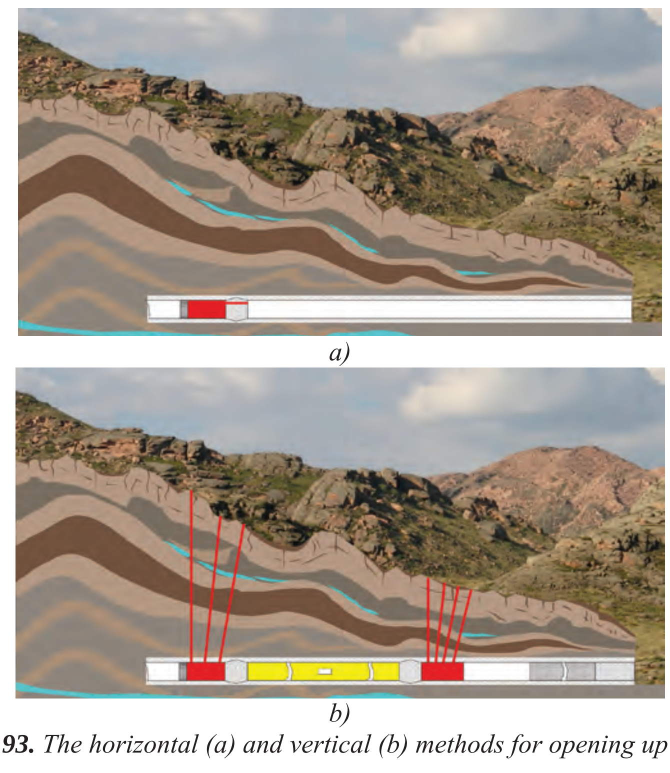
Pursuant to the Appendices to the Works Plans, the additional protection for the engineering structures is mostly erected in three stages. A diagram of the work is presented in *Figure 3.192*.

The sequence of works on the additional protection for the engineering structures depends on the features of the protective barriers of a specific structure.

These tasks need to be resolved primarily by entering the end box (opening the box, containing nuclear waste).

Based on the experience at the mountain sites, this can be done in two ways:

— by opening up a pre-existing entrance to a structure and liquidating the protective barriers in place there – the so-called horizontal method (*Figure 3.193, a*);
— by drilling special boreholes from the working area, located above the axis of the structure, without opening up the entrance and without liquidating the pre-erected protective barriers – the so-called vertical method (*Figure 3.193, b*).



a)

b)

Figure 3.193. *The horizontal (a) and vertical (b) methods for opening up tunnels*

The additional protection method is chosen for each site based on analysis of a range of initial data:

- the features of the site, including available information and predicted levels of radiation contamination inside the structure;
- the preliminary diagram of the structure after installation of the additional protective barriers;
- the relief along the axis of the structure to calculate the depths to the top of the mine working and assessment of the possible construction of working areas and access roads to them;
- prediction of the possible geological condition of the structure.

In the first instance the option that does not involve opening up the entrance to the structure is considered (the vertical method) and, if work is not possible from the surface, a decision is made to open up the entrance (the horizontal method).

Measures applied to protect the engineering structures at the Degelen Mountain sites can be divided into two main stages:

- work on abandonment of nuclear test infrastructure;
- work on preventing proliferation at the former STS.

Between 1996 and 2000 work was performed at all engineering structures at Degelen Mountain to abandon nuclear test infrastructure, including the exclusion of unauthorised access to the structure.

As a result of the work, the entrance to the last structure was closed on 26 August 2000. All the structures were sealed within no more than 50 metres from the entrance (erection of a concrete plug at the portal or collapse of the structure's crown), while the entrances to engineering structures were concealed under the surrounding landscape.

Table 3.2. *Means of closing structure entrances*

No.	Site No.	Date of experiment	Closure date	Length (m)	
				of the collapse, in metres from the entrance when drilling and blasting from inside	of the concrete plug
1	D1	06.06.1987	29.11.1997	15	
2	D3	17.02.1989	17.08.1997		10
3	D5	09.09.1984	04.11.1996	15	5
		18.09.1987			

Table 3.2 presents data on the methods used to abandon and close the entrances to the structures where work was performed in 2008.

Surveys of the condition of the entrances to the engineering structures, conducted in 2002 and 2008, indicated that the protective barriers had been either opened up or breached in about 51% of the sites. 17 sites revealed individual sections near to access points (at 15 sites) and attempts to penetrate structures (at 2 sites), where an increased background radiation level was observed, ranging from 1.5 to 8.0 times higher, with an average of a 2.8-fold increase.

Within the entrance at site D1 there is an access point, joining the surface with the structure (*Figure 3.194*).

Figure 3.194. *Access point at the entrance to site D1*

No access attempts were discovered within the entrances to structures D3 and D5 (*Figure 3.195*).

Specialists from Kazakhstan, Russia and the USA worked from the year 2000 on strengthening the protection of the engineering structures at individual sites of the Semipalatinsk Test Site. During this period, work was completed on operations Groundhog, Matchbox, Blackthorn, Nomad, Golden Eagle and Z.

Site D3

Site D5

Figure 3.195. *View of the site entrances*

The objective of these operations was to erect protective barriers to restrict unauthorised access by way of direct entry into the engineering structure (the horizontal method) or through special boreholes, drilled from the prepared working area above the respective structure (the vertical method).

Table 3.3 presents a description of the engineering structures at sites D1, D3 and D5, as presented by VNIITF representatives as initial information for strengthening the protection of the engineering structures.

Table 3.3. *Brief description of the engineering structures*

No.	Structural characteristic	Conventional designation of the structural element	Location of structure from the portal, in metres		
			D1	D3	D5
1	protector plug			0.0–10.0	5.0–10.0
2	earth pile		11.0–26.0		10.0–25.0
3	hermetically sealed element 1 with hermetically sealed access hatch		434.0–436.0		
4	hermetically sealed element 1			170.0–175.0	175.5–180.5
5	hermetically sealed element 2		442.0–450.0		192.5–197.5
6	free space 1		26.0–434.0	10.0–170.0	25.5–175.5
7	free space 2		436.0–442.0		
8	free space 2	box 2		175.0–203.0	180.5–192.5
9	free space 3	box 2	450.0–455.0		
10	free space – end box (EB)	box 1		198.5–201.5	197.5–200.5
11	free space – explosion-proof chamber	box 1	456.0–460.0		
12	box 1 depth from earth surface (m)		125	40	20

Safe construction of additional protection for the engineering structures was discussed at a technical meeting held in January 2008, involving Russian, Kazakh and US specialists. These discussions resulted in the decision to install protective structures and the methods to be used in their erection.

Table 3.4 presents a brief description of the protective plugs, which will serve as additional barriers to prevent unauthorised access to sites holding nuclear waste.

Table 3.4. *Installation site of additional protective structures*

No.	Additional protective structures	Location of structure from the portal, in metres		
		D1	D3	D5
1	plug from a sand-magnetite solution	456.0–460.0	198.5–201.5	197.5–200.5
2	protective plug 1 from concrete	452.0–456.0	175.0–203.0	180.5–192.5
3	protective plug 2 from concrete	250.0–257.0		
4	protective plug 3 from concrete	53.0–56.0		80.0–105.0
5	earth pile	0.0–15.0		

The following methods were adopted to erect the chosen protective structures:

- site D1 – horizontal;
- site D3 – vertical, from one working area;
- site D5 – vertical, from two working areas.

The decision following the trilateral consultations and discussions on the means and methods of erecting the protective structures at the sites is recorded in the corresponding Works Plan.

The main stages in the work at the sites are set out below.

Step 1: Mobilisation of the area.

Figure 3.196. *Working area at site D1*

Proceeding from radiometric survey data on the mountain area lying adjacent to the mouth of the tunnel at site D1, the location for the working area and the access road was selected (*Figure 3.196*).

The area was laid out to locate the mining and power complexes, the equipment, necessary mechanisms and trailers. The dimensions of the near-entrance area and the volume of the layout work depended on the relief of the locality where the work was performed (*Figure 3.197*).

Figure 3.197. *Laying out the area at site D1*

In addition to the detailed equipment, the following was located at the near-entrance area of the engineering structure:

— a ZUK-type battery charger facility with equipment to charge and maintain batteries for the AM-8D electric locomotive, installed pursuant to Electrical Installation Code (PUE) 6 (supplemented and revised);
— a decontamination room for personnel to change (protective clothing for work in the engineering structure's *clean zone*);
— a decontamination station for the personnel with a hot water supply;
— a radiation monitoring room where personnel are subjected to dosimetric monitoring and where levels of radioactive contamination of the external surfaces of equipment and apparatus are measured (*Figure 3.198*).

Figure 3.198. *Radiation monitoring room*

The layout of the near-entrance area of the tunnel is presented in *Figure 3.199*.

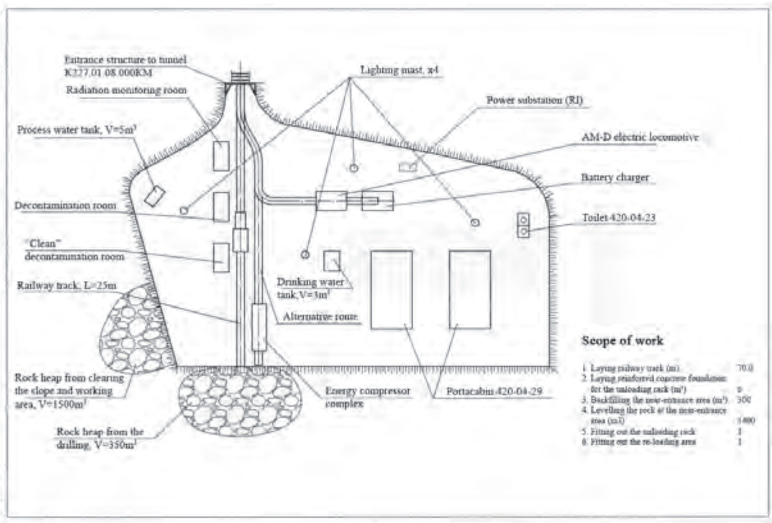


Figure 3.199. Layout of the tunnel's near-entrance area

Step 2: Entry into the structure, expert confirmation that entry has been made to the corresponding locations and confirmation of the presence of nuclear waste.

The engineering structure was opened up by constructing a new cut-in trench and entrance (*Figure 3.200*).

Existing protective elements in the structure's main shaft were dismantled for access to the PB containment vessel (*Figure 3.201*).

The free space in the PB containment vessel was opened up by drilling holes through into its top, using a device to prevent loss of containment (*Figure 3.202*).

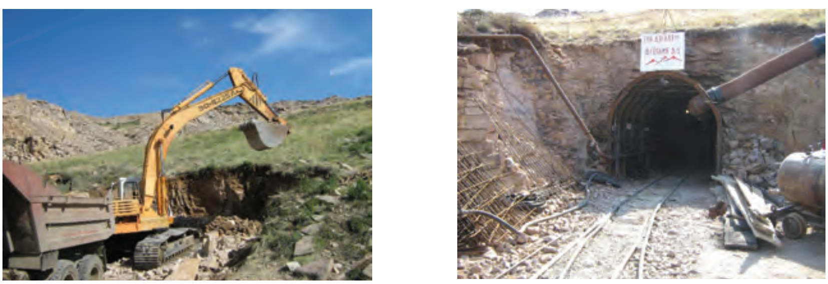


Figure 3.200. *Opening and constructing the cut-in trench and assembly of frame work near the entrance*

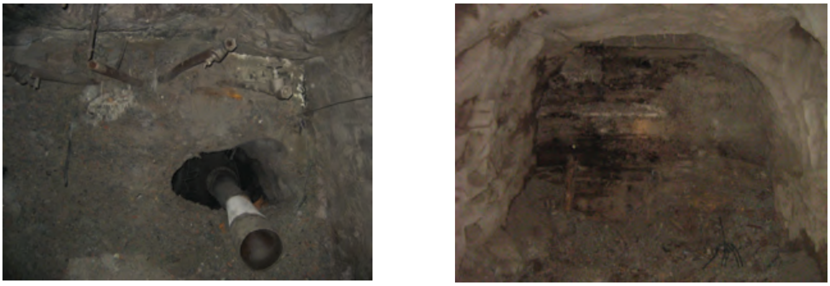


Figure 3.201. *Dismantling protective elements*

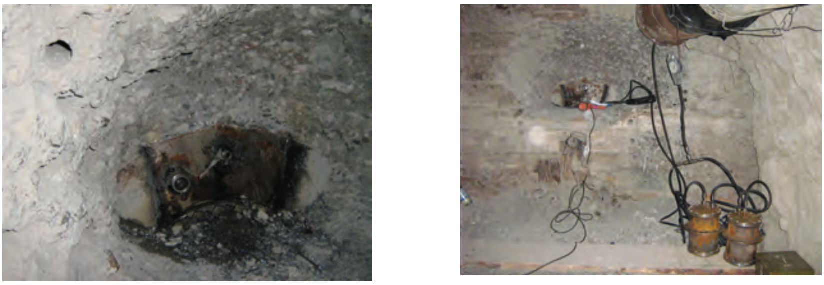


Figure 3.202. *Opening the protective containment vessel*

The opening process confirmed the presence of nuclear waste in the PB containment vessel of the engineering structure.

Step 3: Filling the corresponding volumes with cement mortar/concrete and recovery of the working area.

After verification measures, work began on filling the protective containment vessel (*Figure 3.203*).

Figure 3.203. *Filling the protective containment vessel*

The free space in the PB containment vessel was filled with a binding solution. The gaseous mixture that was expelled during the filling process was filtered through cermet filters of the bleed system, supplied by VNIITF and released onto the daylight surface by the regular ventilation system.

The new entrance and cut-in trench were backfilled and concealed beneath the surrounding landscape (*Figure 3.204*).

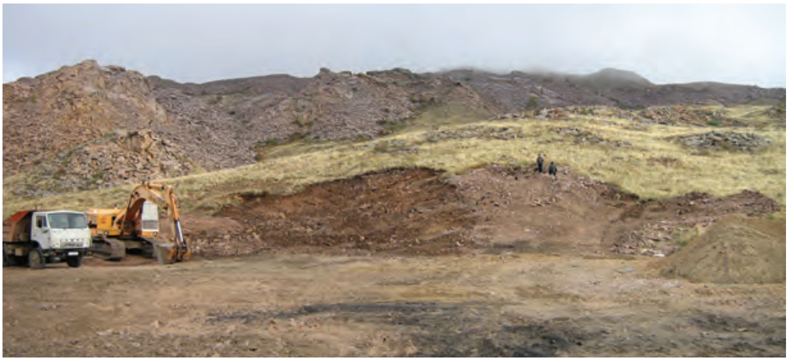


Figure 3.204. *Altering the relief up to the natural landscape*

Upon completion of the work, all engineering structures were accepted by a committee of experts, authorised by the Steering Group as part of performance of the intergovernmental agreement of 28 March 1997.

3.2.5.2. Work using the vertical method

Given the relief over the structure's box at sites D3 and D4, where it was possible to arrange working areas measuring 15 x 20 metres, and also allowing for the experience gained at sites Y and Z, NNC proposed that work on abandonment of the sites (the strengthening of the protection) be performed without opening up the entrances to the structures and without removing materials from within.

The work was performed in several stages.

Step 1: Mobilisation of the area.

Work was performed on arranging the working areas (*Figure 3.205*).

Figure 3.205. *Arrangement of the working areas*


Figure 3.206. *Vertical drilling into the tunnel cavity*

Step 2: Vertical drilling into the structure. Expert confirmation was obtained that entry had been made into the corresponding locations and that there was nuclear waste within them. Drilling work into the tunnel cavity is presented in *Figure 3.206*.

The work in the end box was verified by Russian and US specialists with assistance from NNC operatives (*Figure 3.207*).


Figure 3.207. *Verification of the work*

Step 3: The requisite sections were filled with cement mortar/concrete with subsequent recovery of the working area (*Figure 3.208*).

Upon completion of the work, all engineering structures were accepted by a committee of experts, authorised by the Steering Group as part of performance of the intergovernmental Kolba Agreement.

During the course of the work, the foremen of the organisations involved monitored the work performance, as stipulated in the agreement between NNC and the contractor division in accordance with the contracted specifications and requirements.

The foreman under the contract monitored the course of the work and accepted the deliverables and reporting materials.

The foremen of the organisations involved inspected occupational health and safety aspects at the work sites and the measures to mitigate and eradicate any harmful industrial factors.


Preparation of mortar at the concrete and mortar facilities and pouring the magnetite solution

Abandoning the working area

Recovered relief of the working area

Figure 3.208. *Concluding work stage at the area*

Under contracts with subcontractors, NNC monitored the radiation situation during the course of the work and also rendered medical support for the personnel on site.

DTRA monitored the course of the work through its representative and approved the technical solutions and proposals, adopted to ensure the safe and efficient performance of the operation. The DTRA representative accepted the work on site at the individual stages and was able to access all works and data.

During the course of the work, US and Russian representatives visited the sites on numerous occasions (*Figure 3.209*). Kenneth Handleman visited the work sites from 18 to 24 May and the US Ambassador to Kazakhstan John M. Ordway visited the working areas from 28 to 31 July.

Figure 3.209. *US, Russian and Kazakh specialists at the working sites*

The work resulted in the erection of additional protective barriers at three engineering structures. *Figure 3.210* displays the length of the additional protective structures, in metres.

At the structure at site D1, the protective concrete plugs without sealed access points increased in thickness by 3.0 metres and a sand-magnetite solution was poured into the blast containment vessel.

At the structure at site D3, the thickness of the protective elements increased by 13.0 metres and sand-magnetite and concrete solutions were poured into the site's end box.

At the structure at site D5, the thickness of the protective elements increased by 22.0 metres and a sand-magnetite solution was poured into the site's end box.

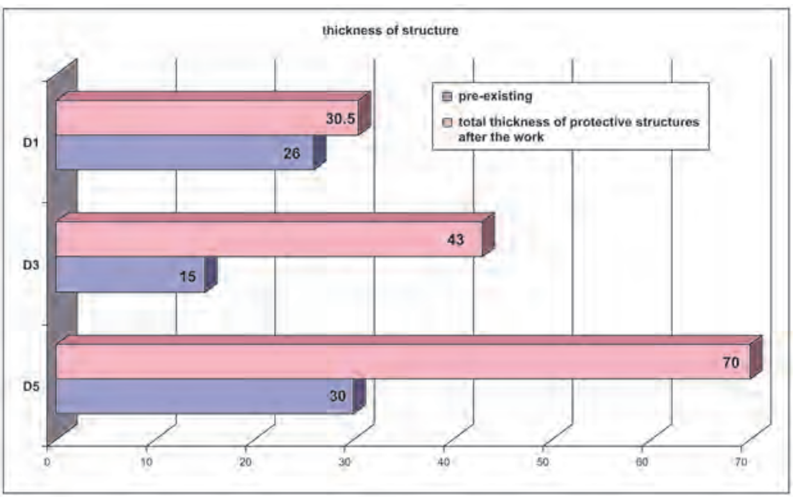


Figure 3.210. *Thickness of protective barriers before and after the work*

The additional protective elements were constructed only after US and Russian specialists had performed their work on detecting and identifying (verifying) the data to confirm the presence of nuclear waste.

The additional protective structures were erected from concrete.

Allowing for the technique used to lay the mix in the structure, the ready mix needed to satisfy the following requirements:

- it had to be producible for mixing and laying by mechanised means;
- the start of the setting time after laying needed to be at least 1.5 hours;
- it had to have a maximum, simple compressive strength of at least 20 MPa on the 28th day.

During the mobilisation period, the companies Degelen and Baikal, who performed the concreting, procured inert materials and cement holding the requisite certificates of quality (*Table 3.5*).

Table 3.5. *Certificates of quality for building materials*

No.	Name and make of material	Certificate number	Date of issue	Details
1	PortlandCement PC 400 D 20	KZ.6328092.01.01.03662	28.04.08	test report 0170 dated 08.04.08
2	PortlandCement PC 400 D 20	KZ.6328092.01.01.03662	29.04.08	test report 3 dated 22.04.08
3	sand and gravel mix for construction	KZ.7100168.05.01.41293	26.01.08	test report 70 dated 23.01.08
4	sand and gravel mix for construction	KZ.6328092.01.01.03680	08.05.08	test report 25 dated 17.04.08 and 013 dated 25.03.08
5	crushed aggregate and gravel from dense rock for construction	KZ.6328092.01.01.03679	08.05.08	test report 24 dated 17.04.08

Based on the cement and inert materials purchased by the contractors, the Semey branch of the Building Materials and Structures Test Centre of the National Expert Review and Certification Centre selected the concrete mix design to satisfy the stated requirements (*Table 3.6*).

Table 3.6. *Concrete mix design*

No.	Description of material	Consumption of materials in kg per 1 m^3
1	PortlandCement PC-400	550
2	sand and gravel mix	1510
3	water	275
	Total	2335

The end boxes of the engineering structures were filled with sand-magnetite solution. The test centre of SAPA INTERSYSTEM (Almaty) tested the procured magnetite (Test Report No. 125/8 of 4 July 2008). Table 3.7 presents the composition of the procured material.

