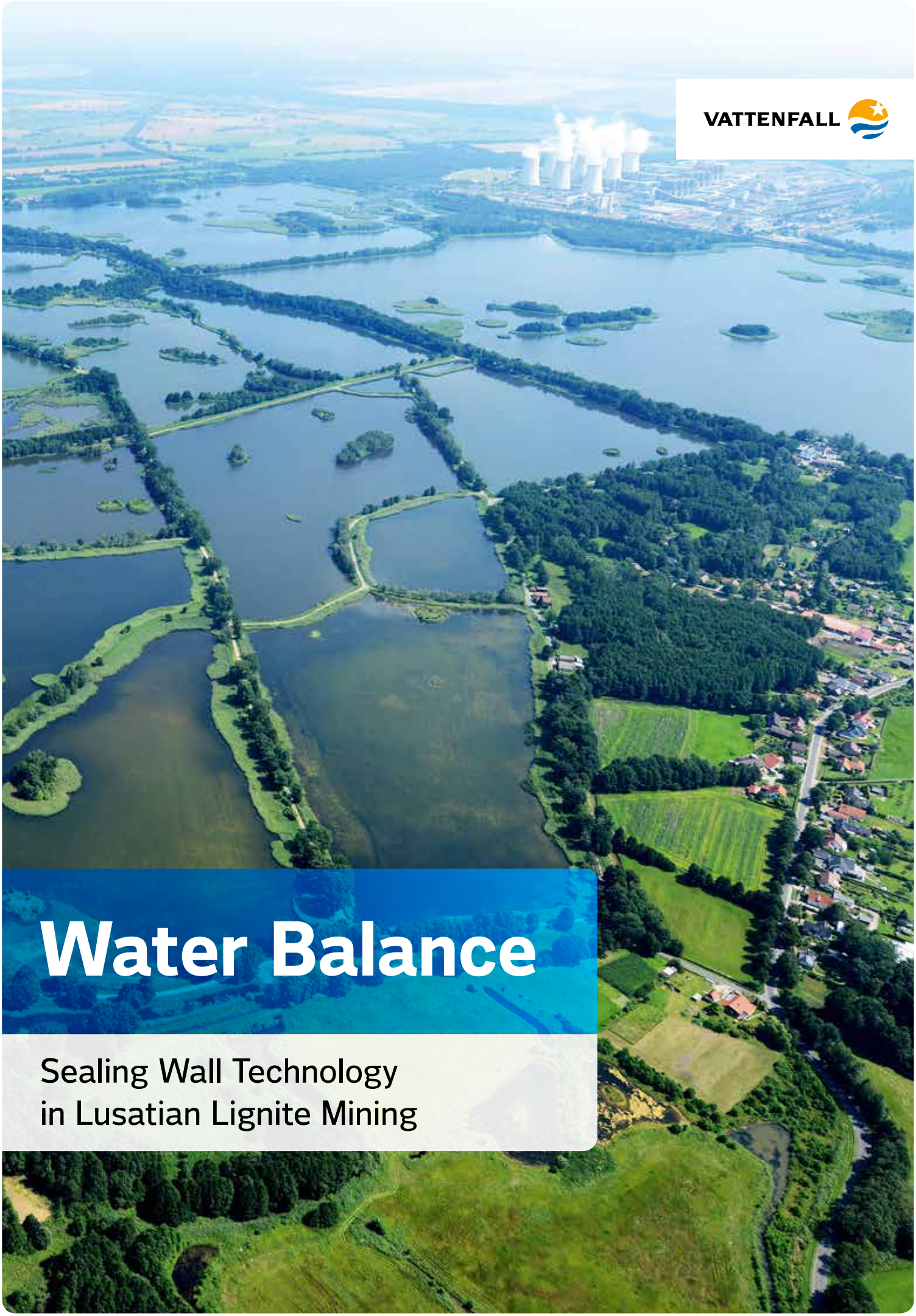


VATTENFALL

Water Balance

Sealing Wall Technology in Lusatian Lignite Mining

Inventive Talents

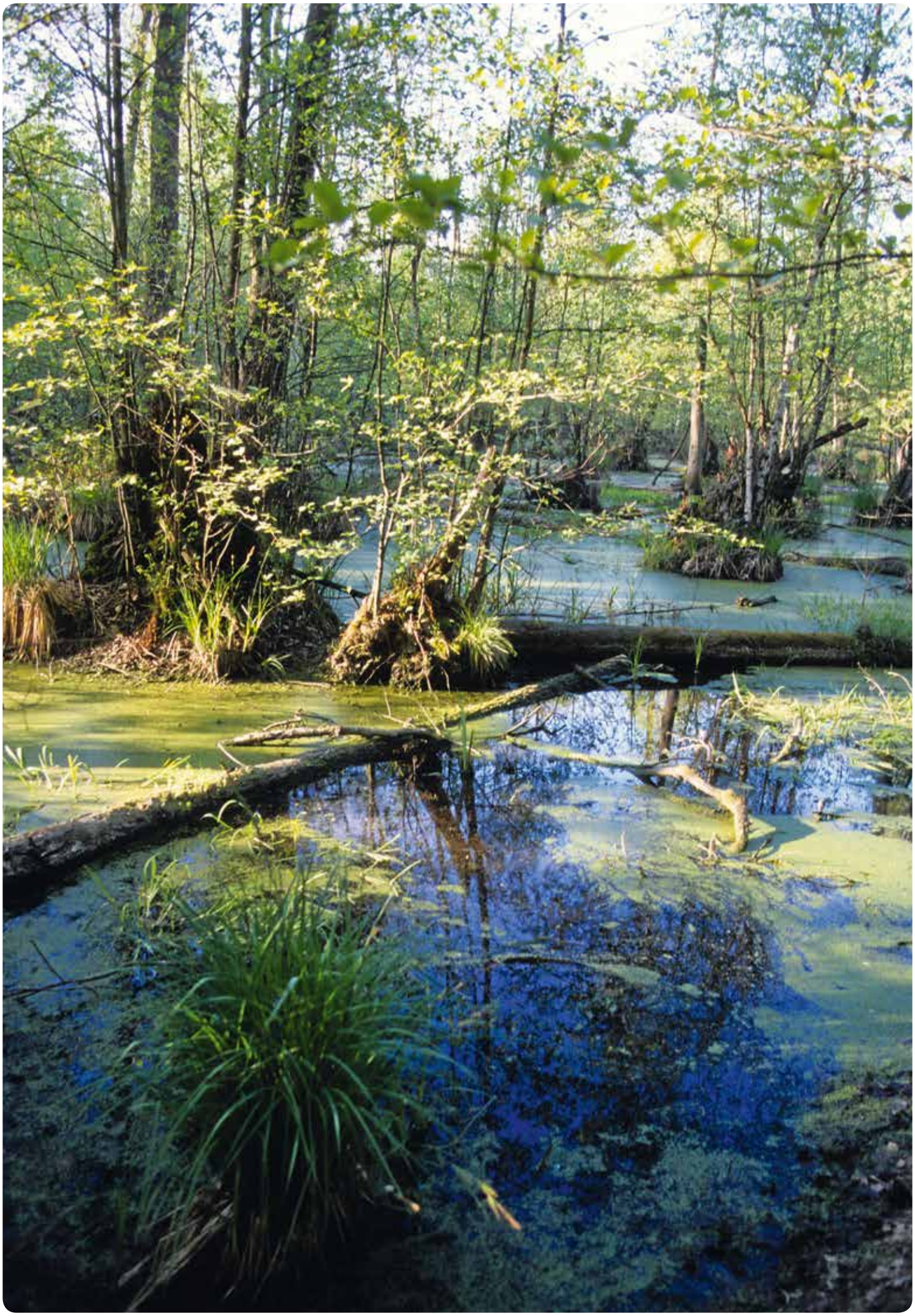
Many technical advances have been invented in the course of the last 200 years of Lusatian lignite mining such as the filter wells which were first used in the beginning of the twentieth century in the Ilse mine pit near Senftenberg or the massive overburden conveyor bridges that are characteristic of Lusatian opencast mines of today.
Then, in the 70s Lusatian engineers and scientists of the Bergakademie Freiberg (Mining Academy of Freiberg) developed techniques and technology for producing sealing walls. By means of this technology groundwater lowering associated with mining activities is limited to a minimum in the direct vicinity of the opencast mine without having an affect on the neighbouring areas. Three of these complexes were built between 1979 and 1982 as a countermeasure to safeguard the Neiße floodplain and the Polish Republic from the impacts of the groundwater being lowered.

German mechanical engineering companies worked together with Lusatian engineers to improve on these designs in the period after 1990 during which the lignite mining industry went through a major restructuring phase. Since then, approximately 25 kilometres of sealing walls with a depth of between 50 and 110 metres have been built along four Lusatian opencast mines. The sealing wall technology has long been recognized internationally as a pioneering environmental technology enabling efficient raw materials extraction and safeguarding sensitive landscapes effectively.

With the long-term continuation of lignite-based power generation in Lusatia the erection of sealing walls plays an important role.