According to the contract, the magnetite component in the sand-magnetite solution needed to be at least 50% of the mass of the sand-gravel mix.

Table 3.7. *Component composition in magnetite*

Description of material	Component composition in %					
	iron oxide, Fe_2O_3	of which iron, Fe	manganese oxide, MnO_2	of which manganese, Mn	silicon oxide, SiO_2	of which silicon, Si
magnetite	96.22	67.5	0.21	0.135	3.32	1.69

The formulation of the sand-magnetite solution is presented in *Table 3.8.*

Table 3.8. *Solution formulation*

Solution type	Components (in kg per 1m^3 of solution)				
	cement PC 300	sand and gravel mix	magnetite	bentonite	water
Sand-magnetite solution	580	735	735	25	280

The consistency (meaning the fluidity and viscosity) of the solution was selected to ensure the solution flowed freely at the expected temperature in the box of from +7 to +10 °C.

The concreting was completed at all structures between 10 August and 14 September. A total of 764.5 m^3 of solutions was mixed and laid, of which 692 m^3 was concrete mortar.

140 m^3 of solution was laid in the protective structures at site D1, of which three samples were taken for laboratory tests. 268 m^3 of solution was poured into the additional protective structures at site D3, of which one sample was taken for testing.

284 m^3 of solution was poured into the additional protective structures at site D5, of which two samples were taken for testing.

The samples were strength-tested at the Semey branch of the Building Materials and Structures Test Centre of the National Expert Review and Certification Centre.

3.2.5.3. Accelerating the creation of additional physical barriers

Starting from 2009, work was performed at the sites, featured in the list of work, subject to mandatory acceleration. This list consisted of 36 sites – tunnels at Degelen Mountain. The USA provided information on 16 sites to Kazakhstan over special channels and was based on data, handed over as part of bilateral consultations and contracts between the USA and Russia. The information exchange between Russia and the USA at the 30th session of the Steering Group, pertaining to execution of the Kolba Agreement (Kurchatov, 24–29 May 2010) also led to information being handed over to the Kazakh side on an additional 20 sites, which had been financed by the USA.

Work on this list was performed as part of the second and third assignment-orders.

Under the second assignment-order, the work was performed in full at 16 sites from 2009 to early 2011.

Work was completed on the remaining 19 sites under the third assignment-order. A decision was made to exclude one site from the list of works (based on the outcome of bilateral consultations between Russia and the USA, as per the minutes of the 32nd session of the Steering Group, approved by the heads of the public authorities charged with implementing the Kolba Agreement).

At the 31st session of the Steering Group on implementing the Kolba Agreement, attended by representatives of the US Department of Defence, the Kazakh party was offered a joint (Russian-US) solution relative to the need for additional reinforcement of physical barriers at 6 sites, erected before, in 2006–2008 and adopted with an all-round rating of “excellent”. At the same time it was noted that the additional reinforcement would increase the degree of protection afforded to the sites and would reduce proliferation risks. This became possible thanks to the positive trilateral experience and development of the technical and technological capabilities of NNC and its subcontractors.

During the course of work at these sites of the Degelen Testing Area of the former STS, additional barriers were erected to prevent access to nuclear waste, which involved a total of about 40,000 m^3 of concrete, rock and special solutions, which constitutes an additional protection stretching over 4 kilometres (an average of 100 metres per tunnel site). The work was fully completed in October 2012.

In addition to the erection of additional physical barriers, the contracts between NNC and DTRA also involved the backfilling of existing access points (from attempted, unauthorised penetration into the tunnel) and strengthening the physical protection of Degelen Mountain.

Between 2008 and 2011, access points were abandoned at 73 sites.

Overall, the work was performed in accordance with the contractual requirements and generated no complaints from the client.

Information on the work volumes is presented below (*tables 3.9* and *3.10*).

Table 3.9. *Volume of work for 2000–2007*

No.	Site	Concrete (m^3)	Soil (m^3)
1	Groundhog	2076	35000
2	*RBSh*	327.5	600
3	Blackthorn	3043	3000

4	K-85	22.5	3000
5	103	102	725
6	603	228	550
7	115	285	200
	Total:	6084	43075

Table 3.10. *Volume of work for 2008–2012*

No.	Site	Sand-magnetite solution (m^3)	Concrete (m^3)	Rock, soil, crushed aggregate (m^3)
1	D1	5	160	0
2	D3	0	280	0
3	D5	30	400	0
4	D2	76	364	200
5	D4	34	197	0
6	B1	12	268	200
7	A	0	172	900
2	B	188	256	0
8	C	357	318	900
9	D	300	250	500
10	E	96	94	0
11	F	92	284	0
12	G	19	323	0
13	I	50	180	1000
14	N	20	180	500
15	O	87	150	900
16	P	108	1264	500
17	Q	95	132	0
18	R	121	180	1000
19	K4-1	57	140	3423
20	K4-2	0	1348	0
21	K4-3	133	121	700
22	K4-4	46	310.5	0
23	K4-5	0	294	0
24	K4-6	29	0	0
25	K4-7	106	254	0
26	K4-8	0	84	0
27	K4-9	68	141.5	0

28	K4-10	0	0	0
29	K4-11	0	750	5150
30	K4-12	0	387.5	1000
31	K4-13	156	171	0
32	K4-14	77	354	0
33	K4-15	100	221	0
34	K4-16	185	245	0
35	K4-17	44	200	790
36	K4-18	0	230	398
37	K4-19	120	126	580
38	K4-20	0	183	3220
39	D1	4	272	320
40	D5	30	54	0
41	K4-6	0	1100	0
42	200ASM	30	1020	0
43	Y	366	0	80
44	Z	1030	0	0
Total:	4271	13458.5	22261	

The following volumes were consumed in 2000–2012:

– concrete and its mixes: 23,813.5 m^3

– rock, crushed aggregate, soil: 65,336 m^3

Total increase in the thickness of the protection: 89,149.5 m^3

3.2.6. Patrolling the area [13–14]

Performance of the contract involved patrolling of the tunnels, abandoned in 1996–2000. The need for these patrols was associated with attempts to access the sites as a result of unauthorised business activity.

The first detailed inspection was performed in 2002 (*figures 3.211* and *3.212*).

During work on preventing proliferation of weapons of mass destruction and associated materials, technologies and buildings, between 2005 and 2007 access points were liquidated at two sites (200ASM-right and Metro) and holes from attempted access at three sites were backfilled (603, 200ASM-left and 103).

In July 2008 NNC specialists, working in collaboration with Russian and American specialists, conducted another inspection of the condition of the entrances to tunnels at Degelen Mountain.

The following was revealed after the 2008 inspection:

- access points, meaning possible entry into the tunnels, were found at 72 sites, where 35 structures had evidence of actual access, while the remaining 37 entrances had access points of only insignificant dimensions;

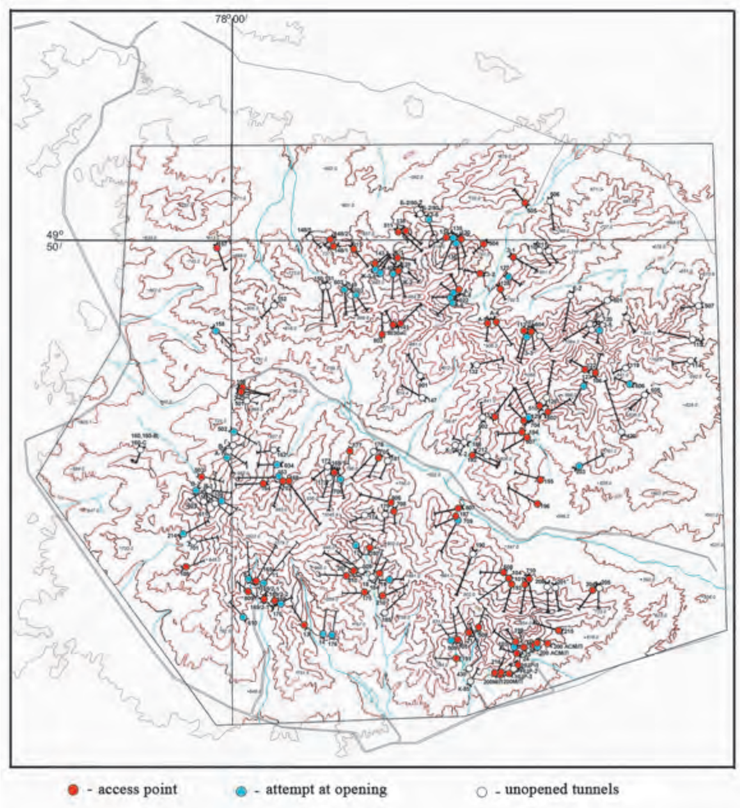


Figure 3.211. *Condition of the tunnel entrances as per the inspection of 2002*

Figure 3.212. *Traces of unauthorised access to tunnels (access points)*

- attempted access, meaning places were points of entry had been sought into the tunnels, were recorded at 35 entrances:
- 74 tunnels had not been opened up, meaning the entrances yielded no evidence of unauthorised activity.

Table 3.11 presents summary data from the inspection.

Table 3.11. *Combined results from examination of the state of entrances*

Characteristic	Number as of 10.07.08	Number of newly revealed (as related to 2002)
total number of tunnels	181	
of which:		
not opened	74	
attempts	35	8
total access hatches	72	17
of which with tunnel access	35	

As the table displays, compared with the inspection results from 2002, the number of tunnels with access points and attempted entry had increased.

Between 2008 and 2012, NNC implemented a number of measures to eradicate traces of human activity at the tunnel entrances at Degelen Mountain. Work was performed to strengthen the protection at 57 engineering structures (*Figure 3.213*).

Figure 3.213. *An example of strengthened protection at certain engineering structures*

Between 13 and 20 May 2013, representatives from the Threat Reduction Agency, the National Nuclear Centre and the All-Russian Scientific and Research Institute for Experimental Physics performed a joint inspection of the tunnels at Degelen Mountain. The aim of this study was to conduct a visual inspection of 181 tunnels in addition to a limited volume of radiological surveying of the possible gathering of metal, recorded after the previous joint survey, conducted in June 2008.

Unlike the tunnel inspections in 2002 and 2008, only six backfilled sections of entrances with opened access points and successful entry into the tunnels, evidencing supposed human activity, were discovered. Eighteen backfilled sections of entrances showed signs of destruction, with certain attempts made to enter the main part of the open tunnel. Of the eighteen indications of destruction, twelve are considered to have been caused naturally and only six seen as points of access made by humans.

At Tunnel No. 24, which documented a successful penetration in 2002, there had been either a repeat attempt or an attempt overlooked in 2008. There is icing in the access point and, based on indications of cold air, there was evidently access achieved into the tunnel. At the very least there were three indications of destruction, along with a minimal egress of water by the base of the entrance. No radiation survey was conducted at this near-entrance area.

At Tunnel No. 147 a repeat entry into the equipment room was discovered. An access point with a repeat entryway measuring 0.75 x 0.75 metres had a shaft (passage), lined with metal (a ventilation hole, lowering into a space measuring 3 x 5 metres). The shaft was located 40–50 metres above and to the right of the entrance in an equipment niche on the right-hand side of the tunnel edge. Cold air with a measurable flow of radon supposes a connection with the tunnel. This access point had been overlooked during the 2002 and 2008 inspections. All radiation indications around the access point remained at background levels.

At Tunnel No. 148/5 there was evidence of metal scavenging which, given the signs of erosion, could have been performed after the June 2008 inspection and prior to April 2009. An access point measuring 1.5 metres across accesses the tunnel, given the discharge of cold air from the access point. Radiological surveys indicated background values exceeding gamma and alpha values by a factor of 1.5, with only a minimal reading for ^{137}Cs. A ^{137}Cs radionuclide was detected by a LaBr gamma spectrometer from the northern side of the access point, by the upper section of the backfilled entrance. The presence of ^{137}Cs showed approximately the detection limit of the device. In addition to this, about 50 or 60 metres from the northern part of the entrance, there was a small section of burnt cable (about 4 m^2). The level of gamma radiation stood at 2–3 mR/hr. The increased level of ^{137}Cs is evidently the result of the burning of plastic or rubber, radioactive contaminated sheaths of copper or aluminium cables. The presence of ^{137}Cs near the access point where there was a successful repeat penetration is perhaps the result of pulling cables out when scavenging for metal.

In Tunnel No. 420 a successful, repeat entry into the tunnel was detected from the entrance's right-hand side. After the 2008 inspection, an access point appeared with a 3-metre diameter, which reduced to 1 metre and entered the tunnel at a distance of 15 metres, immediately behind the concrete plug, installed in 1997. The plug was installed between the survey mark at 00 metres and the survey mark at 35 metres. All indications of radiation parameters around the access point with the repeat entry remained at background levels. This opening into the tunnel was made possibly after the 2008 inspection, but before it was first detected by the security patrol.

In Tunnel No. 803-bis there was an access point with successful entry made in 2002, which had been partially filled with broken rock with access into the tunnel, based on evidence of air flow and icing in the access point. No radiation survey was performed in this area.

In Tunnel B-2/80-1, metal scavenging includes evidence of access (2.0 x 1.5 metres) with repeat entry into the tunnel, based on evidence of a flow of cold air. This opening appears to have been overlooked during the 2008 inspection, as a result of a heavy growth of vegetation. Measurement of radiation around the opening revealed background levels. Radiation surveying was performed at these tunnels, which revealed no signs of extraction of any nuclear waste from within.

The other 139 entrance sections remain unaltered from the previous inspections in 2002 and 2008. Some access points, recorded previously with signs of entry or attempted entry, were liquidated during work on strengthening protection between 2005 and 2012.

In 2013, NNC conducted additional work to eradicate discovered traces of human activity at the tunnel entrances at Degelen Mountain. Additional strengthening of the protection was performed at all tunnel entrances where traces of unauthorised activity had been discovered.

3.2.7. Deliverables

The following is worthy of note when speaking of the erection of additional physical barriers to prevent access.

Previously, between 1997 and 2000, as part of execution of the Kolba Agreement, Rosatom (VNIIEF and VNIITF) and NNC specialists worked on 29 items of the List of Carriers of Sensitive Information that forms part of the Agreement.

The Russian side financed work on a number of facilities in the List (VNIIEF and VNIITF). The following was achieved as a result:

- the permanent shutdown of five tested Kolba containment vessels at two sites of Degelen Mountain and area *RBSh*;
- the destruction of the structure and permanent shutdown of the untested Kolba containment vessel at area *RBSh*;
- destruction of the special process equipment containing nuclear waste in boreholes at the Aktan-Berli Area;
- dismantling and permanent shutdown of the activated special process equipment at the Aktan-Berli Area;
- dismantling and dekitting of twenty-six hardware complexes, designed to record physical parameters during underground nuclear tests and the repatriation to the Russian Federation of the six most significant hardware complexes. At the same time, during performance of the Silo Launcher Agreement at sites of Degelen Mountain and the Agreement between the US Department of Defence and the Kazakh Ministry of Energy and Science on Abandoning Nuclear Weapons Infrastructure dated 3 October 1995, executed as part of the Silo Launcher Agreement, the tunnel entrances were sealed and unauthorised access was prevented.

Figure 3.213. *An example of strengthened protection at certain engineering structures*

In total the Agreement on Abandoning Nuclear Weapons Infrastructure oversaw the abandonment of 181 tunnel entrances and the destruction of 13 unused boreholes, designed for underground testing. The abandonment of the nuclear testing infrastructure was performed by NNC and financed by the American side.

In the year 2000, as part of implementation of the trilateral Agreement (Russia –Kazakhstan – USA), work began at sites of the former STS on excluding any unauthorised access and for additional protection of nuclear waste at the testing areas and tunnels of Degelen Mountain. The aim of this work was to eradicate the threat of proliferation and terrorism. In May 2000, the eleventh session of the Steering Group decided to use the SG mechanism to coordinate this work. The American side financed this work.

Between 2000 and 2012, specialists from the Russian Atomic Energy Ministry (VNIIEF and VNIITF), NNC and the DTRA of the US Department of Defence completed work at 46 sites of the former STS (including 15 items on the List of Carriers of Sensitive Information), specifically referring to the following:

- erection of reinforced concrete structures at sites in the Aktan-Berli Area, bunded in earth and covering the test boreholes containing nuclear waste;
- erection of additional concrete protection at the sites with Kolba containment vessels, filling the internal cavities of four test containment vessels containing nuclear waste and one untested containment vessel with a binding material of cement-sand and magnetite (cement-sand solution with 50% addition of Fe_3O_4) solutions;
- extraction and repatriation to the Russian Federation of activated special process equipment from two sites on Degelen Mountain;
- erection of additional concrete and reinforced concrete protective barriers at forty-two sites at Degelen Mountain, the filling of the internal cavities of boxes with nuclear waste at these sites with a binding material of cement-sand and magnetite solutions. Additional protective barriers were erected and the boxes with nuclear waste were filled at sites at Degelen Mountain using so-called *horizontal* and *vertical* technologies. *Horizontal* technology was used to open up the tunnel entrance and restore the mine working up to the box with nuclear waste, fill the cavity of the box with a binding solution, erect concrete or reinforced concrete barriers, collapse the crown of the tunnel and conceal it beneath the surrounding mountain landscape. *Vertical* technology was used to fill the cavity of the box with binding material and erect concrete protective barriers across boreholes, drilled vertically from the surface of the mountain range. A similar *vertical* method was used to fill the internal cavities of the Kolba containment vessels with binding material.

Horizontal technology was used for work at 19 sites of Degelen Mountain, while *vertical* technology was used at 20 sites. At 2 sites work was performed simultaneously using both *horizontal* and *vertical* technologies. During this work, additional protective barriers were erected at the sites using a total volume of about 40,000 m^3 of material (concrete, rock and special solutions), which is the equivalent of erecting more than 4 km of additional protection (an average of 100 metres per tunnel at the site). Between 2000 and 2012 a total of some 90,000 cubic metres of additional barrier structures were erected at STS sites under the Agreement.

Prior to and after completion of the work on additional protection of nuclear waste, specialists from the Khlopin Radium Institute conducted independent radioecological surveys of the area. The results of these surveys indicated that after completion of the work, the environmental situation improved at all tunnels and areas of the former STS.

In addition to work on erecting additional protection for nuclear waste at sites of Degelen Mountain, NNC eradicated the possibility of attempting unauthorised access to the tunnels by backfilling existing access points into the tunnel cavity. Between 2008 and 2011, access points were abandoned at 73 sites. The American side financed this work as well.

In the main the work under the Agreement between 1997 and 2012 was performed by federal nuclear centres VNIIEF and VNIITF from the Russian side and by NNC from the Kazakh side. Independent radioecological monitoring was performed by the Khlopin Radium Institute.

VNIIEF and other organisations of the Russian State Atomic Energy Corporation were involved in destroying sensitive information and eradicating the threat of nuclear waste proliferation from the former STS, working alongside other institutions and organisations of NNC (the Radiation Safety and Ecology Institute, the Geophysical Research Institute, the Atomic Energy Institute and the enterprises Baikal and Kazakh State Scientific Production Centre for Explosive Work) and contracted organisations from Russia and Kazakhstan (VNIIEF TANIK, Degelen and Vostokavtoprom).

As a result of the work performed as part of the Agreement, reliable, protective barriers were erected at the facilities and areas of the former STS, excluding any unauthorised access (without industrial equipment) to the nuclear waste and sensitive information at the nuclear test sites.

An article was drawn up based on the results of the work: *Plutonium Mountain Inside the 17-year Mission to Secure the Dangerous Legacy of Soviet Nuclear Testing* [15].

The results of joint work on mitigating proliferation risks were given the highest possible rating, as stated in a joint declaration by the presidents of Kazakhstan, Russia and the USA, pertaining to their collaboration at the former Semipalatinsk Test Site, made at the Nuclear Security Summit in Seoul on 27 March 2012.

The joint declaration on trilateral collaboration at the former Semipalatinsk Test Site saw the presidents of Kazakhstan, Russia and the United States committing to combat the threat of nuclear proliferation and nuclear terrorism.

Since 2004 our three countries have been collaborating to implement a number of projects aimed at elimination of the remnants of the former nuclear testing activities within the territory of the former Semipalatinsk Test Site to bring it to a safe and secure state. The presidents of Kazakhstan, Russia and the United States of America have personally supervised the realization of these goals (*Figure 3.214*).

Figure 3.214. *Meeting of the presidents of the three countries at the Nuclear Security Summit*

A significant volume of work has been accomplished by now. As a result of application of modern physical and technical means the level of security at the former site has been substantially enhanced.

This work is nearly complete and we consider it a highly successful example of the trilateral cooperation representing our shared commitment to nuclear security and non-proliferation.

Nursultan Nazarbayev, Dmitry Medvedev and Barack Obama commented on the joint statement on trilateral cooperation on the former Semipalatinsk nuclear test site.

Nursultan Nazarbayev:

As all of you know, the Semipalatinsk nuclear test site was one of the largest test sites in the world, along with the nuclear test site in Nevada. 500 nuclear tests were carried out there, including more than 70 in the open air. After the site was closed by my decree 20 years ago, Kazakhstan, Russia and the United States have been engaged in joint efforts on the elimination of the consequences, the rehabilitation of the test site and the destruction of the infrastructure. Since 2004 we have rehabilitated 3,000 square kilometres of the territory (the test site occupied 40,000 square kilometres, and a million and a half people were affected by the radiation).

This is a positive example of collaboration between states, first, on the rehabilitation and, secondly, on strengthening security and the non-proliferation of nuclear materials. We, the people of Kazakhstan, are grateful to Russia and the United States for such assistance.

As you know, earlier we eliminated ballistic missile silo launchers with 1,100 warheads in the same way. We also worked together on destroying the infrastructure and precluding the possible proliferation of these materials.

I would like to use this occasion to express our country's deep gratitude and hope for further cooperation on this issue.

Barack Obama: Well, I'm going to just make a very brief statement here. We wanted to do this brief appearance to highlight one of the most significant examples of what we've been doing through this Nuclear Security Summit,

and what our three countries have been able to accomplish through some painstaking cooperation over the last several years. As the President of Kazakhstan indicated, this was a major site for nuclear operations during the Cold War.

There was a lot of loose nuclear material that was vulnerable to potential smugglers, to potential infiltration. And as a consequence of extraordinary cooperation between our three countries that actually predates my administration,

but was accelerated as a consequence of this Nuclear Security Summit, we've been able to effectively lock down and secure all this vulnerable material. So we have been able to do this in part because of the outstanding leadership of President Nazarbayev and the people of Kazakhstan. We've also been able to do it because the United States and Russia over the last several years have shown ourselves to have a mutual interest in making sure that nuclear materials are secured and that they do not fall

into the wrong hands. And so this kind of multilateral cooperation is being duplicated as a consequence of this Nuclear Security Summit. And it gives you a specific example of the kind of progress that we're making.

We're going to need to make more progress over the next several years. But I am confident that we can actually meet the goal that we set in the first Washington summit, which is in four years to have made extraordinary progress in making sure that

loose nuclear material is not vulnerable to smuggling or to potential terrorist plots.

Dmitry Medvedev: President of Russia Dmitry Medvedev: Summits are held not only for leaders to meet, shake hands and express good intentions, but also to demonstrate concrete examples of cooperation. Here is one such example: since 2004, Kazakhstan, the United States and Russia have been engaged in eliminating the consequences of the Semipalatinsk nuclear test site use. We are aware of the threats created by preserving the site's former functions, as my colleagues have just said. Today we can say that all these threats have been eliminated and the Semipalatinsk test site exists in a completely different role. Now Kazakhstan can develop the area and look into the future with confidence. I think this is an excellent example of cooperation between our three states.

I would like to thank my colleague President of Kazakhstan Nursultan Nazarbayev for his proactive stance and for creating the necessary conditions for this work. I would also like to note that the Russian Federation and the United States, as countries that bear a special responsibility for nuclear security, have provided the necessary assistance in this matter. Despite the fact that all this is a consequence of previous ideological approaches, we have found the necessary financial and human resources to jointly address this problem and resolve it. I think this is a good example of cooperation and such examples should be multiplied. This is a positive example for other countries to engage in nuclear security issues and mitigate the consequences of the past.

In this way, a number of sites at the former test site have been successfully rendered safe.

As already mentioned above, work on this project was performed at the highest level. At various times during the course of the work, the heads of the participating countries of various levels visited the sites (*Figure 3.215*).

Figure 3.215. *Visit of Kazakh Prime Minister Karim Massimov to Degelen, 22 June 2011*

All work was completed as planned by November 2012. A closing ceremony for the project was held in Kurchatov, attended by project leaders from Kazakhstan, Russia and the USA (*Figure 3.216*).

Figure 3.216. *The Degelen Area. Attendees at the project closing ceremony, October 2012*

A monument was erected at a summit on Degelen Mountain, with an inscription in three languages: *1996–2012. The world has become safer. Honouring the achievement* *of the collaborative work between the Republic of Kazakhstan, the United States of America and the Russian Federation in the territory of the former Semipalatinsk Test Site.*

In concluding the part devoted to the trilateral work at the former Semipalatinsk Test Site, particular mention should be made of the fact that the success of this work was to a great extent determined by the ability of those involved to find compromise, which was required in almost every operation. Perhaps the most important result of this trilateral effort is the experience gained in mutual understanding. One would like to hope that this experience, like all the experience gained by our trilateral team, will prove useful for generations to come, for whose sake this work was performed [2]:

In this connection, it is opportune to cite an excerpt from an article by the Co-Chairperson of the Kazakh-Russian Steering Group on fulfilment of the Kolba Agreement, Vladimir Kutsenko [3]:

"A working team of representatives from the Kazakh and Russian sides was quickly brought together to implement the Agreement. An intergovernmental Steering Group was also created. Only two people now remain from those people, approved by the mutual governments: Vladimir Kutsenko and Viktor Stepanyuk. Many of our comrades have already passed onto another life: Anatoly Matushchenko, Valery Demin, Vadim Logachev. It is sad that they did not live to enjoy this proud moment. It is all the more poignant that their personal contribution was perhaps the most significant.

"I am happy to have been part of that team, formed in 1997. There were not many of us in that compact team of ten or so key figures. I believe all of them are true heroes. To have worked for almost 16 years in the highest possible radiation risks requires rare courage and the recognition of one's high degree of personal responsibility for one's work. It is these qualities that my colleagues possess in abundance. I was present when Anatoly Matushchenko was laid to rest and Valery Demin and Vadim Logachev passed before my very eyes... They never grumbled, just devoted themselves to the work they did and they were proud that they were doing what the vast majority of people could not and would never have taken on. They passed with dignity, without a single regret. And yet it was the polygon that took them away... This needs to be said plainly.

"Only now is it fully clear, how considerable and how important was the work that we did. And how useful their experience would be today. Anatoly Matushchenko, who was involved in the very earliest land-based tests at the polygon, knew perhaps better than anyone, remembered a colossal amount and was fully well aware of what needed to be done to render the site safe. He was full of various plans and projects. One field that he wanted to raise and on which he gathered incredibly rich information was peaceful nuclear blasts. But he never made it, crashing and burning, so to speak, a month and a half too soon... And Valery Demin and Vadim Logachev (a Second World War veteran) valued their involvement in our common work very highly and, when their health took a turn for the worst, they still wished to remain in the Steering Group, workhorses to the very end.

"The value of our joint and their personal efforts for the good of the entire planet were noted by three presidents, Nursultan Nazarbayev from Kazakhstan, Dmitry Medvedev from the Russian Federation and Barack Obama from the United States of

America, in April 2012 at the Nuclear Security Summit in Seoul. The presidents made a special declaration on the uniqueness of their trilateral collaboration, which yielded excellent results. Yes, we can assert with confidence that the polygon has indeed become safer than it was and that the direct threats posed to Kazakhstan and the entire global community have been localised. And this has been done in such a way that it is impossible to penetrate the former test infrastructure without major industrial intervention and the scavengers, who gathered ferrous and non-ferrous metals there, will now find it incredibly hard to access the most sensitive areas of the polygon and cause any serious harm. The area of potential threats has been brought to a decent condition, in terms of engineering and physical protection alike. The most sensitive parts of the polygon are patrolled by internal affairs agencies and unmanned drones, brought in by the Americans, are used for surveillance. The area is now monitored by the IAEA, including with the use of satellites. Therefore, any indications of industrial intervention into potentially hazardous sites will be detected and suppressed quickly.

"In 2000, some participants were under the impression that we had completed work under the bilateral Agreement. Yes, the main objective was achieved, but plenty of problems still remained. We had a good idea of what they were. Therefore, the first contacts we had with the American team were not off-the-cuff on our part, but fully conscious. Overall, the nature of our relations were determined by three leading figures: the Russian Deputy Minister for Atomic Energy Lev Ryabev, US Department of Energy Assistant Secretary Rose Gottemoeller, and the Kazakh Minister for Energy, Industry and Trade Vladimir Shkolnik. The format for our collaboration was elaborated at their meeting. It is noteworthy that no documents were signed; this was a gentleman's agreement, based on word of honour. Subsequently, when any roughness appeared around the edges of our trilateral collaboration and, of course, this did occur from time to time, we always reverted to the format that the leading figures had developed. This format was strictly adhered to and not one party ever violated the verbal agreements of our senior figures.

"The adopted order had a powerful impact on the course of the work. From 2004, the time they entered the active phase, and to their completion in 2013, the work progressed without serious incident or complication. In 2007, headed by the First Deputy Chief Executive of the state corporation Rosatom Ivan Kamenskikh, an expanded programme was developed for the work of the national laboratories of Russia and the USA. And here it should be said that Russia encountered a great many difficulties with its implementation. Of primary importance for use were issues surrounding the protection of our interests and, by participating in the Agreement, we had literally to walk on a knife edge to avoid violating Russian laws. Nevertheless, we managed to coordinate and implement a transparent programme. This fact warranted a separate high appraisal by the presidents of our nations in Seoul. Sensitivity surrounding the nuclear field is very high and especially so when a non-nuclear state is involved. And where matters of state secrets are concerned, the sensitivity is extremely high. To minimise risks, the parties elaborated special steps to safeguard information. And here too, interesting incidents were not to be avoided. At one stage of the work, the American side requested non-disclosure undertakings from the Russian participants, while the Kazakh side blocked access to their information to the Russians. Naturally, we eradicated these problems quickly. This, however, is one indication of how the restrictions were observed without fail and, generally, the discipline within our trilateral alliance remains rock-solid to this day."

When setting out the position of the Russian participants, it would be right and proper to cite the appraisal of the American partners. One available source on this subject, the article titled *Plutonium Mountain* [15] by Eben Harrell and David E. Hoffman, stated the following:

"The Semipalatinsk operation secured substantial amounts of plutonium and reduced the threat that it could fall into the hands of scavengers, terrorists, or a state with malevolent intentions. But it was a very close call. Had the governments of the United States, Russia, and Kazakhstan not been prodded, the large and expensive clean-up might never have been launched, or the bad actors might have arrived on the scene before the materials could be secured. The Degelen Mountain operation highlighted the valuable and effective role of unofficial collaboration and contact among scientists and others who are devoted to achieving results without cumbersome negotiations. Yet securing the plutonium in Kazakhstan proved to be a laborious and long undertaking which required 17 years, including a decade after the 9/11 attacks, which raises the question of whether some combination of low-level cooperation and high-level oversight might have proven more effective."

3.3. Collaborative efforts of Kazakhstan and the USA

Successful implementation of the trilateral operation gave hope that this collaboration would continue. And there were good reasons for this. The fact of the matter is that during their own research, NNC specialists discovered separate sections within the Experimental Field that contained nuclear waste. This information was brought to the attention of all participating stakeholders. The US representatives, having evaluated the information they obtained, decided to launch a new operation. Unfortunately, the Russian side refused to take part.

NNC and the DTRA entered a separate contract under the existing framework agreement to perform a detailed radiological survey of the entire testing area at the Experimental Field and part of the area that adjoined it.

3.3.1. Reducing proliferation risks at the Experimental Field Testing Area [16]

3.3.1.1. Detailed radiological survey of the area

In 2012, as part of implementation of the HDTRA contract, NNC commenced a detailed radiological survey of the area at the Experimental Field of the Semipalatinsk Test Site and its adjacent territory (1 km) (*Figure 3.217*). This work continued for three years.

The aim of the survey was to seek sectors with high nuclear waste content at the Experimental Field, assess the volume of nuclear waste at the detected sectors and elaborate recommendations on how to handle this nuclear waste. In 2012–2013 all the main technical areas were surveyed: P-1, P-2, P-7, P-3, P-5 and P-2M, which is located outside the Experimental Field (c. 1 km from the boundary of the area). 3 sectors were discovered at areas P-2 and P-7, where the nuclear waste concentration in the surface layer exceeded 9 ppm, while at another sector the nuclear waste concentration was recorded at the level of 1–8 ppm.

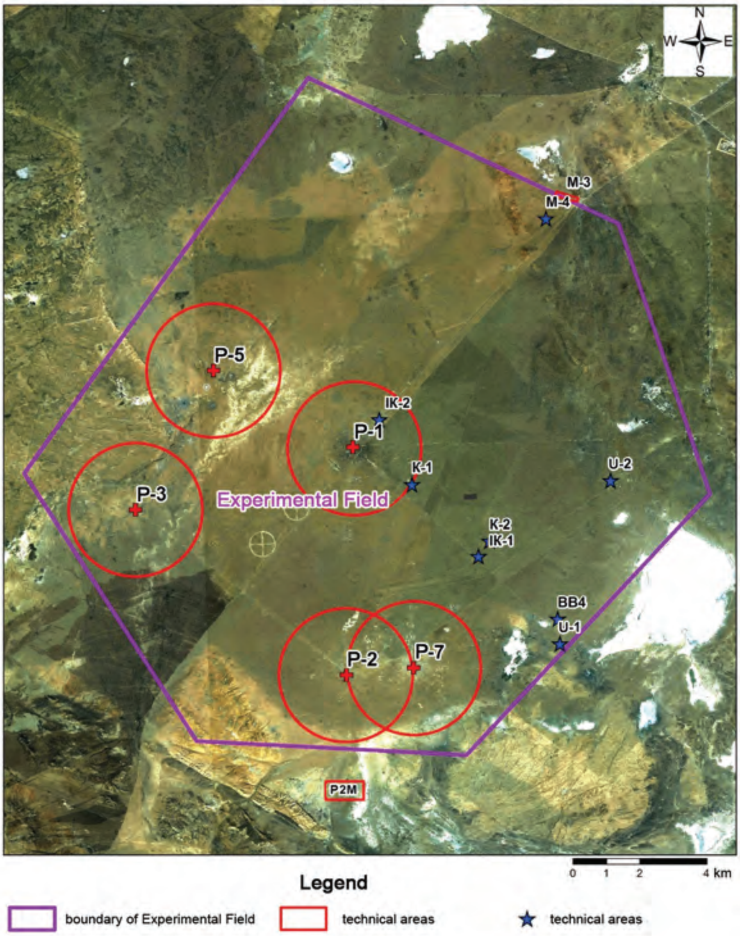


Figure 3.217. *Map of technical areas at the Experimental Field*

Increased concentrations of nuclear waste (>8 ppm) were recorded at the area P-2M not only on the surface but also at a depth of up to three metres. It is assumed that experiments with nuclear materials were performed in 2–3 metre trenches. There were a total of 24 trenches in this area.

In 2014, in addition to the survey of the remaining part of the Experimental Field, an additional survey was performed at the areas P-1, P-3 and P-2M.

General survey technique The surveying of the remaining part of the Experimental Field was performed in accordance with a technique, the key aspects of which are as follows: 1) general assessment of the surface distribution of radionuclides over the area in question; 2) detailed description of sections with abnormally high concentrations of ^{241}Am and ^{137}Cs; 3) calculation of the reserves of nuclear waste at the discovered sections. A gamma-spectrometry survey was performed on foot for a general assessment of the distribution of radionuclides over the area in question, over sectors (moving over set coordinates), with a 20-metre distance between sectors (*Figure 3.218*).

Figure 3.218. *Gamma-spectrometry survey on foot at the Experimental Field*

A discrete gamma-spectrometry survey was conducted over a denser grid (up to 2 x 2 metres) for a detailed description of the discovered sectors with abnormally high concentrations of ^{241}Am and ^{137}Cs. In addition to the more detailed gamma-spectrometry survey, soil samples were also taken. The depth of the sampling depended on the degree of penetration of the radionuclides. This was followed by a calculation of nuclear waste reserves at the discovered sectors.

To do this, the vertical distribution of radionuclides in the subsurface was studied based on the results of laboratory measurements of soil samples layer by layer (*Figure 3.219*). In addition, the relationships between $^{239}Pu/^{241}Am$ and $^{235}U/^{241}Am$, which lay at the heart of the gauging of nuclear waste quantities, were calculated.

A somewhat different technique was used for the detailed survey of area P-2M. At the first stage boreholes were drilled in places where the epicentres of tests in trenches were assumed to be located. Then the depth of the nuclear waste was determined, for which core samples (drill mud) was measured using field spectrometers (*Figure 3.220*). The quantities of nuclear waste were assessed by determining the coefficient of conversion from the count rate of the field spectrometer (cps) to the specific activity of the radionuclide in the soil (Bq/kg).

Figure 3.219. *Laboratory studies*

Figure 3.220. *Drilling boreholes and spectrometry studies*

Recommendations were drawn up based on the obtained data for adjusting the spatial characteristics of the location zones of nuclear waste, in order to elaborate methods for rendering them safe.

Survey results for areas P-2, P-7, P-3 and P-5 The gamma-spectrometry survey conducted on foot led to the receipt and analysis of over 500,000 gamma spectra. Based on the data, obtained during the analysis, maps were constructed of areal contamination by industrial radionuclides ^{241}Am and ^{137}Cs over the areas in question (*figures 3.221* and *3.222*).

Analysis of the maps detailing the distribution of industrial radionuclides, obtained after the gamma-spectrometry survey on foot at the areas P-2 and P-7, with a distance of 20 metres between sectors, determined that there were significantly contaminated areas there. The surveyed area was divided into provisional regions, where contaminated sections were revealed, of interest for further study. Each section was subjected to additional study. The following parameters were determined during the course of this study:

- spatial distribution of radionuclides over the surface;
- distribution of radionuclides in the subsurface (up to 50 cm);
- determination of isotope fractionation.

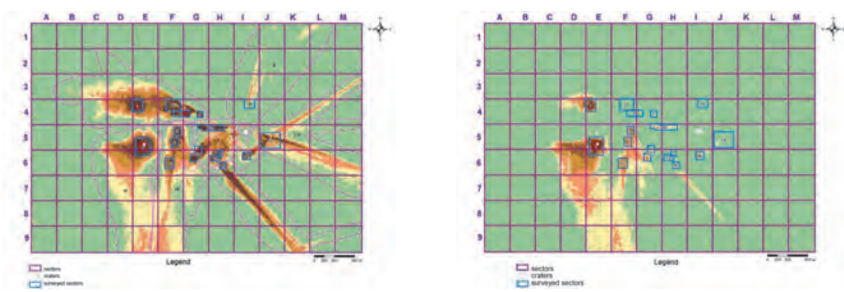


Figure 3.221. *Distribution of ^{241}Am and ^{137}Cs at areas P-2 and P-7. Contaminated sectors and regions are labelled*

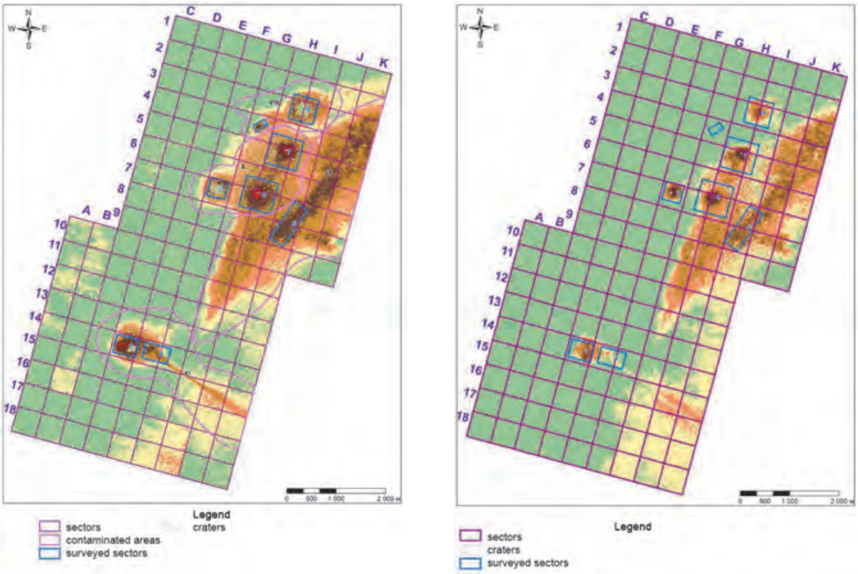


Figure 3.222. *Distribution of ^{241}Am and ^{137}Cs at areas P-3 and P-5. Contaminated sectors and regions are labelled*

A discrete gamma-spectrometry survey was performed over a 10 x 10-metre grid (2 x 2 metres for certain sections) to determine these factors, plus soil sampling with subsequent laboratory analysis for ^{137}Cs, ^{241}Am and $^{239+240}$Pu content (plutonium isotopes were determined by a radiochemical method). A panoramic photo survey was additionally performed for each sector.

19 localised sectors containing nuclear waste were revealed from the survey at areas P-2 and P-7, and 8 localised sectors at areas P-3 and P-5. The study of these sectors over a denser survey grid helped clarify their boundaries and the distribution of nuclear waste within the sectors. Distribution maps of ^{241}Am and ^{137}Cs were constructed based on the results of the gamma-spectrometry survey on foot. Based on the adjusted data, soil samples were taken for laboratory analysis. The laboratory analysis helped determine the isotope ratio of ^{241}Am and $^{239+240}$Pu, the distribution of ^{241}Am by depth of the soil layer was studied and the results of field gamma-spectrometry studies were adjusted.