Uwe Grosser
Board Member Mining Division

Route of sealing wall along Welzow-Süd opencast mine safeguarding the Lusatian lakeland



Water World Lusatia

Lusatia's abundance of water is already anchored in its name:
Łužica – Swampland the name given to the region by the first settlers.
A mosaic of swampy areas, dry sandy soil and heathland characterises the area.

For centuries Lusatia was repeatedly subject to extremely dry periods and devastating floods. Especially the catchment areas of rivers were frequently flooded. According to historical documents there were only 15 normal harvests in the period between 1894 and 1938. Harvests were partially or even completely destroyed by floods in the other years. To be able to cultivate the land extensive trench systems were dug. By regulating the water courses it was possible to cultivate the land affordably.

What this meant for life in Lusatia was described by a senior teacher Gottlieb Paulitz from Calau in the year 1899:

"Where today there are lush meadows, well-cultivated fields, gardens and attractive settlements, when there was a flood the whole area was covered in water for several weeks and resembled a vast undulating lake. On hot summer days, the water produced rot from the vegetation buried below. With the musty smell that emanated from these swamps the inhabitants often suffered from diseases."

◂ Spreewald biosphere reserve

However, trench systems do not provide sufficient drainage to mine Lusatia's mineral resources. The opencast mine has to be kept free of groundwater to allow miners to reach the coal without getting their feet wet. To fully reach the reserves excavation depths have increased particularly from 1960s onwards. The water is continuously pumped up using filter wells around the periphery of the opencast mine fields.

The extensive lignite mining particularly in the GDR period meant a continuous lowering of the water level affecting the water balance in Lusatia strongly. By 1989, up to 200 million tonnes of lignite were excavated here and up to 1,200 cubic metres of water were pumped up. As a consequence a groundwater deficit of 13.6 billion cubic metres developed in the 2,500 square kilometres area - equivalent to the size of the Saarland. The water level in the surrounding area was even lowered to 70 metres below the surface level in some areas.

Lignite mining in Lusatia has dropped by over 70 per cent as from 1990. This is also reflected in the water balance. The groundwater is now rising again and the region is regaining its balance, partly with the help of this worldwide unique technology:

Underground sealing walls are produced in Lusatia to limit groundwater lowering to an area absolutely necessary for mining of coal.
Simultaneously, the sealing wall ensures that the groundwater level on the "water side" is maintained. Sensitive areas like wetlands, floodplains and water bodies will be protected in this way and will be preserved in their original purity. This way the Neisse floodplain, Lasszinswiesen and Lusatian Lakeland region can co-exist in the direct vicinity of the opencast mine.

Landscape Protection and Water Balance

The sealing wall acts as an artificial watershed.
Whereas the groundwater level is lowered on the mine side it is fully maintained on the land side and thus mine water pumping is reduced to a minimum.