In the majority of the studied sectors, the greater part of the nuclear waste (up to 95%) was concentrated in the top 10-cm layer. Craters were revealed in some sectors or next to them, the discharge of earth from which could have concealed a considerable portion of nuclear waste. This is confirmed by the results of studies into the distribution of radionuclides in the subsurface at these sectors, where the maximum quantity of nuclear waste was detected at a greater depth.

The studies helped assess the volumes of nuclear waste at the areas in question, which serve as the basis for elaboration of measures to strengthen the physical protection of the revealed nuclear waste.

It is noteworthy that analysis of the spatial distribution of nuclear waste in the areas under study helped establish traces of radioactive fallout from blasts, the epicentres of which were not detected. The epicentre of some traces could be located in the centre of area P-7, where there is now a crater from a chemical blast. The clean earth, discharged from this blast, covered a considerable area, with a radius of up to 400 metres from the centre of the blast. According to obtained data, the epicentre of several tests with fissionable substances could be concealed under the layer of clean earth. Traces of radioactive fallout from blasts were also revealed, the epicentres of which could be located outside the studied area (in north-easterly and southerly directions).

Study results at area P-2M The test area P-2M is located in the southern part of the area adjoining the Experimental Field (*Figure 3.217*) and occupies a territory of 0.63 km^2. The results of the studies that involved continuous and discrete gamma-spectrometry surveys on foot with a resolution of from 20 to 2.5 metres, became the basis for detailed maps of areal contamination by ^{137}Cs and ^{241}Am over the area (*figures 3.223* and *3.224*). In addition to the areal spectrometric study of the territory, spot and layer sampling of soil was performed to study the radial and vertical distribution of industrial radionuclides at the epicentral sections and in the zones of fallout of dispersed nuclear materials.

By analysing the maps of areal contamination, the central zone of the area can be highlighted, in which a number of indicative tests were performed, evidence of which is found in multiple traces of radioactive fallout (*Figure 3.223*). There are a minimum of 16 such traces. The length of the traces of radioactive fallout varies from 500 to 4,000 metres. The indicative width for all traces, on average, does not exceed 40 metres. The majority of traces display an axial symmetry, where the axis of the trace is practically a straight line.

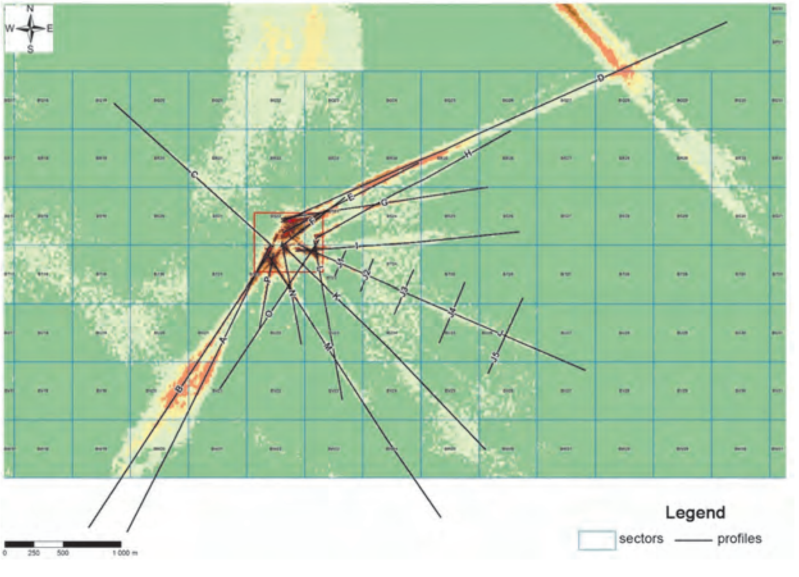


Figure 3.223. *Map of distribution of ^{241}Am at the area P-2M with labelling of traces*

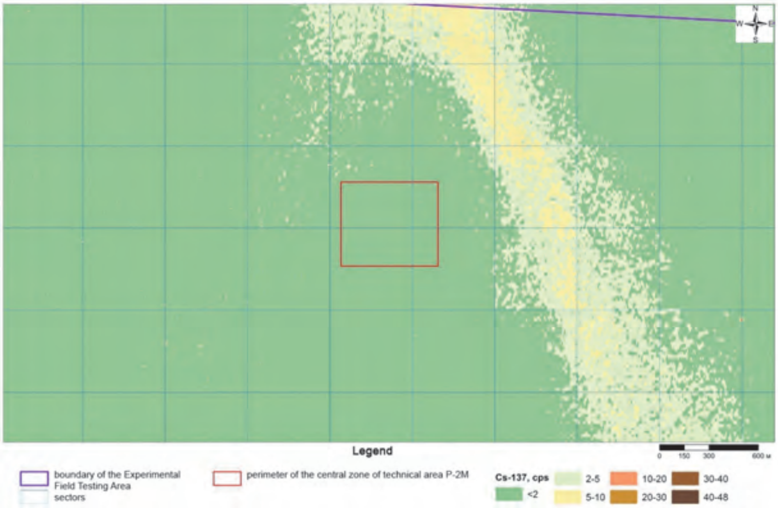


Figure 3.224. *Distribution of ^{137}Cs at the area P-2M*

Superficial radioactive contamination of the area is formed by ^{241}Am and $^{239+240}$Pu. The almost total lack of fission products, except for an insignificant trace of radioactive fallout in terms of ^{137}Cs activity, of which the source was nuclear testing at technical area P-2, led to the assumption that this area was the site of non-nuclear blast experiments (without a chain reaction, or with an extremely small formation of neutron flux).

Testing area P-2M has an extremely high degree of human-caused damage to the natural landscape, in the form of trenches (foundation pits), earth mounds, downholes and other objects, associated with the work of heavy machinery on the surface of the earth. During the research work it was discovered that the epicentres of sectors of superficial contamination are linked with industrial sites at area P-2M. Therefore, one of the objectives of the 2014 studies was to research the vertical distribution of radionuclides in the subsurface of certain sites at testing area P-2M and to assess the possible subsurface reserves of nuclear waste.

In 2014, given the features of the radiation situation and data from interpreting industrial sites at area P-2M, a vertical survey was conducted of the sites of human activity with traces of activity on the top layer of soil (site G) and at trench-type sites (T) both with and without earth banking. To do this, an auger drilling method and soil sampling using the set technique were applied. In addition, to ensure a comprehensive understanding of the distribution of sites in the area, consideration was given and a partial description made of other sites without contamination, but which could assist in detecting cable networks and determining the points of detonation of hydronuclear and hydrodynamic devices at this site.

The research involved drilling work and sampling of soil layer by layer from the extracted core sample. The depth of drilling at the trench-type (foundation pit) (T) sites reached 305 cm with a vertical increment of 15 cm between samples, while it reached 55 cm on earth ridges, with a vertical increment of 5 cm, in accordance with the diagrams (*figures 3.225* and *3.226*).

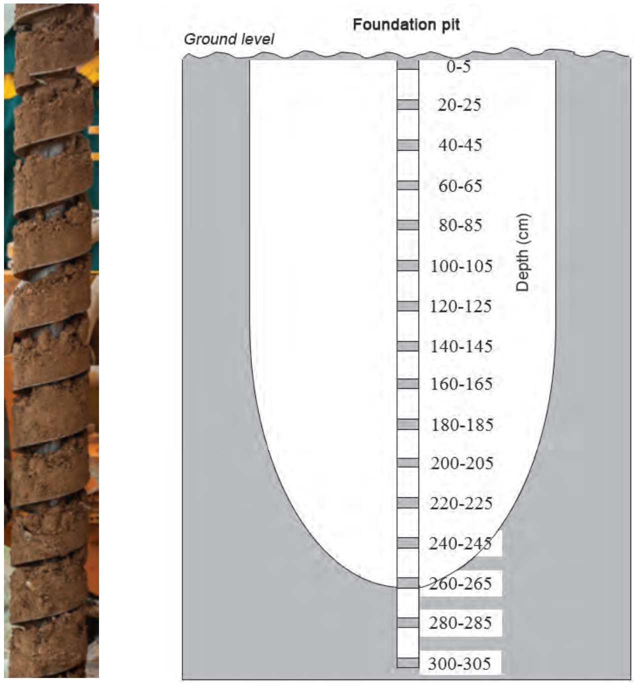


Figure 3.225. *General diagram of soil sampling layer by layer when drilling in foundation pits (trenches) and the auger type*

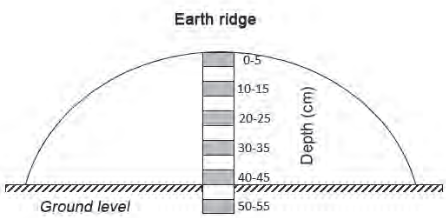


Figure 3.226. *General diagram of soil sampling layer by layer when drilling in earth ridges*

Owing to the complexity of the relief, the drilling at certain sites was performed at sites, shifted relative to the most probable detonation point of the devices. Mounted drilling equipment was needed for drilling in remote locations. In the majority of cases, points were selected for drilling that were as close as possible to the geometric centre of the site for trenches, while arbitrary drilling points were selected for earth ridges. It is noteworthy that the high degree of human-caused damage and the uneven nature of the landscape in certain instances meant that drilling could not be performed in points where the discovery of maximum concentrations of nuclear waste in the subsurface was most probable.

Based on the results of the research, one could say that there is a considerable quantity of nuclear waste at testing area P-2M. It was determined from studies of superficial contamination that the nuclear waste concentrations reach 8 and more ppm. It should also be noted that the contamination is a result only of the presence of fissionable materials. This is an indication that this area was the site of non-nuclear blast experiments. In 2014 research was performed of the vertical distribution of nuclear waste at a number of indicative industrial sites. The set of research at testing area P-2M helped reveal the main industrial sites of testing area P-2M that contained nuclear waste.

Additional research was needed at all sites where nuclear waste was confirmed in the subsurface, with determination of the depth of the nuclear waste, the area of the contamination, the volume of material and the isotope fractionation. In addition, in order to reduce the threat of nuclear waste proliferation, work is needed to prevent access to nuclear materials.

Results of research of the remaining area of the Experimental Field In 2014, comprehensive radioecological surveying of the remaining part of the Experimental Field was completed. The survey area constituted 275 km^2 (not including areas P-3, P-5, P-2 and P-7, surveyed in 2012).

The gamma-spectrometry survey conducted on foot led to the receipt and analysis of over 1.3 million gamma spectra. Based on the data, obtained during the analysis, maps were constructed of the areal contamination by industrial radionuclides ^{241}Am and ^{137}Cs over the areas in question (*Figure 3.227*).

The epicentre of a nuclear test, located in the south-eastern part of the Experimental Field, was detected during the course of the survey. The site, with the provisional name B-1, is a blast crater and a trace of radioactive fallout, extending beyond the Experimental Field. The total area of the radioactive contamination (within the testing area) stands at about 5 km^2. The results of a detailed survey of site B-1 revealed no significant concentrations of nuclear waste.

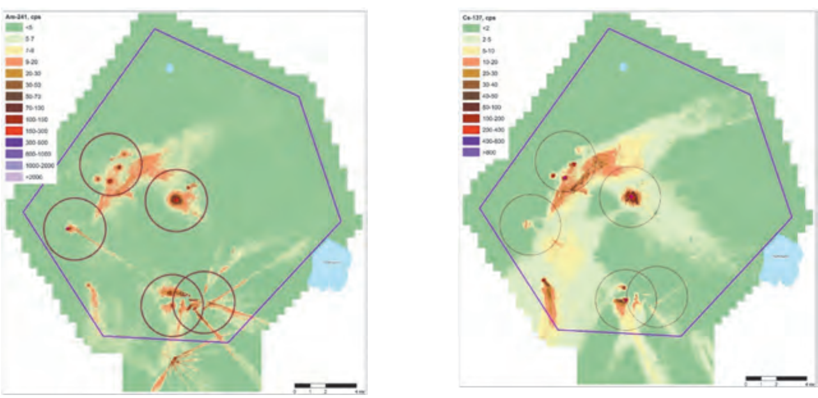


Figure 3.227. *Distribution of ^{241}Am and ^{137}Cs at the Experimental Field, with sectors and regions of contamination labelled*

An area of radioactive contamination of the soil cover was also detected in the central part of the Experimental Field, near to area P-1 This region is a trace of radioactive fallout from testing at area P-5. The radioactive contamination covered an area of about 7 km^2. The concentration levels of nuclear waste in this sector, however, were significantly lower than 1 ppm.

No other increased concentrations of nuclear waste were discovered in the remaining part of the area under study.

Thus, during the course of the areal survey of the remaining part of the Experimental Field, no sectors were revealed where the nuclear waste concentration exceeded 1 ppm.

3.3.1.2. Comprehensive reclamation of the area and rendering individual sectors safe

As part of the reduction of proliferation risks from the Experimental Field, NNC implemented measures to extract nuclear waste and till (plough) the upper soil layer at a number of sectors on the Experimental Field (*Figure 3.228*).

The sectors where nuclear waste was extracted and the soil tilled were determined based on the results of surveying the Experimental Field in 2012. The nuclear waste content in the soil served as the criterion for selecting sectors, as follows: for extraction – more than 8 ppm; for tilling – more than 1 ppm.

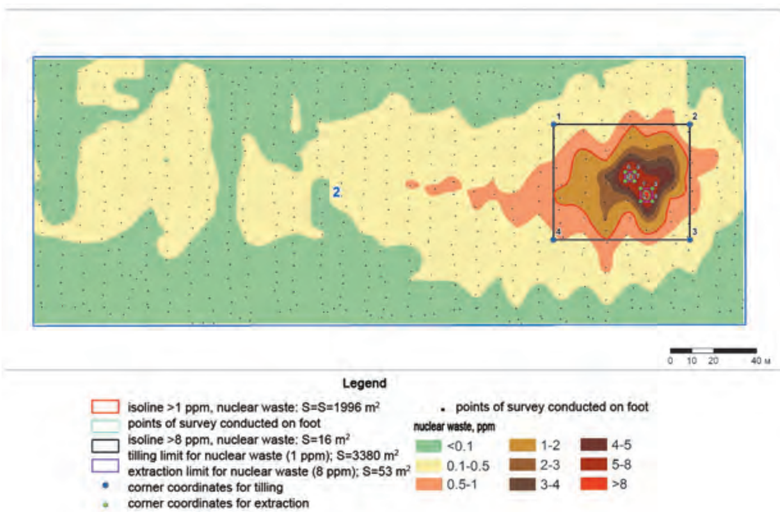


Figure 3.228. *One sector where comprehensive reclamation work was performed*

The nuclear waste was extracted manually (*Figure 3.229*).

Figure 3.229. *Nuclear waste extraction*

Manual extraction helped reduce the depth of earth extraction which, in turn, reduced the volumes of the extracted nuclear waste. In addition, the dimensions of the sectors were adjusted (upwards), which guaranteed the extraction of nuclear waste with values over 8 ppm. At the same time, the activity of the soil, after removal of the top layer, was controlled by a spectrometrist at the work site. If certain values of total activity were higher (based on spectrometer readings (cps) to ppm), the earth was extracted at a greater depth (*Figure 3.230*) and, in some cases, beyond the initially set perimeter of the sector, until values of nuclear waste content were lower than 8 ppm.

Figure 3.230. *Adjusting extraction depths based on the results of real-time monitoring*

The ground extracted from sectors 2, 12 and 13, after processing, was placed in transport packaging containers for onward transport to the storage site (*Figure 3.231*). A total of 346 transport packaging containers were prepared with a total volume of 86.5 m^3.

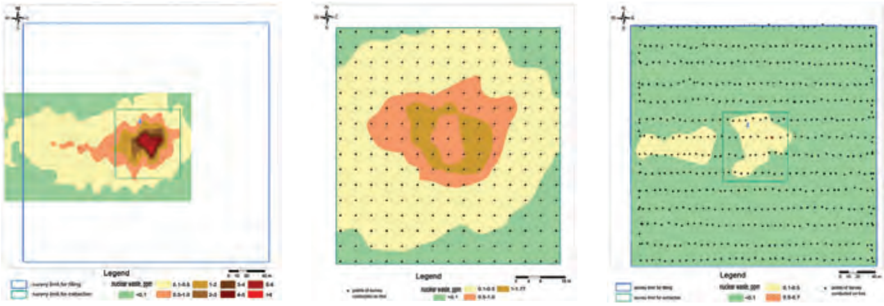
Figure 3.231. *Making up and placement of packaging containers for transport to the radioactive waste storage facility*

After the nuclear waste was extracted, the sectors were tilled. Prior to the work commencing, the corner (turning) points and boundaries for the areas to be tilled were marked out with stakes and warning tape. The corner points were sited using high-precision GPS gridding.

The earth was tilled (ploughed) to a depth of 40–50 cm (*Figure 3.232*).

Figure 3.232. *Ploughing over the sectors*

After the nuclear waste was extracted and the earth tilled, a gamma-spectrometry survey on foot was performed at each sector. The gamma survey results confirmed that the earth containing nuclear waste of over 8 ppm had been completely removed; after tilling the nuclear waste content in the surface layer was no more than 1 ppm (*Figure 3.233*).



a) *b)* *c)*

Figure 3.233. *Results of gamma-spectrometry survey on foot of one of the sectors, a) before reclamation began; b) after extraction of nuclear waste; c) after tilling*

It was therefore at the Experimental Field that nuclear waste was first extracted at STS, rendered safe and placed in storage under controllable conditions (under an IAEA safeguards guarantee). Thus, the main objective of the project was achieved: rendering the area of the former STS safe and secure. The work led to a fall in contamination of the Experimental Field to a safe level.

The measures to prevent unauthorised access to the nuclear waste promoted a general improvement in the environmental state at one of the sectors of STS.

3.3.1.3. Radioecological support

All work associated with the extraction and tilling was conducted with radiation support, meaning with radiation monitoring of personnel, facilities, equipment and work places.

As the entire process, from the extraction of the soil to the making up of the packaging containers, involved the rising of dust, the roads, extraction sites and working areas were wetted throughout the course of each working shift. The sectors were also thoroughly watered prior to the tilling of the earth. This irrigation almost completely prevented dusting (*Figure 3.234*).

When equipment needed to travel out onto provisionally clean territory, a radiometric examination was performed and, if necessary, decontamination measures were applied (*Figure 3.235*).

Radiation monitoring of air contamination with industrial radionuclides was conducted where the work itself was performed and where the personnel resided. The air was monitored using electromechanical air-sampling devices, which settle airborne aerosols onto the filtering element (filter) (*Figure 3.236*).

Figure 3.234. *Irrigating the sector for tilling and the working area*

Figure 3.235. *Examination and decontamination of a vehicle*

Figure 3.236. *Radiation monitoring of the residential zone*

The content of industrial radionuclides ^{241}Am and ^{137}Cs in the air of the residential zone over the entire period of the work did not exceed 2.0 x 10^{-4} and 6.5 x 10^{-5} Bq/m^3 respectively, which is no higher than the permissible volume activity for personnel according to normative requirements. The content of the radionuclide $^{239+240}$Pu in the air of the residential zone is likewise within the level of the permissible volume activity for personnel.

The content of industrial radionuclide ^{137}Cs in samples of airborne aerosols, taken in the industrial zone, was below the detection limit of the equipment used. The concentration of radionuclide ^{241}Am at the *open* work site reached 4 Bq/m^3 and it reached 2 Bq/m^3 in the hangar, which is 20 and 10 times more, respectively, than the permissible volume activity for the personnel category, as established under hygiene standards. The concentration of radionuclide $^{239+240}$Pu also exceeded the permissible volume activity for the personnel category and stood at 30 Bq/m^3 in the open locality and 6 Bq/m^3 in the hangar.

Given that the personnel used personal protective respiratory equipment (with an attenuation factor of 200), the internal ingress of industrial radionuclides was not higher than permissible levels. The maximum increase in volume activity of industrial radionuclide $^{239+240}$Pu in the air (1,000 times higher than permissible volume activity) was recorded at the moment of the greatest dust elevation (during a dust storm). Here, work in the sector was not performed and there were no personnel in the working area. Taken this circumstance into consideration, these values were not used when calculating exposure from possible inhalation. Moreover, a strict count was taken of the time that personnel spent in the work zone, to reduce the radiation exposure from inhalation of radionuclides.

The radiation support for the extraction of nuclear waste and tilling of the sectors containing nuclear waste helped not to exceed exposure limits, as established under Kazakh law for personnel conducting the work.

3.3.2. Research and experimental work performed to strengthen the physical protection of the work locations

Analysis of the work performed under the programme to mitigate proliferation risks at STS indicated that the sites of the former nuclear test site will never be completely secure in terms of the threat of proliferation and terrorism risks, at least for the foreseeable future. This means that a simple physical protection for the sites is not sufficient. We need to exclude not only the possibility of negative consequences from unauthorised activity but also for authorised activity to be conducted in a strictly specified framework. First, any form of business needs to be banned in the vicinity of sites with radioactive waste from testing. Second, this region needs to be protected from any attempts to penetrate it.

NNC decided to perform a series of research and experimental work to strengthen the physical protection of the work locations.

3.3.2.1. The research and selection of hardware for the series of remote observations.

In late 2009, after the Harris detection system equipment, provided by the American side, had proved to be ineffective and economically impracticable, the search began for less costly equipment with better tactical and technical parameters. The tasks for the first stage were drawn up, involving determination of the following system capabilities:

- equipment operation in the Degelen Mountain conditions;
- transmission of alarm and equipment control signals to Kurchatov and to the location where the security was deployed;

- use of alternative power sources;
- creation of an official radio communication system.

As part of these tasks, the equipment was sought and options for its application were considered. At the same time the search continued for detection and data transmission systems over a distance from 40 to 140 km. The difficulty in the selection of equipment involved the fact that there were no communication lines of any kind at the secure site. Therefore, the power requirements were very specific. Either the equipment had to operate from an autonomous source, or a separate autonomous power system needed to be created to provide for the equipment's operation. Work proceeded in parallel on choosing the video-monitoring system and the autonomous power supply.

In early 2010 a team from NNC visited a manufacturer of intrusion detection equipment. The manufacturer organised a demonstration of the equipment in operation and gave a tour of its facility. Preliminary agreement was reached as part of the visit on the possible supply of the equipment and its further adaptation to the conditions at the secure site.

3.3.2.2. Installation of the first package of equipment and testing of its operational integrity and efficiency

The physical protection takes the form of a set of engineering tools, consisting of detection, video surveillance, communications, technical and physical barriers.

As part of the basic agreement between NNC and the DTRA, a three-level physical protection system was created at Degelen Mountain, the areas *RBSh* and Aktan-Berli. The system includes special signs, barriers to prevent access and a remote detection system. The sites at STS have a non-standard configuration, they have long perimeters (the largest site has a perimeter, stretching over 60 km), there is no life-support infrastructure at the sites and the equipment needs to operate in complex climatic conditions. The systems were created in an experimental manner. The equipment was selected by testing small batches in specific conditions, with the ability to expand and build it up. The equipment is now installed, configured and functioning in detection and barring access to potential trespassers.

The systems have been built based on the principle of multi-level, column protection. A three-level physical protection system has been created at the secure sites at STS:

Level 1 (warning) – special signs with warning notices in the national and Russian languages are installed every 200 m around the edge of the site, stretching over 60 km. They read: *Prohibited zone. No pedestrian or vehicular access*;

Level 2 (deterrence) – physical barriers and elements for barring access to potential trespassers:

- gates with special signs;
- barbed wire fencing;
- moats measuring from 1.5 metres deep and across, with banking;
- boulders (in places where no moat can be dug).

All these elements are placed in locations where the secure sites can be approached in transport.

Level 3 – physical protection system equipment:

— detection system;
— video-monitoring system;
— radio-communication system;
— data transmission system;
— autonomous power supply system;
— operator, administrator and situation room work stations;
— UAVs.

The systems have been installed at sites, located from 80 to 200 km from Kurchatov (*Figure 3.237*).

Figure 3.237. *Physical protection system at Degelen Mountain*

Experimental work. A system concept was developed, which included the following components:

— radio-communication system;
— autonomous power supply system;
— data transmission system;
— detection system.

It was assumed that the possible operation of these systems would be checked in experimental mode in conditions of a severe winter and in a mountainous locality.

In early summer 2010 contracts were executed for the delivery of the equipment and the points in the site for their installation were chosen. Pursuant to the corresponding requirements, NNC conducted experimental work on possible application of the package for remote observation with data transmission by radio in Degelen Mountain conditions. The experimental work was performed in parallel with maintenance of the previously installed Harris remote detection system.

At the initial stage it was assumed that experimental work would proceed using several sensors and a mobile control console of the detection system at a number of sites in the mountain area. At the same time it was planned to test the video surveillance system, consisting of television signalling apparatus and a portable television receiver.

The aim of this work was to ascertain the operational integrity of the system in various conditions and at varying degrees of remoteness from the system of sensors without data transmission via radio, and to determine the effectiveness of detecting intruders (individual people or vehicles).

The second stage of the experimental work involved plans to install and calibrate the data transmission system from a group of detection system sensors to the information collection centres.

The aim of this work was to seek a route for transmission of a stable radio signal to the data equipment installation point, using various antennae and other sensors that operate as a relay station.

It was planned at the concluding stage to configure the work of the entire experimental detection system, with data received at the information collection centres.

The equipment was assembled by the technical support team in difficult natural and climatic conditions. The equipment was raised to the highest points of the sites manually, a task that required considerable time and energy (*Figure 3.238*).

Figure 3.238. *Delivery of equipment and materials to point 1008*

Detection system. In accordance with the Works Plan, NNC procured an automatic, terrestrial, remote control system. The supplier delivered the equipment (*Figure 3.239*) to Kurchatov. Specialists from the equipment manufacturer came to Kurchatov to test and complete the initial installation of the equipment.

Figure 3.239. *System equipment*

Allowing for the relief of the locality and the distance involved, secure sites were selected where detectors were installed (*Figure 3.240*). The system was configured and tested and the personnel were trained.

The main objective of the study was to determine the ability to build a stable detection system in the conditions of the Degelen Mountain locality.

Figure 3.240. *Installation and concealment of detectors*

Detectors operating as relays were installed to increase the communication range and to compensate signal deterioration at intermediate altitudes.

The following was established during the course of the experiment:

- The detectors operate according to features, set by the manufacturer. The human detection range is up to 70 metres from the point of installation; the range for detecting a vehicle is up to 100 metres.
- The signal can be transmitted from remote points on Degelen using relays. Without a relay, the communication range is up to 2.5 km.
- Signals are transmitted over a radio channel.
- The signals that are received from the detectors are delivered to the operator in graphic and text form and are intuitive.

Radio-communication system. The system is designed to provide for stable voice communication between the production sites of NNC and its subcontractors.

The system operation is served by a relay, installed within Degelen Mountain, at an altitude of about 1,000 metres (*Figure 3.241*).

The relay is housed in a sealed metal box. The fixed antenna is installed on an 8-metre mast. The power for the relay is supplied from an autonomous, uninterrupted power supply.

The positioning of the relay at the highest point of the mountain ensured the maximum radius of coverage. In other words, network users with handheld radio stations were able to communicate all over Degelen Mountain and over the entire route to Kurchatov. *Figure 3.242* displays the GM-340 radio station with power unit.

Figure 3.241. *Antennae, installed at altitude point 1008*

Figure 3.242. *GM-340 radio station with power unit, installed at NNC*

Autonomous power supply system. The system was designed as an autonomous power supply for the radio communication, data transmission and security alarm equipment.

The autonomous power supply system equipment was installed at the top of the mountain. Solar panels with a total power capacity of 520 W/hr were installed on purpose-built structures, enabling adjustment of inclination angle relative to the horizon. The panels of the operating surface are directed southwards. The inclination angle was set at 45^{o} (*Figure 3.243*).

Figure 3.243. *Solar panels*

Figure 3.244. *Battery and solar charge controller*

The electricity produced by the solar panels, through the solar charge controller, charges the batteries with a total capacity of 580 A/hr. 220V equipment is powered through an inverter, connected to the battery (*Figure 3.244*).

Given a maximum of 5–7 daylight hours during the winter, the minimum daily power output is 5 x 520 = 2,600 W. This is enough to provide for the operation of the communication and data transmission equipment. Expanded systems would be needed if the power requirement is increased.

Experimental work proved that the equipment could operate in winter, even when there is a high level of snow cover and access is restricted to the solar panels and batteries for maintenance purposes.

Data transmission system. The system was designed to transmit alarm and control data signals between the equipment at the site and the receiver equipment where the security forces were located in Kurchatov.

It was presumed earlier that the data transmission system would be built using Mikran radio-relay equipment (Russia). For certain reasons, at the equipment procurement stage, preference was given to different equipment, which was no inferior in specification.

The data transmission system is built on Motorola wireless-access equipment, designed for point-to-point, high-speed radio channels. The maximum bandwidth of the communication channel is 300 Mbps. The maximum radio channel length is 140 km.

A study was made of the possibility of arranging a channel from point 1 to Kurchatov. It was assumed that this equipment would provide for a communication channel from Degelen to Kurchatov without the need to install additional relays. It proved impossible to obtain a stable communication channel at this sector as the elevated nature of the locality on the signal's route prevented the signal from getting through. Although the equipment does allow operation without line of sight, this is only possible at distances up to 60 km. An additional relay needs to be installed in Kurchatov to resolve this data transmission issue. Its location needed to be determined additionally, allowing for the following factors: the availability of electricity, a tower to locate the equipment and a suitable relief of the locality.

The installation of the first series of the physical protection system and the testing of the operational integrity and effectiveness of all systems demonstrated the following:

1. The official radio communication system can operate in the existing mode. A set of spare batteries needs to be procured for the handheld radio stations. If the usage capabilities need to be expanded (connection to the telephone network or expansion of the relay network), a switchover would be needed to digital equipment.

2. The autonomous power supply system – the system capacity was designed for performance of existing tasks. A check was needed of the operability of the system in winter conditions. It is advisable to divide the power supply systems between the radio communication and data transmission equipment to ensure the energy independence of the systems. If the user capacity is increased, the system would need to be expanded (with the acquisition of additional solar panels, replacement of controllers and inverters and the addition of a petrol generator to the system with a remote start facility). Consideration should also be given to the use of a wind generator as an additional power source.

3. The data transmission system transmits data to the information collection centre. Data can be transmitted to Kurchatov using an interim relay. Consideration is needed of the possible use of a fibre-optic communication line.

4. The detection system – detectors can be used to provide security for the most important boundaries. To create a security alarm network requires the installation of the necessary number of detectors at the secure site and of detectors used as relays.

It is inadvisable to use television transmitters in their current design at each site, owing to the short distance of signal transmission. The developer is working to update the television equipment, specifically focussing on saving the video pictures on a detachable carrier. This equipment is more preferable.

Work on creating the physical protection system has been performed in accordance with security rules and regulations and is designed to ensure the protection of nuclear sites. The work ensures the reliable operation of physical protection systems for sites of STS, meeting security requirements. Implementation of this project has provided for the protection of the above-mentioned sites, allowing for modern-day threats and the scientific and technical achievements, and this means that any probable sabotage or acts of terrorism and any form of intervention by unauthorised individuals or unqualified personnel can be prevented in the early stages.

3.3.2.3. Expanding capabilities and increasing the monitored area

NNC regularly performs modernisation work to expand capabilities and increase the monitored area, to maintain the control systems at the latest technological level. To this end, the following key tasks were addressed:

Task 1. Red posts bearing warning signs reading *Hazardous Area. No pedestrian or vehicular access* were installed around the perimeter of these sites to create the first level of physical protection and observe legal norms during application of security equipment. These signs, safeguarding the perimeter of certain sites, represent a continuation of the pre-existing, first-level system.

Task 2. The following was performed to make the second level of physical protection as hard as possible to negotiate:

1. Recovery and reinforcement of additional, diagonal rows of the existing barbed wire fencing;
2. Construction of additional obstacles for vehicular access and livestock movement, with their placement in front of the barbed wire fencing;
3. The existing second-level gates were replaced with reinforced, hinged barriers, fitted with two locks and an anti-vandal protective coating.

Task 3. New video monitoring systems were installed and trialled near the monitored sites to facilitate automatic surveillance in real time and to record events in the most vulnerable places of the strategic facility.

Task 4. A video recording and archiving system was installed to monitor traffic at the intersection of major roads.

Task 5. An interim relay was installed at the sector from site 100 to Kurchatov to increase the data transmission speed.

Task 6. Given the importance of ensuring uninterrupted operation of the data system, a hot standby was made from high-risk equipment for rapid replacement in the event of a malfunction.

Task 7. Linked with the fact that the newly installed equipment at altitude needs an additional power supply, the capacity of the autonomous power supply system, the reserve of solar modules and other ancillary equipment was increased.

Tests and training sessions were performed upon completion of the work.

3.3.2.4. Joint training sessions and testing of the remote access control and management system for a number of sites at the former STS.

In August 2015 a comprehensive examination of the entire physical protection system was performed. The tasks of the comprehensive assessment included the following:

1. An inspection of the technical detection systems upon attempts by a simulated trespasser to gain access to the secure site (*figures 3.245* and *3.246*).
2. An assessment of the round-the-clock operation of the systems, the control, communication and computer equipment and cooperation between those involved in the process (*Figure 3.247*).

Figure 3.245. *Attempts by simulated trespassers to gain access*

Figure 3.246. *Detention of simulated trespassers*

Figure 3.247. *Inspection of system functioning at night*

The comprehensive inspection demonstrated the high effectiveness of detection, control, communication and computing system facilities (both during the day and at night) and also of effective cooperation between parties involved in the process.

All systems have now been commissioned.

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CONCLUSION

For the first time in the history of the creation, development and partial destruction of nuclear weapons, one of the types of weapons of mass destruction, a test site was abandoned. This was the Semipalatinsk Test Site, built in the former Soviet Union to test such weapons. Moreover, fate was to dictate that, immediately after its closure, this test site was to become the property of another, this time a non-nuclear state—the Republic of Kazakhstan—a state that became a sovereign nation after the collapse of the USSR.

Kazakhstan, declaring itself a non-nuclear state, set about addressing the difficult problem of how to use this former nuclear test site for the benefit of the national economy. To do this work had to begin on abandoning the nuclear test infrastructure. And begin it did. Assistance was and still is being given in this work by specialists from the USA, Russia and various international organisations, including the IAEA and NATO.

After tunnels were sealed and boreholes abandoned, considerable work was done to return the natural appearance to the landscape near the tunnel entrances and borehole mouths, by backfilling these areas with earth. The reclamation work significantly improved the appearance of the Degelen and Balapan testing areas and, to a great extent, improved the radiation situation at these areas. The sealing of tunnels with watercourses play a major role in reducing radioactive contamination of the locality at Degelen Mountain, as a result of which the rise of radioactivity onto the daylight surface dropped markedly. The erection of crushed aggregate filters at a number of water-bearing tunnels helped reduce the ejection of radionuclides with water.

We have to admit that the reclamation work performed in 1995–2000 at the Degelen and Balapan testing areas significantly improved the landscape in these places. At the same time, research results indicated that at Degelen Mountain, where the natural aqueous system greatly influences the environment, the sealing of tunnels with water ingress where nuclear tests were performed does not completely stop the migration of radionuclides from the blast cavities, including over new watercourses, especially when precipitation levels rise sharply.

After the cessation of tests at the former Semipalatinsk Test Site, facilities still remained that contained sensitive information on the nuclear testing technology. Such facilities include the Kolba containment vessels, individual tunnels at Degelen Mountain, areas containing dispersed nuclear waste and other special process equipment for tests and recording hardware. Economic activity within the test site, including unauthorised activity, considerably raised the likelihood of access to sensitive information and could have led to breaches in observance of the provisions of the Nuclear Weapons Non-proliferation Treaty and to a threat of radiation-based and nuclear terrorism.

The search for ways for scientists and technical specialists from the nuclear state of the Russian Federation and the non-nuclear state of the Republic of Kazakhstan to collaborate in order to resolve this situation generated the need for the 28 March 1997 Agreement between the Government of the Russian Federation and the Government of the Republic of Kazakhstan on the Kolba containment vessels and special process equipment at the former Semipalatinsk Test Site. The Agreement stipulated a package of works with five tested (containing nuclear waste) and one untested Kolba containment vessel and other special process equipment at the former STS. Procedures were determined for implementing security measures and ensuring radiation and environmental safety during the course of the work.

From 1996 to 2000, NNC abandoned the nuclear weapons test infrastructure at the former STS. The operations were implemented as part of the 3 October 1995 Agreement between Kazakhstan and the USA on Abandoning Nuclear Weapons Infrastructure.

Starting from the year 2000, the work was performed on a trilateral basis (Kazakhstan, Russia and the USA), allowing for the Agreement on Abandoning Nuclear Weapons Infrastructure. The Kolba Agreement acts as the mechanism for Russia's involvement in this type of work. The full series of work, associated with supporting non-proliferation at the former STS, has a considerable social and economic significance and facilitates a stepwise transition to the full-scale rehabilitation of the area and the handover of lands for the needs of the economy.

In the year 2000, as part of implementation of the trilateral Agreement, work began at sites of the former STS on excluding any unauthorised access and for additional protection of nuclear waste at the testing areas and tunnels of Degelen Mountain. The aim of this work was to eradicate the threat of proliferation and terrorism. In May 2000, the eleventh session of the Steering Group on implementation of the Kolba Agreement decided to use the SG mechanism to coordinate this work. The American side financed this work.

Between 2000 and 2012, specialists from Rosatom (VNIIEF and VNIITF), NNC and the DTRA of the US Department of Defence completed work at 46 sites of the former STS, specifically referring to the following:

- erection of reinforced concrete structures at sites in the Aktan-Berli Area, bunded in earth and covering the test boreholes containing nuclear waste;
- erection of additional concrete protection at the sites with Kolba containment vessels, filling the internal cavities of four test containment vessels containing nuclear waste and one untested containment vessel with a binding material of cement-sand and magnetite solutions;
- extraction and repatriation to the Russian Federation of activated special process equipment from two sites on Degelen Mountain;
- erection of additional concrete and reinforced concrete protective barriers at forty-two sites on Degelen Mountain, the filling of the internal cavities of boxes with nuclear waste at these sites with a binding material of cement-sand and magnetite solutions. Additional protective barriers were erected and the boxes with nuclear waste were filled at sites at Degelen Mountain using so-called *horizontal* and *vertical* technologies. *Horizontal* technology was used to open up the tunnel entrance and restore the mine working up to the box with nuclear waste, fill the cavity of the box with a binding solution, erect concrete or reinforced concrete barriers, collapse the crown of the tunnel and conceal it beneath the surrounding mountain landscape. *Vertical* technology was used to fill the cavity of the box with binding material and erect concrete protective barriers across boreholes, drilled vertically from the surface of the mountain range. A similar *vertical* method was

used to fill the internal cavities of the Kolba containment vessels with binding material.

Horizontal technology was used for work at 19 sites of Degelen Mountain, while *vertical* technology was used at 20 sites. At 2 sites work was performed simultaneously using both *horizontal* and *vertical* technologies. During this work, additional protective barriers were erected at the sites using a total volume of about 40,000 m^3 of material (concrete, rock and special solutions), which is the equivalent of erecting more than 4 km of additional protection (an average of 100 metres per tunnel at the site). Between 2000 and 2012 a total of some 90,000 cubic metres of additional barrier structures were erected at STS sites under the Agreement.

Prior to and after completion of the work on additional protection of nuclear waste, specialists from the Khlopin Radium Institute conducted independent radioecological surveys of the area. The results of these surveys indicated that after completion of the work, the environmental situation improved at all tunnels and areas of the former STS.

In addition to work on erecting additional protection for nuclear waste at sites of Degelen Mountain, NNC eradicated the possibility of attempting unauthorised access to the tunnels by backfilling existing access points into the tunnel cavity. Between 2008 and 2011, access points were abandoned at 73 sites. The American side financed this work as well.

In the main the work was performed by federal nuclear centres VNIIEF and VNIITF from the Russian side and by NNC from the Kazakh side. Independent radioecological monitoring was performed by the Khlopin Radium Institute.

VNIIEF and other organisations of the Russian State Atomic Energy Corporation were involved in destroying sensitive information and eradicating the threat of nuclear waste proliferation from the former STS, working alongside other institutions and organisations of NNC (the Radiation Safety and Ecology Institute, the Geophysical Research Institute, the Atomic Energy Institute and the enterprises Baikal and Kazakh State Scientific Production Centre for Explosive Work) and contracted organisations from Russia and Kazakhstan (VNIIEF TANIK, Degelen and Vostokavtoprom).

From the year 2000 representatives of a third party, the DTRA of the US Department of Defence were involved in work at areas and sites of the former STS.

As a result of the work performed as part of the Agreement, reliable, protective barriers were erected at the facilities and areas of the former STS, excluding any unauthorised access (without industrial equipment) to the nuclear waste and sensitive information at the nuclear test sites.

One of the main results of this joint work is the close collaboration and cooperation in such a sensitive subject.

In 15 years of tireless trilateral work to liquidate the consequences of nuclear testing at the former STS, the participants now enjoy excellent and respecting relations, as everyone understood that they were part of the solution to a global problem. The success of this trilateral work was to a great extent determined by the ability of those involved to find compromises, which were part and parcel of almost every operation. The most important result of this trilateral effort is the experience gained in mutual understanding. It would be good if this experience could find application in the future, too.

The value of the results for the entire planet was recognised by three presidents, Dmitry Medvedev from the Russian Federation, Nursultan Nazarbayev from the Republic of Kazakhstan and Barack Obama from the United States of America, in April 2012 at the Nuclear Security Summit in Seoul. The presidents made a special declaration on the uniqueness of their trilateral collaboration, which yielded excellent results. We can assert with confidence that the polygon has indeed become safer than it was and that the direct threats posed to Kazakhstan and the entire global community have been localised. And this has been done in such a way that it is impossible to penetrate the former test infrastructure without major industrial intervention and the scavengers, who gathered ferrous and non-ferrous metals there, will now find it incredibly hard to access the most sensitive areas of the polygon and cause any serious harm. The area of potential threats has been brought to a decent condition, in terms of engineering and physical protection alike. The most sensitive areas of the test site are patrolled by the National Guard of Kazakhstan and state-of-the-art remote detection systems are used for surveillance. The area is now monitored by the IAEA, including with the use of satellites. Therefore, any indications of industrial intervention into potentially hazardous sites will be detected and suppressed quickly.