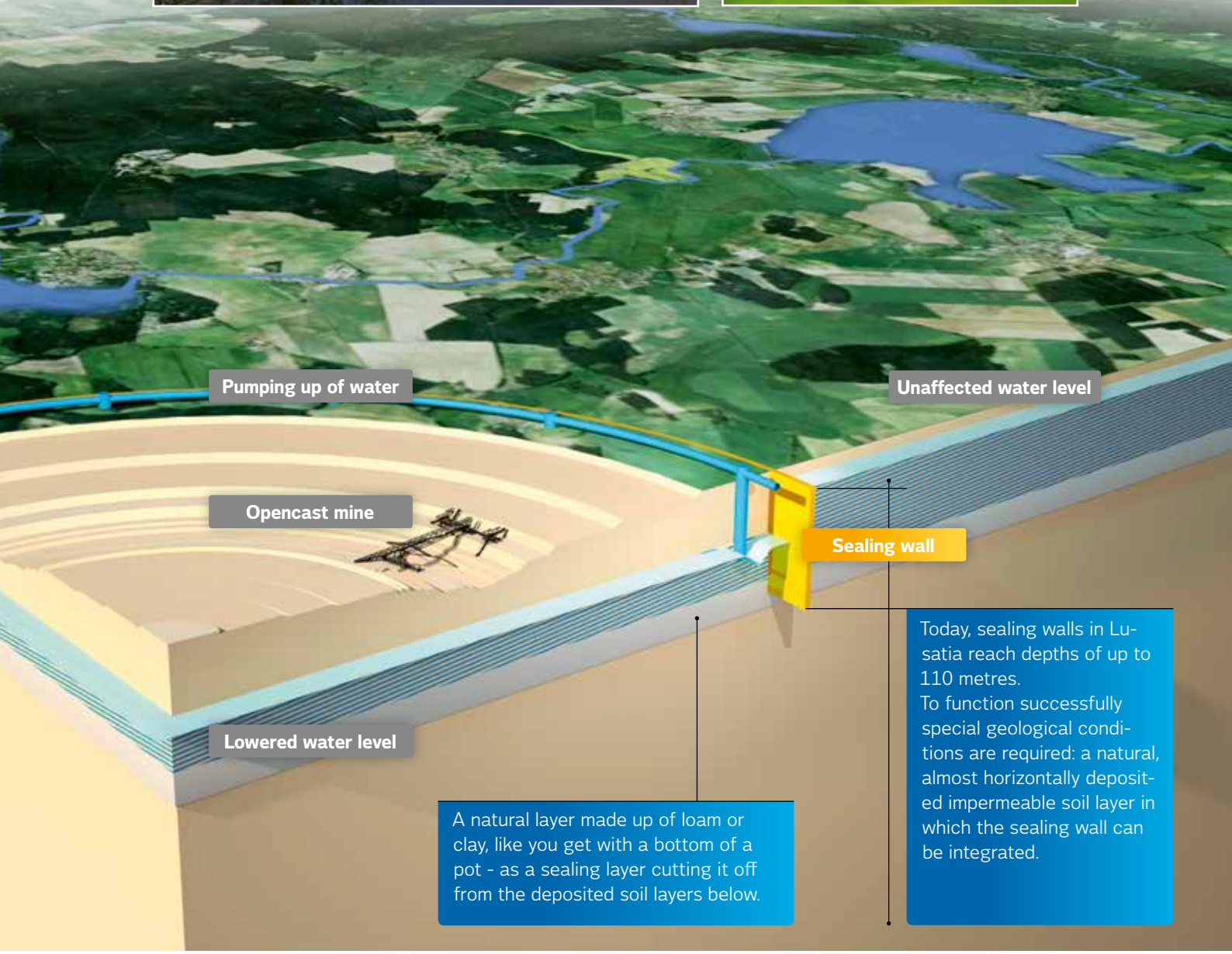
The construction material takes one by surprise at first. They are the same materials a potter uses to produce ceramics: clay and water. When mixed with natural soil they form a stable wall.
This underground dam is as water permeable as a tabletop made of good oak. This means less than 0.00000000001 cubic metres of water per second flow through it. One drop of water would therefore take 60 years to reach the other side.

Already during the construction phase samples are taken at regular intervals to check the impermeability of the wall. It is almost impossible for permanent leaks to occur. This is mainly due to the self-repairing properties of the clay-filter-crust. Their plastic consistency ensures that "wounds" can be closed within a few seconds.

From the surface the massive construction is hardly visible although the construction site starts with a trail width of 25 to 30 metres. The rehabilitation activities follow the construction trail section by section just one year after the installation. The natural character of the landscape is reinstated.
But the activities don't stop here. As long as mining influences the landscape groundwater measurements are carried out on both sides of the sealing walls to monitor its effectiveness.

After mining activities come to an end, sealing walls can be kept fully intact, particularly when they can be used as a means of controlling groundwater. If there is any damming affect hampering the natural water flow, large holes can be bored to perforate the wall. Openings 30 metres deep are drilled at 80 metre intervals and then filled with gravel. The water can thus flow through these holes freely.

Around the opencast mine filters wells protect the opencast mine space from inflowing groundwater.
As an example in the Welzow-Süd opencast mine, 8,400 m³ of water per hour is continuously pumped.
The water is purified and then discharged into the surrounding rivers.



A natural layer made up of loam or clay, like you get with a bottom of a pot - as a sealing layer cutting it off from the deposited soil layers below.

Today, sealing walls in Lusatia reach depths of up to 110 metres.
To function successfully special geological conditions are required: a natural, almost horizontally deposited impermeable soil layer in which the sealing wall can be integrated.

An integrated Technology

Like a yellow caravan the equipment complex travels across the countryside. Here, between the Lusatian Lakeland and the Welzow-Süd opencast mine, a barely visible construction of enormous dimensions is being created.

In the construction industry diaphragm walls/slot walls are now part of the day to day technology. It would be difficult to imagine building underground car parks with several floors below surface without the aid of subterraneous diaphragm walls, as they are called in the construction industry. The size is according to the size of the building and can be up to 1,000 metres long.