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ҚАЗАҚ СОВЕТТІК СОЦИАЛИСТІК РЕСПУБЛИКАСЫ ПРЕЗИДЕНТІНІҢ

ЖАРЛЫҒЫ

УКАЗ

ПРЕЗИДЕНТА КАЗАХСКОЙ СОВЕТСКОЙ СОЦИАЛИСТИЧЕСКОЙ РЕСПУБЛИКИ

О закрытии Семипалатинского испытательного ядерного полигона

На территории Казахской ССР в Семипалатинской области с 1949 года осуществлялись испытания ядерного оружия. За это время здесь было произведено около 500 ядерных взрывов, которые нанесли урон здоровью и жизни тысяч людей.

Учитывая, что Казахская ССР выполнила свой долг по созданию ядерного потенциала, обеспечившего стратегический военный паритет между СССР и США, и, принимая во внимание требования общественности республики, постановляю:

1. Закрыть Семипалатинский испытательный ядерный полигон.

2. Кабинету Министров Казахской ССР по согласованию с Министерством обороны СССР и Министерством атомной энергетики и промышленности СССР преобразовать Семипалатинский испытательный полигон в союзно-республиканский научно-исследовательский центр. В 1991 году разработать и утвердить его статус и перечень основных направлений научно-исследовательских работ.

3. Учитывая, что при проведении воздушных и наземных испытаний с 1949 по 1962 годы нанесен ущерб здоровью населения районов, прилегающих к Семипалатинскому полигону, совместно с союзными органами определить размеры и порядок компенсационных выплат пострадавшим гражданам Казахской ССР.

4. Кабинету Министров Казахской ССР совместно с союзными министерствами и ведомствами, причастными к проведению ядерных взрывов на территории республики, утвердить программу социально-экономического развития, улучшения условий жизни и медицинского обслуживания населения районов Семипалатинской, Карагандинской и Павлодарской областей, прилегающих к испытательному полигону, с привлечением на указанные цели средств соответствующих союзных источников.

Настоящий Указ вступает в силу с момента его принятия.

Президент
Казахской Советской Социалистической
Республики Н. НАЗАРБАЕВ

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DECREE
OF THE PRESIDENT OF THE KAZAKH SOVIET SOCIALIST REPUBLIC

On closure of the Semipalatinsk Nuclear Test Site

Since 1949, nuclear weapons have been tested in Semipalatinsk Region of the Kazakh Soviet Socialist Republic. In this time, about 500 nuclear blasts have been detonated, which have caused harm to the lives and health of thousands of people.
Given that the Kazakh Soviet Socialist Republic has fulfilled its duty as regards the creation of nuclear potential, ensuring strategic military parity between the USSR and the USA and, taking into account the demands of the republic's public, I hereby decree:
1. To close the Semipalatinsk Nuclear Test Site.
2. That the Cabinet of Ministers of the Kazakh Soviet Socialist Republic, in coordination with the USSR Ministry of Defence and Ministry of Atomic Energy and Industry, transform the Semipalatinsk Test Site into a union and republican scientific research centre and, in 1991, draw up and approve its status and the list of key directions of said scientific research work.
3. Given that the performance of atmospheric and land-based tests between 1949 and 1962 caused harm to the health of the regions laying adjacent to the Semipalatinsk Test Site, to determine the amounts and procedure for payment of compensation to affected citizens of the Kazakh Soviet Socialist Republic, jointly with union authorities.
4. That the Kazakh Soviet Socialist Republic, jointly with union ministries and departments, involved in the nuclear blasts within the republic, approve a programme for socioeconomic development and improvement of the living conditions and medical care for residents of districts of the Semipalatinsk, Karaganda and Pavlodar regions, adjacent to the test site, engaging in this undertaking the funds of the corresponding union sources.
This Decree comes into effect from the moment of its adoption.

N. Nazarbayev,
President of the Kazakh Soviet Socialist Republic

ҚАЗАҚСТАН
РЕСПУБЛИКАСЫ
МИНИСТРЛЕР КАБИНЕТІНІҢ
ҚАУЛЫСЫ

ПОСТАНОВЛЕНИЕ
КАБИНЕТА МИНИСТРОВ
РЕСПУБЛИКИ
КАЗАХСТАН

от 21 января 1993 года
№ 55

О мерах по обеспечению деятельности Национального ядерного центра Республики Казахстан

Во исполнение Указа Президента Республики Казахстан от 15 мая 1992 г. № 779 "О Национальном ядерном центре и Агентстве по атомной энергии Республики Казахстан" Кабинет Министров Республики Казахстан п о с т а н о в л я е т :

1. Установить, что Национальный ядерный центр Республики Казахстан (в дальнейшем Ядерный центр) является самостоятельным учреждением республиканского подчинения, входит в состав Академии наук Республики Казахстан, которая осуществляет научное руководство и координацию его работы.

Ядерный центр осуществляет свою деятельность на основании законодательства Республики Казахстан и в соответствии с Положением о Центре, утверждаемым Кабинетом Министров Республики Казахстан. Ядерный центр имеет самостоятельный баланс и расчетный счет, печать с изображением Государственного герба Республики Казахстан и со своим наименованием на казахском и русском языках.

Руководство Ядерным центром осуществляет Генеральная дирекция во главе с Генеральным директором Центра, назначаемым Кабинетом Министров Республики Казахстан.

Определить местонахождение Генеральной дирекции Ядерного центра в г.Курчатове Семипалатинской области.

2. Возложить на Ядерный центр:

функции головной организации в области атомной науки и техники Республики Казахстан;

√ проведение работ по радиационной безопасности и экологии;

√ изучение и ликвидацию последствий ядерных взрывов и радиационного загрязнения окружающей среды в результате производственной деятельности на территории республики;

2.

исследование проблем и разработку технологий утилизации, хранения и захоронения радиоактивных отходов;

повышение надежности ядерных энергетических установок и исследование проблем безопасности атомной энергетики;

разработку и практическую реализацию ядерно-физических методов и ядерных технологий в интересах науки и народного хозяйства Республики Казахстан;

осуществление контроля за проведением испытаний ядерного оружия и несанкционированных ядерных взрывов на полигонах других стран;

проведение фундаментальных и прикладных исследований в области ядерной физики и атомной энергетики;

подготовку и повышение квалификации кадров в области атомной науки и промышленности;

осуществление работ по повышению уровня знаний населения республики в области использования атомной энергии в мирных целях;

информационно-издательская деятельность;

международное и межреспубликанское сотрудничество в области использования атомной энергии.

3. Включить в состав Ядерного центра:

Объединенную экспедицию НПО "Луч" Министерства науки и новых технологий Республики Казахстан;

Институт ядерной физики Академии наук Республики Казахстан;

предприятие "Байкал" Министерства промышленности Республики Казахстан;

геофизическую обсерваторию "Боровое";

геофизическую партию № 35 Министерства геологии и охраны недр Республики Казахстан.

Рекомендовать Государственному комитету Республики Казахстан по государственному имуществу делегировать Ядерному центру права владения, пользования и управления имуществом организаций, учреждений, переданных в состав Центра.

4. Установить, что Ядерный центр осуществляет научное руководство подразделениями реактора БН-350 Мангышлакского энергокомбината и другими научно-исследовательскими подразделениями ядерного направления в Республике Казахстан в рамках выполнения государственной программы по атомной энергетике независимо от их ведомственной подчиненности.

3.

5. Считать целесообразным создать на базе войсковой части № 52605 Научно-исследовательский комплекс оборонных программ с включением его в состав Ядерного центра.

Министерству обороны, Министерству науки и новых технологий Республики Казахстан совместно с заинтересованными организациями решить вопрос о статусе войсковой части № 52605 на основе заключения соответствующего соглашения между Республикой Казахстан и Российской Федерацией.

6. Распространить на руководителей и научных работников научных учреждений Ядерного центра условия оплаты труда, установленные для аналогичных должностей системы Академии наук Республики Казахстан.

Сохранить действующие на I января 1993 года тарифные ставки и должностные оклады остальным категориям работников учреждений Ядерного центра Республики Казахстан.

Министерству труда, Министерству финансов Республики Казахстан совместно с Ядерным центром, Министерством науки и новых технологий Республики Казахстан в месячный срок разработать и внести в Кабинет Министров Республики Казахстан на утверждение предложения по дополнительным льготам, имея в виду установление для различных категорий работников Центра дифференцированного отраслевого коэффициента и надбавок к должностным окладам и тарифным ставкам с учетом особых условий труда и разъездного характера работы.

7. Установить, что финансирование Ядерного центра производится из государственного бюджета, инвестиций зарубежных партнеров, международных фондов и собственных средств, полученных за реализацию разработок центра.

Министерству науки и новых технологий обеспечить, начиная с 1993 года, целевое финансирование Ядерного центра за счет средств, предусматриваемых бюджетом на финансирование науки в размерах, необходимых для выполнения государственной целевой научно-технической программы по атомной энергетике.

8. Поручить Государственному комитету Республики Казахстан по антимонопольной политике совместно с Министерством науки и новых технологий, Министерством геологии и охраны недр, Министерством энергетики и топливных ресурсов, Министерством экономики

Республики Казахстан, главами Карагандинской, Павлодарской и Семипалатинской областных администраций в двухмесячный срок разработать и представить на рассмотрение Кабинета Министров Республики Казахстан предложения о передаче в установленном порядке Ядерному центру разработки месторождений полезных ископаемых, расположенных на территории бывшего Семипалатинского ядерного полигона, и создании акционерной компании для осуществления крупномасштабной промышленно-финансовой деятельности, направленной на развитие атомной энергетики и социально-экономической реабилитации региона.

9. Возложить на Генеральную дирекцию Национального ядерного центра функции генерального заказчика по развитию производственной и жилой зоны в г.Курчатове и пос.Алатау Фрунзенского района г. Алма-Аты.

10. Установить, что сотрудникам Ядерного центра, проработавшим в г.Курчатове более 10 лет, а также военнослужащим, уволенным в запас, и желающим выехать на постоянное место жительство в другие города и населенные пункты Республики Казахстан, участки для индивидуального строительства предоставляются главами местных администраций в первоочередном порядке.

Рекомендовать Национальному государственному банку Республики Казахстан, начиная с 1993 года, выделение льготного кредита для индивидуального строительства или приобретения жилья в сумме 100 млн.рублей.

11. Министерству экономики, Министерству финансов Республики Казахстан предусматривать, начиная с 1993 года, выделение необходимых средств, а главам областных администраций Республики Казахстан обеспечить в установленном порядке строительство жилья для сотрудников Ядерного центра.

12. Государственному комитету по архитектуре и строительству Республики Казахстан, Генеральной дирекции Ядерного центра по согласованию с местной администрацией разработать и утвердить в Кабинете Министров Республики Казахстан генеральные планы застройки г.Курчатова и пос.Алатау с учетом развития их как центров международного сотрудничества в области мирного использования атомной энергии.

5.

13. Рекомендовать Комитету национальной безопасности Республики Казахстан совместно с Министерством обороны, Министерством внутренних дел Республики Казахстан, Генеральной дирекцией Ядерного центра, Главой Семипалатинской областной администрации разработать и внести в месячный срок в Кабинет Министров Республики Казахстан предложения о снятии режимности жилой зоны г.Курчатова и обеспечению государственных и коммерческих секретов промышленных зон.

14. В целях укомплектования Ядерного центра высококвалифицированными специалистами различного профиля Министерству образования, Министерству науки и новых технологий, Министерству финансов, Министерству экономики Республики Казахстан, Ядерному центру совместно с Академией наук Республики Казахстан в двухмесячный срок рассмотреть и внести предложение в Кабинет Министров Республики Казахстан об организации в составе Ядерного центра Казахского инженерно-физического института.

15. Ядерному центру совместно с Агентством по атомной энергии, Министерством науки и новых технологий, Министерством обороны, Министерством экологии и биоресурсов, Академией наук Республики Казахстан, другими заинтересованными министерствами и ведомствами республики в двухмесячный срок разработать и представить в Кабинет Министров Республики Казахстан:

проект положения о Ядерном центре Республики Казахстан;

предложения по организации технополисов, в том числе со статусом свободных экономических зон на базе г.Курчатова и поселка Актау Алма-Атинской области.

16. Ядерному центру совместно с Министерством обороны Республики Казахстан и Государственным комитетом Республики Казахстан по земельным отношениям и землеустройству по согласованию с главами Семипалатинской, Павлодарской и Карагандинской областных администраций в двухмесячный срок разработать и внести на рассмотрение в Верховный Совет Республики Казахстан предложения по определению на территории бывшего Семипалатинского полигона границ г.Курчатова и прилегающих к нему территорий, связанных с деятельностью Ядерного центра, в соответствии с проектом межхозяйственного землеустройства, включив в черту города земли с жилой и техническими зонами, межобъектовых коммуникаций связи и систем жизнеобеспечения, охранных и санитарных зон, а также о статусе города Курчатова.

6.

I7. Министерству здравоохранения Республики Казахстан совместно с Министерством обороны, Министерством науки и новых технологий, Министерством экономики, Министерством финансов Республики Казахстан, Ядерным центром, главой Семипалатинской областной администрации в двухмесячный срок рассмотреть и внести в Кабинет Министров Республики Казахстан предложение об образовании Регионального лечебно-диагностического центра на базе Медико-санитарной части I67 Министерства здравоохранения Республики Казахстан и военного госпиталя войсковой части 52605 в составе Ядерного центра.

I8. Установить Ядерному центру лимит служебных легковых автомобилей в количестве 2 единиц.

I9. Министерству связи Республики Казахстан по прямым договорам обеспечить Ядерный центр необходимой телефонной, телеграфной и телексной связью.

20. Республиканскому валютному комитету предусматривать необходимые валютные средства для осуществления международного сотрудничества по вопросам, относящимся к компетенции Ядерного центра.

Премьер-министр
Республики Казахстан

С. Терещенко

RESOLUTION OF THE
CABINET OF MINISTERS
OF THE REPUBLIC OF
KAZAKHSTAN
21 January 1993
No. 55

On providing for the activity of the National Nuclear Centre of the Republic of Kazakhstan

In execution of Decree No. 779 of the President of the Republic of Kazakhstan dated 15 May 1992 *On the National Nuclear Centre and Atomic Energy Agency of the Republic of Kazakhstan*, the Cabinet of Ministers of the Republic of Kazakhstan hereby resolves:

1. To establish that the National Nuclear Centre of the Republic of Kazakhstan (hereafter, the Nuclear Centre) is a standalone republican institution, forming part of the Academy of Science of the Republic of Kazakhstan, which manages and coordinates its scientific work.

The Nuclear Centre operates pursuant to the laws of the Republic of Kazakhstan and according to Provision on the Centre, approved by the Cabinet of Ministers of the Republic of Kazakhstan.

The Nuclear Centre holds its own balance sheet and current account, its own seal, bearing the State Emblem of the Republic of Kazakhstan and with its name detailed in Kazakh and Russian.

The management of the Nuclear Centre shall perform the general running of the Centre, headed by the Centre's Chief Executive Officer, appointed by the Cabinet of Ministers of the Republic of Kazakhstan.

To determine that the management of the Nuclear Centre shall run operations, headed by the Centre's Chief Executive Officer, in the city of Kurchatov, Semipalatinsk Region.

2. To entrust the Nuclear Centre with the following:

- the functions of a lead organisation in atomic science and technology within the Republic of Kazakhstan;
- work on radiation security and ecology;
- the study and liquidation of the consequences of nuclear blasts and radiation contamination to the environment as a result of industrial activity within the republic;
- research of the problems and elaboration of technologies to recycle, store and bury radioactive waste;
- enhance the reliability of nuclear energy installations and study the problems of atomic energy security;
- development and practical implementation of nuclear-physics methods and nuclear technologies in the interests of science and the national economy of the Republic of Kazakhstan;
- monitor the testing of nuclear weapons and unauthorised nuclear blasts at the test sites of other countries;
- perform basic and applied research in nuclear physics and atomic energy;
- train and further the qualification of personnel working in atomic science and industry;
- increase the level of knowledge of the republic's population as regards the use of atomic energy for peaceful ends;
- information and publishing activity;
- international and inter-republican collaboration in the use of atomic energy;

3. Include the following into the composition of the Nuclear Centre:

- a joint expedition of NPO Luch of the Ministry of Science and New Technologies of the Republic of Kazakhstan;
- the Institute of Nuclear Physics of the Academy of Sciences of the Republic of Kazakhstan;
- the enterprise Baikal of the Ministry of Industry of the Republic of Kazakhstan;
- the Borovoye geophysical observatory;

- the geophysical party No. 35 of the Ministry of Geology and Subsoil Security of the Republic of Kazakhstan.

To recommend that the State Committee of the Republic of Kazakhstan for State Property delegates ownership, usage and management rights to the Nuclear Centre as regards the property of organisations and institutions that have become part of the Centre.

4. To establish that the Nuclear Centre implements scientific management of the BN-350 reactor divisions at the Mangyshklyak Energy Plant and other nuclear-based research divisions in the Republic of Kazakhstan, as part of performance of the public atomic energy programme, regardless of their departmental affiliation.

5. To deem it expedient to create a research complex for defence programmes, under the auspices of Military Unit 52605, including it within the composition of the Nuclear Centre.

The Ministry of Defence, the Ministry of Science and New Technologies of the Republic of Kazakhstan, in cooperation with stakeholder organisations, shall address the status of Military Unit 52605, based on execution of the corresponding agreement between the Republic of Kazakhstan and the Russian Federation.

6. To apply salary conditions, as established for similar positions within the system of the Academy of Science of the Republic of Kazakhstan, to management and scientific staff of research institutions of the Nuclear Centre.

Retain tariff rates and salaries for positions, effective as of 1 January 1993 for all other staff of the Nuclear Centre of the Republic of Kazakhstan.

Within one month, the Ministry of Employment and the Ministry of Finance of the Republic of Kazakhstan, in collaboration with the Nuclear Centre and the Ministry of Science and New Technologies of the Republic of Kazakhstan, shall elaborate and submit to the Cabinet of Ministers of the Republic of Kazakhstan for approval their proposals on additional benefits, meaning the establishment of a differentiated industry coefficient and salary and rate supplements for different categories of Centre staff, allowing for special employment conditions and the frequent travel that such work entails.

7. Establish that the Nuclear Centre shall be financed from the state budget, investment from foreign partners, international funds and own funds, generated from the sale of the Centre's own developments.

The Ministry of Science and New Technologies shall, from 1993, provide for the targeted financing of the Nuclear Centre using funds, stipulated under the budget for the financing of science, in the quantity needed for implementing the state's science and technology programme for the atomic energy industry.

8. Instruct the State Antimonopoly Policy Committee of the Republic of Kazakhstan to work with the Ministry of Science and New Technologies, the Ministry of Geology and Subsoil Security, the Ministry of Energy and Fuel, the Ministry of the Economy of the Republic of Kazakhstan, the heads of the Karaganda, Pavlodar and Semipalatinsk regional administrations, to elaborate and present for the consideration of the Cabinet of Ministers of the Republic of Kazakhstan, within a two-month period, proposals pertaining to the due and proper handover to the Nuclear Centre of mineral mine workings within the former Semipalatinsk Nuclear Test Site and the creation of a large-scale, joint-stock, industrial and financial company to develop the atomic energy industry and the socioeconomic rehabilitation of the region.

9. To entrust the General Directorate of the National Nuclear Centre with the functions of key client in development of an industrial and residential zone in Kurchatov and the settlement of Alatau of the Frunzensky District of Alma-Ata.

10. To establish that the heads of local administrations shall grant as a priority plots of land for the construction of individual housing to the staff of the Nuclear Centre who have worked in Kurchatov for more than ten years, military service personnel, transferred to the reserve, and also those so wishing to move permanently to other towns and cities of the Republic of Kazakhstan.

To recommend that, from 1993, the National State Bank of the Republic of Kazakhstan grants favourable lending terms for individual housing construction or the purchase of residential housing in the amount of 100 million roubles.

11. Starting from 1993, the Ministry of the Economy and the Ministry of Finance of the Republic of Kazakhstan shall stipulate the allocation of the necessary funds, while the heads of the regional administrations of the Republic of Kazakhstan shall provide, in the due and proper manner, for the construction of residential housing for staff of the Nuclear Centre.

12. The State Architecture and Building Committee of the Republic of Kazakhstan and the General Directorate of the Nuclear Centre, in agreement with the local administration, shall elaborate and gain approval from the Cabinet of Ministers of the Republic of Kazakhstan for general development plans for the city of Kurchatov and the settlement of Alatau, allowing for their development as centres of international collaboration, pertaining to the peaceful use of atomic energy.

13. To recommend to the National Security Committee of the Republic of Kazakhstan to work with the Ministry of Defence, the Ministry of Internal Affairs of the Republic of Kazakhstan, the General Directorate of the Nuclear Centre and the Head of the Semipalatinsk Regional Administration to elaborate and submit proposals within a one-month period to the Cabinet of Ministers of the Republic of Kazakhstan, pertaining to removal of restrictions on the residential area of Kurchatov and the safeguarding of state and commercial secrets of industrial areas.

14. In order to supply the Nuclear Centre with highly qualified specialists of various fields, the Kazakh Ministry of Education, the Ministry of Science and New Technologies, the Ministry of Finance, the Ministry of the Economy and the Nuclear Centre shall work with the Academy of Science of the Republic of Kazakhstan and, within two months, shall submit a proposal to the Cabinet of Ministers of the Republic of Kazakhstan regarding the organisation of the Kazakh Engineering and Physics Institute as part of the Nuclear Centre.

15. The Nuclear Centre shall work with the Atomic Energy Agency, the Ministry of Science and New Technologies, the Ministry of Defence, the Ministry of the Environment and Bioresources, the Academy of Science of the Republic of Kazakhstan and other stakeholder ministries and departments in the republic within a two-month period to draw up and submit the following to the Cabinet of Ministers of the Republic of Kazakhstan:

- a draft provision on the Nuclear Centre of the Republic of Kazakhstan;
- proposals pertaining to the organisation of technopolises, including those with the status of free economic zones, based in the city of Kurchatov and the settlement of Alatau in the Alma-Ata Region.

16. Within a two-month period, together with the Ministry of Defence of the Republic of Kazakhstan and the Kazakh State Committee for Land Relations and Land Tenure, the Nuclear Centre, in agreement with the heads of the Semipalatinsk, Pavlodar and Karaganda regional administrations, shall draw up and submit for consideration to the Supreme Soviet of the Republic of Kazakhstan proposals pertaining to determination of the borders of Kurchatov and adjoining territory within the former Semipalatinsk Test Site, associated with the operations of the Nuclear Centre, pursuant to a project for inter-farm land tenure, by including land in the city limits with both residential and technical zones, intersite communications and life support systems, security and buffer zones, and also proposals on the status of the city of Kurchatov.

17. Within a two-month period, the Ministry of Health of the Republic of Kazakhstan, together with the Ministry of Defence, the Ministry of Science and New Technologies, the Ministry of the Economy, the Ministry of Finance, the Nuclear Centre and the head of the Semipalatinsk Regional Administration, shall consider and submit a proposal to the Cabinet of Ministers of the Republic of Kazakhstan about the formation of the Regional Treatment and Diagnostics Centre based at Medical Department 167 of the Ministry of Health of the Republic of Kazakhstan and the military hospital of Military Unit 52605 as part of the Nuclear Centre.

18. To set the Nuclear Centre a limit of two (2) official passenger cars.

19. The Ministry of Communication of the Republic of Kazakhstan shall furnish the Nuclear Centre with the necessary telephone, telegraph and telex communications under direct contracts.
20. The Republican Currency Committee shall make provision for the requisite funds in currency for international collaboration on matters falling under the remit of the Nuclear Centre.

S. Tereshchenko
Prime Minister of the Republic of Kazakhstan

КАЗАКСТАН
РЕСПУБЛИКАСЫ
МИНИСТРЛЕР КАБИНЕТIНIН
КАУЛЫСЫ

ПОСТАНОВЛЕНИЕ
КАБИНЕТА МИНИСТРОВ
РЕСПУБЛИКИ
КАЗАХСТАН

29 октября 1993 года
№ 1082

Об организации институтов в составе Национального ядерного центра Республики Казахстан

Кабинет Министров Республики Казахстан ПОСТАНОВЛЯЕТ:

1. Принять предложения Национального ядерного центра Республики Казахстан, согласованные с Национальной академией наук, Министерством науки и новых технологий, Министерством экономики и Министерством финансов Республики Казахстан, об организации в составе Центра следующих институтов:

Института атомной энергии в г.Курчатове Семипалатинской области на базе Объединенной экспедиции ШПС "Луч", предприятия "Байкал", соответствующих лабораторий и отделов Института ядерной физики Национального ядерного центра Республики Казахстан;

Института геофизических исследований в п.Боровое Кокчетавской области на базе геофизической обсерватории "Боровое" и геофизической партии № 35 ~~Национального ядерного центра Республики Казахстан~~;

Института радиационной безопасности и экологии в г.Курчатове Семипалатинской области на базе радиоэкологических подразделений Национального ядерного центра Республики Казахстан с последующим включением в состав организованного института научного сектора войсковой части № 52605.

Организацию указанных институтов провести в пределах финансовых и материально-технических ресурсов, штатной численности и других нормативов, установленных Национальному ядерному центру Республики Казахстан на 1993 год.

2. Согласиться с предложениями Национального ядерного центра Республики Казахстан, согласованными с Национальной академией

3

наук и Министерством науки и новых технологий Республики Казахстан, об установлении следующих основных направлений научной деятельности созданных институтов:

по Институту атомной энергии:

концепции и программы развития атомной энергетики в Республике Казахстан;

безопасность атомной энергетики;

космические ядерно-энергетические установки;

радиационная физика твердого тела и реакторное материаловедение;

по Институту геофизических исследований:

контроль за испытаниями ядерного оружия;

геофизические методы изучения и мониторинга геологических структур бывших ядерных полигонов;

определение площадок для строительства атомных теплоэлектростанций, пунктов хранения и захоронения радиоактивных отходов;

регистрация и прогноз землетрясений;

по Институту радиационной безопасности и экологии:

медико-биологические аспекты радиационных воздействий;

радиоэкология и радиационный мониторинг регионов проведения ядерных испытаний и мест расположения радиационно опасных объектов;

состояние и консервация подземных полостей, образованных в результате ядерных испытаний;

рекультивация радиационно-загрязненных территорий;

системы сбора, транспортировки, хранения, захоронения и переработки радиоактивных отходов.

Премьер-министр
Республики Казахстан | С. Терещенко

RESOLUTION OF THE
CABINET OF MINISTERS
OF THE REPUBLIC OF
KAZAKHSTAN
29 October 1993
No. 1082

On organisation of institutions forming part of the National Nuclear Centre of the Republic of Kazakhstan

The Cabinet of Ministers of the Republic of Kazakhstan HEREBY RESOLVES:

1. To accept the proposals of the National Nuclear Centre of the Republic of Kazakhstan, as agreed with the National Academy of Science, the Ministry of Science and New Technologies, the Ministry of the Economy and the Ministry of Finance of Republic of Kazakhstan on the organisation of the following institutes as part of the Centre:

- the Atomic Energy Institute in Kurchatov, Semipalatinsk Region, under the auspices of the NPO Luch United Expedition, the enterprise Baikal and the corresponding laboratories and divisions of the Institute of Nuclear Physics of the National Nuclear Centre of the Republic of Kazakhstan;
- the Geophysical Research Institute in the village of Borovoe, Kokshetau Region, based at the Borovoe Geophysical Observatory in Geophysical Crew No. 35 of the National Nuclear Centre of the Republic of Kazakhstan;
- the Radiation Safety and Ecology Institute in Kurchatov, Semipalatinsk Region, based at the radioecological divisions of the National Nuclear Centre of the Republic of Kazakhstan with subsequent inclusion as part of the organised institute of the scientific sector of Military Unit 52605.

These institutes are to be organised using available financial, material and technical resources, the current staff list and the standards, established for the National Nuclear Centre of the Republic of Kazakhstan for 1993.

2. To agree with the proposals of the National Nuclear Centre of the Republic of Kazakhstan, as approved by the National Academy of Science and the Ministry of Science and New Technologies of the Republic of Kazakhstan on the setting of the following key directions for the scientific activity of the created institutes:

- for the Atomic Energy Institute:
  - concepts and programmes for development of the atomic energy industry in the Republic of Kazakhstan;
  - safety and security of the atomic energy industry;
  - space installations using nuclear energy;
  - solid state radiation physics and reactor materials studies;
- for the Geophysical Research Institute:
  - monitoring of nuclear weapons tests;
  - geophysical methods for studying and monitoring geological structures of former nuclear test sites;
  - specification of areas for building atomic heat and power plants and radioactive waste storage and burial sites;
  - recording and predicting earthquakes;
- for the Radiation Safety and Ecology Institute:
  - medical and biological aspects pertaining to radiation effects;
  - radioecology and radiation monitoring of the regions where nuclear tests are performed and of radiation-hazardous sites;

- the state and abandonment of underground cavities that formed following nuclear tests;
- reclamation of areas, contaminated with radiation;
- a system for collecting, transporting, storing, burying and processing radioactive waste.

S. Tereshchenko
Prime Minister of the Republic of Kazakhstan

03-11-93 06:34 FROM:Kazakhstan Atomic Energy Agency ID: 3272 633356 Б.01

АТОМ ЭНЕРГИЯСЫ
ЖӘНІНДЕГІ АГЕНТТІГІ

ПО АТОМНОЙ ЭНЕРГИИ
РЕСПУБЛИКИ КАЗАХСТАН

480013, Алматы қ., Республика алаңы,13
Телефондары 63-48-85, 63-73-74
Телетайп 251179 ИНФОР
Факстар (3272) 63-48-85, 63 33 56

480013, г. Алматы, Площадь Республики, 13
Телефоны: 63-48-85, 63-73-74
Телетайп: 251179 ИНФОР
Факсы: (3272) 63 48 85, 63 33-56

№ 650-21/7

199__ жылғы ______________
1 ноября 1993 года

Директору ИБФ
тов. Ильину Л.А.

Прошу командировать
в г. Курчатов
тов. Логачева В.А.
для пользы дела

04.11.93

03.11.93

МИНИСТРУ АЭ
РОССИИ
МИХАЙЛОВУ В. Н.

FAX (095) 2302420

Копия: ВНИИЭФ
ТРУТНЕВУ Ю. А.
FAX 54585

УВАЖАЕМЫЙ ВИКТОР НИКИТОВИЧ!

9 НОЯБРЯ 1993 г. В г. КУРЧАТОВЕ НАМЕЧЕНО ПРИБЫТИЕ ГРУППЫ ЭКСПЕРТОВ США ПОД РУКОВОДСТВОМ ДР. ДОНА ЛИНГЕР., С ЦЕЛЬЮ ИЗУЧЕНИЯ И АТТЕСТАЦИИ ПОСЛЕДСТВИЙ ПРОВЕДЕНИЯ ЯДЕРНЫХ ИСПЫТАНИЙ НА СЕМИПАЛАТИНСКОМ ПОЛИГОНЕ.

ДЛЯ УЧАСТИЯ В ПЕРЕГОВОРАХ ПРОСИМ ВАС НАПРАВИТЬ ГРУППУ ЭКСПЕРТОВ ОТ МАЭ В СОСТАВЕ:

ЧЕРНЫШЕВА А. К.; ДУБАСОВА Ю. В.; МАТУЩЕНКО А. М.; ЛОГАЧЕВА В. А. ГУДИНА Ф. М.; РУБАШКИНА В. Н.; ГОРИНА В. В.

ГЕНЕРАЛЬНЫЙ ДИРЕКТОР В. ШКОЛЬНИК

Матущенко
04.11.93г.

03.11.93

Возглавляет делегацию от России
поручено академику Трутневу Ю.А.

Вх. зарег. 1
5-2705

Kazakhstan Atomic Energy Agency

1 November 1993

[handwriting: *Attn: L.A. Ilyin, Director of Biological Physics Institute, Please send V.A. Logachev to Kurchatov to assist in matters*]

To: V.N. MIKHAILOV
MINISTER OF ATOMIC ENERGY
OF RUSSIA

FAX: (095) 2302420

CC. Yu.A. TRUTNEV
VNIIEF
FAX 54565

DEAR VIKTOR NIKITOVICH [MR MIKHAILOV],

ON 9 NOVEMBER 1993, THE ARRIVAL OF A GROUP OF EXPERTS IS PLANNED IN KURCHATOV, HEADED BY DR. DON LINGER, THE AIM OF WHICH IS TO STUDY AND CERTIFY THE CONSEQUENCES OF NUCLEAR TESTS AT THE SEMIPALATINSK TEST SITE.
PLEASE ARRANGE FOR A GROUP OF EXPERTS TO TAKE PART IN TALKS FROM THE MAE, TO INCLUDE THE FOLLOWING:
A.K. CHERNYSHEV, Yu.V. DUBASOV, A.M. MATUSHCHENKO, V.A. LOGACHEV, F.M. GUDIN, V.N. RUBASHKIN AND V.V. GORIN.

V. SHKOLNIK
CHIEF EXECUTIVE

[handwriting: *Signed by Matushchenko on 4 November 1993. Academician Yu.A. Trutnev to head the delegation from Russia*]

…СТАН РЕСПУБЛИКАСЫНЫН

ПРЕЗИДЕНТІ

ПРЕЗИДЕНТ

РЕСПУБЛИКИ КАЗАХСТАН

от ... декабря ...9...

№ ...-770

Президенту
Российской Федерации
Ельцину Б.Н.

Глубокоуважаемый Борис Николаевич !

Семипалатинский испытательный ядерный полигон в течение 40 лет использовался для проведения исследований и совершенствования ядерного оружия в Советском Союзе. В результате испытаний был нанесен серьезный ущерб здоровью людей и окружающей природной среде.

На территории Семипалатинского полигона было произведено около 500 ядерных взрывов (87 воздушных, 26 наземных и 360 подземных). Образовалось около 12 млн. тонн радиоактивных отходов общей активностью порядка 13 млн. кюри.

В этой связи проблемы изучения состояния природной среды в районах проведения ядерных испытаний, ликвидация последствий и оказание помощи пострадавшему населению, по нашему мнению, являются общей ответственностью всех стран бывшего СССР, в первую очередь, Российской Федерации и Республики Казахстан и должны решаться в рамках вывода ядерного оружия с территории Казахстана и передачи его в ведение Российской Федерации.

Ликвидация последствий ядерных испытаний и проведение конверсии Семипалатинского полигона позволит кроме того использовать в интересах двух наших стран значительный научно-технический потенциал, созданный на полигоне и вокруг него. Исследования проблем безопасности в атомной энергетике, разработка эффективных методов захоронения радиоактивных отходов могут получить существенное развитие в результате конверсии и расширения возмож-

Пр-1858

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ностей существующих научно-технических и производственных объектов полигона.

В связи с этим полагаю необходимым рассмотреть и принять специальную Программу ликвидации последствий испытаний ядерного оружия на Семипалатинском полигоне с определением конкретного участия в ней Российской Федерации и Республики Казахстан. Наличие такой Программы позволит также привлечь для ее выполнения финансовые средства других стран и международных организаций, проявляющих большую заинтересованность в судьбе бывшего Семипалатинского ядерного полигона и населения, оказавшегося помимо своей воли, в зоне радиоактивного заражения.

Надеюсь, Борис Николаевич, на Ваше понимание этой сложной общечеловеческой проблемы и уверен в Вашей полной поддержке.

С уважением

Н. Назарбаев

PRESIDENT
OF THE REPUBLIC OF KAZAKHSTAN

Attn. B.N. Yeltsin
President
of the Russian Federation

Dear Boris Nikolayevich [Mr Yeltsin],

The Semipalatinsk Nuclear Test Site was used over a period of 40 years to research and perfect nuclear weapons in the Soviet Union. The tests performed caused serious damage to the health of the population and the surrounding natural environment.

About 500 nuclear blasts were detonated at the Semipalatinsk Test Site (87 atmospheric, 26 land-based and 360 underground). About 12 million tonnes of radioactive waste was formed with a total activity of some 13 million curies.

We therefore believe that the problems of studying the state of the natural environment in the areas where the nuclear tests were performed, liquidating the consequences and rendering assistance to the affected population is the common responsibility of all countries of the former USSR and primarily of the Russian Federation and Kazakhstan and that these issues should be addressed as part of the removal of nuclear weapons from Kazakhstan and their repatriation to the Russian Federation.

Liquidating the consequences of nuclear tests and the conversion of the Semipalatinsk Test Site will also help use the considerable scientific and technical potential, created at and around the test site in the interests of both our countries. Research of security issues in the atomic energy industry and the design of effective methods of burying radioactive waste may see extensive development as a result of the conversion and the expansion of the capabilities of the existing scientific, technical and industrial facilities of the test site.

In this regard I believe it essential to consider and adopt a special Programme for Liquidating the Consequences of Nuclear Weapons Tests at the Semipalatinsk Test Site, specifying the particular involvement therein of the Russian Federation and the Republic of Kazakhstan. Having such a programme will also help attract finance for its implementation from other countries and international organisations who express a considerable interest in the fate of the former Semipalatinsk Nuclear Test Site and the population who, against their will, found themselves in the zone of radioactive contamination.

Dear Boris Nikolayevich, I hope for your understanding in this complex, human problem and I am confident of your complete support.

Yours sincerely,
N. Nazarbayev

Министру Российской Федерации
по делам гражданской обороны,
чрезвычайным ситуациям и ликвидации последствий стихийных бедствий

С.К.Шойгу

30.12.1994г. N01-8096

О Соглашении между Российской Федерацией и Республикой Казахстан по вопросам Семипалатинского полигона

Уважаемый Сергей Кужугетович!

I. Поручениями Правительства Российской Федерации от 13.04.94 № ВЧ-П8-09805 и от 11.08.94 № ВЧ-П8-25000 определено, что Минатом России совместно с Минобороны России, Минфином России и другими привлеченными и заинтересованными министерствами и ведомствами должны доработать и представить для подписания проект Соглашения о ликвидации последствий испытаний ядерного оружия на Семипалатинском полигоне и других ядерных взрывов на территории Республики Казахстан. Это предусмотрено Меморандумом по итогам встречи в г.Алма 25.12.93 Председателя Правительства Российской Федерации В.С.Черномырдина и Премьер-министра Республики Казахстан С.А.Терещенко и Протоколом встречи Глав Правительства Российской Федерации и Республики Казахстан от 28.03.94.

В Минатоме России на основе предложений Российской и Казахстанской Сторон с участием Ваших полномочных представителей Л.И.Анисимовой и С.А.Бублия в результате длительных и сложных переговоров разработан вариант проекта Соглашения, который направлен на рассмотрение (прилагается по состоянию на 19.12.94, в порядке информации) В данном варианте проекта Соглашения позиция МЧС России (исх.№ 22-2270-37 от 28.09.94, В.Я.Возняк) учтена.

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Основным механизмом обеспечения реализации Соглашения является назначение исполнительными органами Сторон Координационной группы из компетентных экспертов, ответственных за конкретные направления (статья 3 Соглашения).

Прошу Вашего решения о назначении в состав формируемой Координационной группы Ваших представителей - ведущих специалистов по вопросам, отраженным в статьях I-6 проекта Соглашения, а также Ваших указаний о подготовке соответствующих предложений по данным вопросам.

2. Одновременно сообщаю, что Минатом России очень озабочен ситуацией, складывающейся по проблеме Соглашения в контексте Закона Республики Казахстан от I8.I2.92 "О социальной защите граждан, пострадавших вследствие ядерных испытаний на Семипалатинском испытательном ядерном полигоне" и Указа Президента Российской Федерации от 20.I2.93 № 2228 "О социальной защите граждан, подвергшихся радиационному воздействию вследствие ядерных испытаний на Семипалатинском полигоне" с развивающим его постановлением Правительства Российской Федерации от I7.II.94 № I263 "О порядке предоставления компенсаций и льгот гражданам Российской Федерации, проживающим в I949-I963 годах за пределами Российской Федерации и подвергшимся радиационному воздействию вследствие ядерных испытаний на Семипалатинском полигоне". В соответствии с этим постановлением МЧС России совместно с Минобороны России, Минздравмедпромом России и Госкомсанэпидемнадзором России предписано выполнить ретроспективные оценки радиационной обстановки на территории бывшей Казахской ССР с целью определения перечня населенных пунктов этой республики, подвергшихся в I949-I963 годах радиационному воздействию от ядерных испытаний на Семипалатинском полигоне. В этом отношении наша озабоченность обуславливается различными подходами в законодательных актах двух республик к механизму гарантий соответствующих компенсаций и льгот населению, подвергшемуся на территории Казахстана радиационному воздействию, а также тем, что в Республике Казахстан осуществляется достаточно активная работа по выдаче удостоверений, подтверждающих право на льготы, пострадавшему вследствие ядерных испытаний на Семипалатинском испытательном полигоне (его образец прилагается в порядке информации), которые уже предоставлены около двум миллионам граждан, в том числе проживающим и на территории Российской Федерации. Игнорировать это

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обстоятельство нельзя. В этой связи требуется разработка в рамках Соглашения единого научного подхода к оценке радиационной обстановки на территории Республики Казахстан с целью определения влияния проведенных ядерных взрывов на состояние здоровья населения и реализации мер по оздоровлению людей, с учетом результатов медицинских обследований населения в 50-60 годы, что, несомненно, является прерогативой Минздравмедпрома России.

В этом плане, исходя из важности проблемы, предлагается выполнить опережающим порядком в обеспечение реализации Соглашения целевую НИР "Оценка радиационной обстановки на территории бывшей Казахской ССР вследствие ядерных испытаний на Семипалатинском полигоне и определение степени ее влияния на население", поручив ее Институту биофизики Минздравмедпрома России на базе лаборатории профессора В.А.Логачева, подготовленной, по нашему мнению, к соответствующим экспертным исследованиям на основе архивных материалов, содержащих данные радиационных разведок на территории Республики Казахстан и результаты комплексных медицинских обследований населения этой республики, что является сферой компетенции Минздравмедпрома России. При этом следует считать принципиально важным осуществление долевого участия в финансировании данной НИР (по согласованию), с тем, чтобы при последующих взаимоотношениях с Казахстанской Стороной Российская Сторона именно в лице наших ведомств могла объективно отмечать свой реальный вклад в решение задачи обеспечения выполнения обязательств по Соглашению. Это необходимо и с точки зрения оптимизации расходов со стороны Российской Федерации.

Проект соответствующего Технического задания на НИР может быть представлен от ИБФ Минздравмедпрома России (отв.профессор В.А.Логачев).

Прошу Вашего решения

В.Н.Михайлов

To: S.K. Shoigu
Russian Federation Minister for Civil Defence, Emergency Situations and Natural Disaster Recovery

30 December 1994 No. 01-3096
On the Agreement between the Russian Federation and the Republic of Kazakhstan on the Semipalatinsk Test Site

Dear Sergey Kuzhugetovich [Mr Shoigu],

1. Under Russian Federation Directives No. VCh-P8-09805 dated 13 April 1994 and No. VCh-P8-25000 dated 11 August 1994, it is hereby ruled that Minatom of Russia, in collaboration with the Russian Ministry of Defence, the Russian Ministry of Finance and other engaged or interested ministries and departments, shall refine and present for signature a draft Agreement on Liquidation of the Consequences of Nuclear Weapons Tests at the Semipalatinsk Test Site and other Nuclear Blasts in the Republic of Kazakhstan. This is stipulated in a Memorandum following the meeting in Almaty on 25 December 1993 of the Chairman of the Russian Federation Government V.S. Chernomyrdin and Prime Minister of the Republic of Kazakhstan S.A. Tereshchenko and in the Minutes of the meeting between the heads of government of the Russian Federation and the Republic of Kazakhstan on 28 March 1994.
Based on the proposals of the Russian and Kazakh sides, with the involvement of your plenipotentiary representatives L.I. Anisimova and S.A. Bubliy, following long and difficult negotiations, a draft Agreement has been elaborated at Minatom of Russia, which has been sent for consideration (attached as of 19 December 1994 for information purposes). This version of the draft Agreement takes into account the stance of the Russian Ministry for Civil Defence, Emergency Situations and Natural Disaster Recovery (your ref. No. 22-2270-37 dated 28 September 1994, V.Ya. Voznyak).
The main mechanism for facilitating implementation of the Agreement is the appointment by the executive agencies of the Parties of a Steering Group of competent specialists, who shall be responsible for specific aspects of the work (Article 3 of the Agreement).
I request that you appoint your representatives to sit on this Steering Group from among leading specialists in matters, reflected in articles 1 to 6 of the draft Agreement, and also your instructions on preparation of the corresponding proposals on these matters.
2. I would also like to inform you that Minatom of Russia is very concerned with the situation surrounding the Agreement in the context of the Law of the Republic of Kazakhstan dated 18 December 1992 *On social protection for citizens who have suffered from nuclear tests at the Semipalatinsk Nuclear Test Site* and Russian Federation Presidential Decree No. 2228 of 20 December 1993 *On social protection for citizens, affected by radiation as a consequence of nuclear tests at the Semipalatinsk Test Site* with expounding Resolution No. 1263 of 17 November 1994 *On the procedure for providing compensation and benefits to citizens of the Russian Federation, living between 1949 and 1963 outside the Russian Federation and who were subjected to the effects of radiation following nuclear tests at the Semipalatinsk Test Site.* In accordance with this Resolution, the Russian Ministry for Civil Defence, Emergency Situations and Natural Disaster Recovery, the Russian Ministry of Defence, the Russian Ministry of Health and the Medical Industry and the Russian State Committee for Sanitary and Epidemic Supervision are instructed to perform retrospective assessments of the radiation situation within the former Kazakh Soviet Socialist Republic, in order to determine the list of population centres in this republic which, between 1949 and 1963, were affected by radiation from nuclear tests at the Semipalatinsk Test Site. In this respect, our concern stems from there being a number of approaches in the legislative enactments of the two countries to the mechanism for

guaranteeing the corresponding compensation and benefits to the public subjected to the effects of radiation within the Republic of Kazakhstan and also from the fact that reasonably active work is performed in the Republic of Kazakhstan as regards the issue of certificates, confirming the right to benefits for people affected by the nuclear tests at the Semipalatinsk Test Site (a specimen is attached for information purposes), which have already been awarded to about two million citizens, including those residing within the Russian Federation. This is something that cannot be ignored. Therefore, as part of the Agreement, a unified scientific approach needs to be developed to assess the radiation situation in the Republic of Kazakhstan, to determine the impact of the nuclear blasts on the health of the population and to implement measures to improve public health, given the results of medical surveys of the population in their 50s and 60s which, without doubt, is the prerogative of the Russian Ministry of Health and the Medical Industry.

In this respect, given the importance of the problem, it is proposed, as a matter of urgency, so as to execute the Agreement, to fulfil the targeted *Assessment of the radiation situation in the former Kazakh Soviet Socialist Republic as a consequence of nuclear tests at the Semipalatinsk Test Site and determination of the degree of its impact on the population,* by entrusting it to the Biophysics Institute of the Russian Ministry of Health and the Medical Industry, based at the laboratory of Professor V.A. Logachev, prepared what we believe to be in accordance with expert research as per archive materials, containing data on radiation surveillance within the Republic of Kazakhstan and the results of comprehensive medical surveys of the republic's population, which is the remit of the Russian Ministry of Health and the Medical Industry. Here, the participatory interest in the financing of this research (under agreement) should be seen as fundamentally important, so that in subsequent relations with the Kazakh Party, the Russian Party, represented specifically by our departments, could objectively register its actual contribution to performance of obligations under the Agreement. This is also essential from the point of view of optimising expenditure on the part of the Russian Federation.

The draft of the corresponding requirements specification for the research may be submitted from the Biophysics Institute of the Russian Ministry of Health and the Medical Industry (leading professor V.A. Logachev).

I request your decision on this matter.

V.N. Mikhailov

White Paper
On
Kazakhstan NNC Radiation Materials Issue

Introduction

During the CTR and Seismic Calibration efforts at the Republic of Korea/NNC, several issues were identified which raised concern about the potential availability of radioactive material for terrorist activities. The openness of the Semi Palatinsk Test Site, the activities of local citizens at the test site salvaging material for resale, makes the issue of theft of radiation material very important.

Issues

Three issues have been identified at the Semi Palatinsk Test Site:

Issue 1. The availability of the large explosion containment containers referred to as KOLBA's which were used for fully contained hydronuclear, HPEOS and/or FBR testing and would contain available radioactive material.

Issue 2. The use of a simplified uncontained shallow subsurface testing for HPEOS or hydronuclear which would contain available radioactive material (the P-7 TOR Test Site).

Issue 3. A test area in which it is rumored that many shallow subsurface tests (approx 100) were conducted in an organized grid. These tests supposedly contained varying amounts of radioactive material which is still available if excavated carefully.

Scope

The following tasks were deemed as necessary in order to identify and access the radioactive material. It was assumed in these tasks that considerable excavation and/or construction was necessary, but does not include characterizing, removing and containerizing the radioactive material.

Task 1. Locate and provide the necessary access to all KOLBA containers to allow trained personnel to retrieve the Material which may be in the containers. Preliminary information, three (3), located at Tunnel 200m; one (1), located in a Sarcophagus; and one (1) at a reactor site. (The U.S. Government proposes to train NNC personnel to perform the material retrieval under the supervision of U. S. personnel.) (Est ROM Cost $400K)

Task 2. Locate the P-7 (TOR) locations where tests occurred. Excavate the Material at each area to allow trained personnel to retrieve and place the material in containers for permanent storage. Preliminary information, three sites exist, the Material is buried 3 to 5 meters. (Est ROM Cost $100K)

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Task 3. Locate the ACTON BERLY test grid. Identify the sites where the material is buried. Excavate each site to allow trained personnel to retrieve and place the material in containers for permanent storage. Preliminary information, approximately 100 sites exist, located in a 4 meter by 4 meter grid, the Material is buried approximately 6 meters. (Est ROM Costs $3,500K)

The ab ve est mates should include personnel, material, and equipment costs and the estimated time necessary to accomplish each task. And it should also include a total dollar estimate.

DTRA will provide oversite, training and specialized personnel safety equipment and material to National Nuclear Center to accomplish each task. The identification, characterization, containerization, removal, storage and/or elimination is not included in these estimates.

Dr. Don Linger/DTRA (CP)/325-7694/13 Jan 00

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Report
Of the Trilateral Working Group Meeting
Of the Technical Experts
On the Secure Containment of Residues of Nuclear Activities

At the Former Semipalatinsk Test Site (STS)

Washington, D.C.
June 14-16, 2000

The objective of the meeting was to develop a mutually acceptable technical solution for project implementation assuring safe and secure containment of the residues of nuclear activites (RONA) at the agreed area at the Semipalatinsk Test Site.

The participants of the meeting authorized by their respective agencies as provided in the agreements reached at the trilateral meeting (Moscow, May 04, 2000) reviewed technical approaches that would preclude unauthorized access to the RONA and allow for a long-term containment of the RONA.

1. During the meeting the following technical options for the joint project were discussed:
   1.1. Removing (extracting) the RONA from all the wells at the site and moving the RONA for interim storage to another site at the STS.
   1.2. Partial removal (from 35 wells) of the RONA by excavation and moving the RONA for interim storage to another site at the STS.
   1.3. Pouring concrete pad (entombing) over the whole area of the site.
   1.4. Removing (extracting) the RONA from all the 35 wells at the site using excavation technologies and pouring a concrete pad over the whole area of the site.

2. The parties agreed that all these options are technically feasible; however the preferred options are Options 3 and 4. The Russian side will provide information concerning the wells at the site; the information will be needed to implement the project. It is agreed to involve the International Atomic Energy Agency (IAEA) for both options in accordance with the laws of the Republic of Kazakhstan (RK).
   2.1. Option 3 can be implemented with minimal additional requirements.
   2.2 Implementation of Option 4 requires the following considerations:
   - The storage conditions of the removed material should preclude access to the material by any person or by any organization without joint decision of all (three) parties participating in the project.
   - Interim storage will be at the "Baikal" test-stand site of the NNC RK. During the interim storage period, the question of long-term storage should be solved.

3. Responsibilities of the participating parties:
   3.1. The Russian side:
   - Provides the information required to carry out the project;
   - Monitors project implementation and participates in the project.

   3.2. The U.S. side:

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- Defines the statement of work (in concurrence with the other participants);
- Monitors project implementation.

3.3. The Kazakhstan side:

- Carries out actual implementation of the project.

4. The participants of the meeting agreed that:

4.1. Implementation of either option by the RK will be done in consultation with the Russian and American sides. The Russian and Kazakhstan sides are prepared to start immediately on Option 3 (concrete entombing of the site).

4.2. It is agreed that the work on the selected option should be completed before the end of year 2000. For this reason, the parties agreed to reach a final decision on the option to be implemented as quickly as possible with the goal of commencing work in mid-July.

5. All the information related to this project is considered to be in confidence and dissemination of this information to fourth parties is permitted only upon mutual agreement of the three parties participating in this project.

The list of the participants is attached.

On behalf of the U.S. DOE	On behalf of Minatom RF	On behalf of Minenergo RK
Robinson, P.W.	Kutsenko, V.M.	Tukhvatulin, Sh.T.

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Brief timeline of events, associated with the Semipalatinsk Test Site (STS) following its closure

19 September 1989 – The USSR's last nuclear test at the Semipalatinsk Test Site.

29 August 1991 – With a Decree, President of the Kazakh Soviet Socialist Republic closes the Semipalatinsk Nuclear Test Site, four months before the collapse of the Soviet Union.

30 December 1991 – The Soviet Union officially ceases to exist. Kazakhstan inherits the world's fourth largest nuclear arsenal: 1,410 nuclear warheads, fitted on 104 SS-18 ground-based strategic missiles and 40 Tu-95 strategic bombers, loaded with cruise missiles, plus a scientific research and production infrastructure to create its own weapons of mass destruction.

15 May 1992 – The President of Kazakhstan signs a decree to create the Atomic Energy Agency of the Republic of Kazakhstan.

15 May 1992 – The President of Kazakhstan signs a decree to create the National Nuclear Centre of the Republic of Kazakhstan at the former Semipalatinsk Test Site and at the corresponding scientific organisations and facilities, located within Kazakhstan.

23 May 1992 – Kazakhstan signs the Lisbon Protocol to the Strategic Arms Reduction Treaty, or START, between the USSR and the USA on the reduction and limitation of strategic offensive arms, in which it turns away from ownership of nuclear weapons and sets out its obligations on the non-proliferation of nuclear weapons.

13 December 1993 – The Parliament of Kazakhstan ratifies the Nuclear Weapons Non-proliferation Treaty. On the same day, Kazakh President Nazarbayev and US Vice-president Al Gore meet in Almaty and sign an umbrella agreement between Kazakhstan and the United States on destroying the silo launcher installations for intercontinental ballistic missiles, eradicating the consequences of emergencies and preventing proliferation of nuclear weapons, opening the way for implementation of the Cooperative Threat Reduction (CTR) Programme (the Nunn-Lugar Programme) in Kazakhstan.

13 February 1994 – Kazakh President Nazarbayev presents the ratification documents to US President Bill Clinton in Washington, as a consequence of which Kazakhstan officially accedes to the Nuclear Weapons Non-proliferation Treaty as a state with no nuclear weapons.

February 1994 – Kazakhstan joins the International Atomic Energy Agency (IAEA). All 40 Tu-95 strategic bombers, with weapons, are repatriated from Kazakhstan to Russia.

31 May 1995 – As a result of the detonation of a regular explosive charge and the subsequent collapse without the release of nuclear energy, the last nuclear charge in Tunnel No. 108-K, which has remained there since 1990, is destroyed.

3 October 1995 – The Agreement between the Kazakh Ministry of Science and New Technologies and the US Department of Defence on destruction of nuclear infrastructure.

1995 – Work begins at STS to abandon all tunnels at Degelen Mountain, where nuclear tests were either conducted or planned.

1996–1997 – Areal radioecological research begins at STS (Abralinskiy District, 4,500 km^2).

18 November 1997 – The US Department of Energy and the Kazakh Ministry of Science of the Academy of Science sign an agreement concerning placement into long-term storage of BN-350 spent reactor fuel at the Baikal-1 reactor facility of NNC, located at STS.

17 September 1998 – A 25-tonne experimental, calibrated blast is detonated to seal the last test borehole (No. 1071) at the Balapan Testing Area.

September 1999 – All 148 silo launchers for intercontinental ballistic missiles in four regions of Kazakhstan are destroyed, 61 at Derzhavinsk, 61 at Zhangyz-Tube, 14 test silo launchers at STS and 12 test silo launchers at Leninsk.

1999 – The Comprehensive Nuclear-Test-Ban Treaty Organisation conducts the first onsite field exercises at STS. Visual observation, passive seismic survey procedures and security measures are completed. 12 specialists from 9 countries and the CTBTO take part in these exercises.

2000 – Work continues at STS, now on a trilateral basis (Kazakhstan, Russia and the USA) to prevent the proliferation of weapons of mass destruction (WMD) and associated materials, technologies and knowledge. The purpose of this work is to reinforce the barriers (sealed entrances), erected between 1995 and 2000, stop unauthorised access to nuclear waste, prevent the proliferation of fissionable and radioactive materials and, accordingly, the information, classed as sensitive as regards the criteria for non-proliferation of WMD.

July 2000 – The entrance to the last tunnel at Degelen Mountain of the former STS is destroyed. As a result of work at the test site to destroy nuclear weapons testing infrastructure, from 1996 to 2000, 181 tunnels at the Degelen Testing Area and 13 unused test boreholes at the Balapan Testing Area are abandoned.

2002 – At STS, the CTBTO conducts the large-scale FE02 field experiment. Video survey, radioecological and seismic surveys are completed. 42 specialists from 24 countries and the CTBTO take part in these exercises.

2005 – The CTBTO performs the FE05 PrepCom exercise at STS (at the Balapan Testing Area). 38 specialists from 22 countries and the CTBTO take part in these exercises.

2008 – A comprehensive environmental survey is started at STS to return the land stock to the national economy.

2008 – At STS, the CTBTO conducts the largest IFE08 integrated field experiment, involving more than 200 participants from 40 countries. For the fourth time, Kazakhstan presents the former Semipalatinsk Test Site for international inspection teams to conduct exercises, to reinforce the role of the contracts and agreements on international nuclear non-proliferation and disarmament.

2 December 2009 – the sixty-fourth session of the United Nations General Assembly unanimously adopts Resolution 64/35 to declare 29 August the International Day against Nuclear Tests. The Resolution calls for greater public enlightenment and information *on the consequences of nuclear weapons test blasts and any other nuclear blasts and on the need to stop them as a means of achieving a world, free of nuclear weapons*.

6 April 2010 – As part of an official visit to Kazakhstan, US General Secretary Ban Ki-Moon visits Kurchatov and STS.

11 April 2010 – The results of work by NNC to support non-proliferation, are recognised in a Joint Declaration by Kazakh President Nursultan Nazarbayev and US President Barack Obama during a meeting in Washington.

24 November 2010 – The first official resolution of the Kazakh Government on the transition to economic use and the provision of land parcels at the former Semipalatinsk Test Site.

13 October 2011 – IAEA Director General Yukiya Amano visits the Semipalatinsk Test Site as part of events under the International Conference for a Nuclear-Weapon-Free World.

27 March 2012 – The results of work by NNC to support non-proliferation, are recognised in a joint declaration of the presidents of Kazakhstan, the USA and Russia at the Nuclear Security Summit in Seoul.

27–29 August 2012 – Astana hosts the international conference From a Nuclear Test Ban to a Nuclear Weapons Free World. The conference is timed to coincide with the International Day against Nuclear Tests. On 28 August, the participants visit NNC facilities in Kurchatov and take part in a meeting in Semey, devoted to the closure of the Semipalatinsk Test Site.

29 August 2012 – At the international conference International Day against Nuclear Tests, the Kazakh President announces the launch of the international project ATOM (Abolish Testing. Our Mission). The project is designed to bring together global public efforts to achieve a complete and final ban on nuclear weapons testing.

October 2012 – The main work is completed under the HDTRA project, as part of the agreement with the Defence Threat Reduction Agency (DTRA) of the US Department of Defence to strengthen the physical protection of tunnels at Degelen Mountain. The barriers, erected to prevent access to nuclear waste at STS, use a total of about 90,000 cubic metres of concrete, special solutions and rock.

October 2013 – In support of the joint threat reduction programme, Kazakhstan and the USA, backed by the DTRA, perform an experiment to test the physical protection systems at test site facilities.

11–12 March 2014 – Kazakhstan and the UN Security Council Committee hold a workshop, titled: The Contribution of UN Security Council Resolution 1540 (2004) to Regional and Global Disarmament and Non-Proliferation, to mark the 10th anniversary of Resolution 2540 (Astana, Kazakhstan).

24–25 March 2014 – The President of Kazakhstan attends the Nuclear Security Summit in the Hague, Netherlands. An initiative is put forward for full and comprehensive nuclear disarmament, which is the only guarantee of nuclear security. Kazakhstan supports the creation of new zones, free from nuclear weapons, including in the Middle East.

27–29 August 2014 –Kazakhstan hosts a conference, devoted to the 25th anniversary of the creation of the Nevada Semipalatinsk anti-nuclear movement (Kurchatov, Kazakhstan).

10–12 August 2015 – to support the joint threat reduction programme, the Republic of Kazakhstan and the National Guard of the Republic of Kazakhstan, assisted by the DTRA, perform an experimental operation at the Semipalatinsk Test Site.

28 September 2015 – The President of the Republic of Kazakhstan takes part in the 70th session of the UN General Assembly. An initiative is put forward to achieve a nuclear-free world by 2045 (the 100th anniversary of the UN), the offer to adopt the Universal Declaration on the Achievement of a Nuclear-Weapon-Free World.

28 September 2015 – the Republic of Kazakhstan takes part as co-chair of the 9th Conference (under Article XIV) as part of the UN General Assembly (New York, USA).

31 March – 1 April 2016 – The President of Kazakhstan attends the IV Nuclear Security Summit in Washington, USA. An initiative is put forward on creating a global network to fight terrorism, under the auspices of the UN. During the Summit the Manifesto *The World. The 21st Century* is unveiled. The Manifesto acquires the status of an official document of the General Assembly and the UN Security Council.

28 June 2016 –Kazakhstan is elected a non-permanent member of the United Nations Security Council from the Asian-Pacific group of nations for 2017–2018. The Organisation's Charter vests the Republic of Kazakhstan with powers devoted to maintaining peace and security.