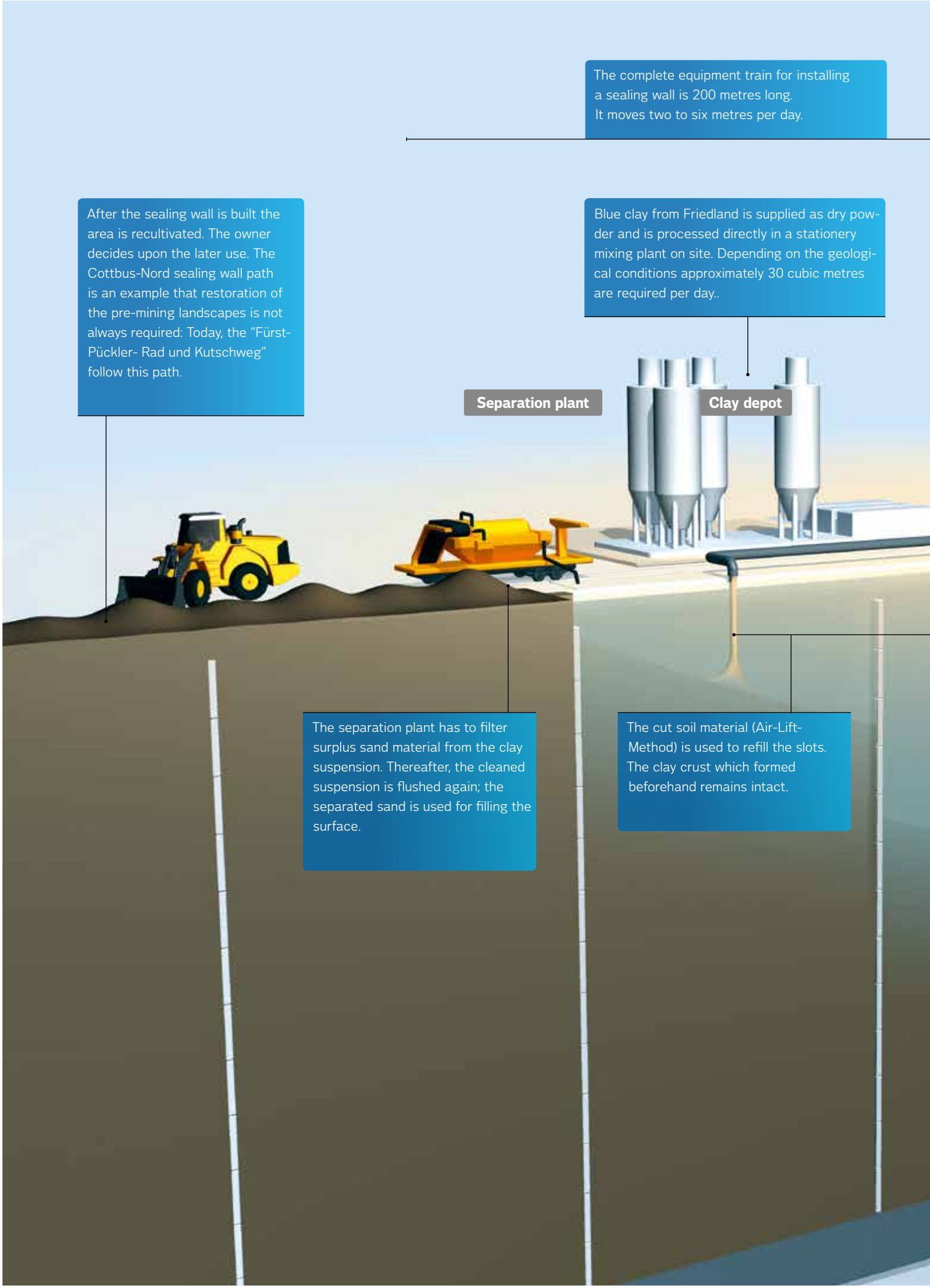
In contrast sealing walls in mining are still considered to be something unusual. They are often of massive scale: The sealing wall in the Jänschwalde opencast mine, for example, is almost 11,000 metres long. The sealing wall of the Welzow-Süd opencast mine at 120 metres is the deepest of its kind.

Four generations of equipment have been in use in Lusatia's mining operations since the end of the 70s. Each new generation was a further refinement of the sealing wall technology. But essentially each generation follows one basic principle:

In contrast to the slot grabs used in the building industry slot cutters are used in the mining industry. Their advantage: Instead of installing single segments which require a lot of time to harden, a continuous uninterrupted retaining wall, extending slowly but continuously, is created with the help of the slot cutter. The wall built in one pour has the advantage of having no joints and is almost completely vertical.

In the meantime the technology used in Lusatia's mining industry can build sealing walls down to a depth of 110 metres. The potential applications for this modern technology are on the increase.

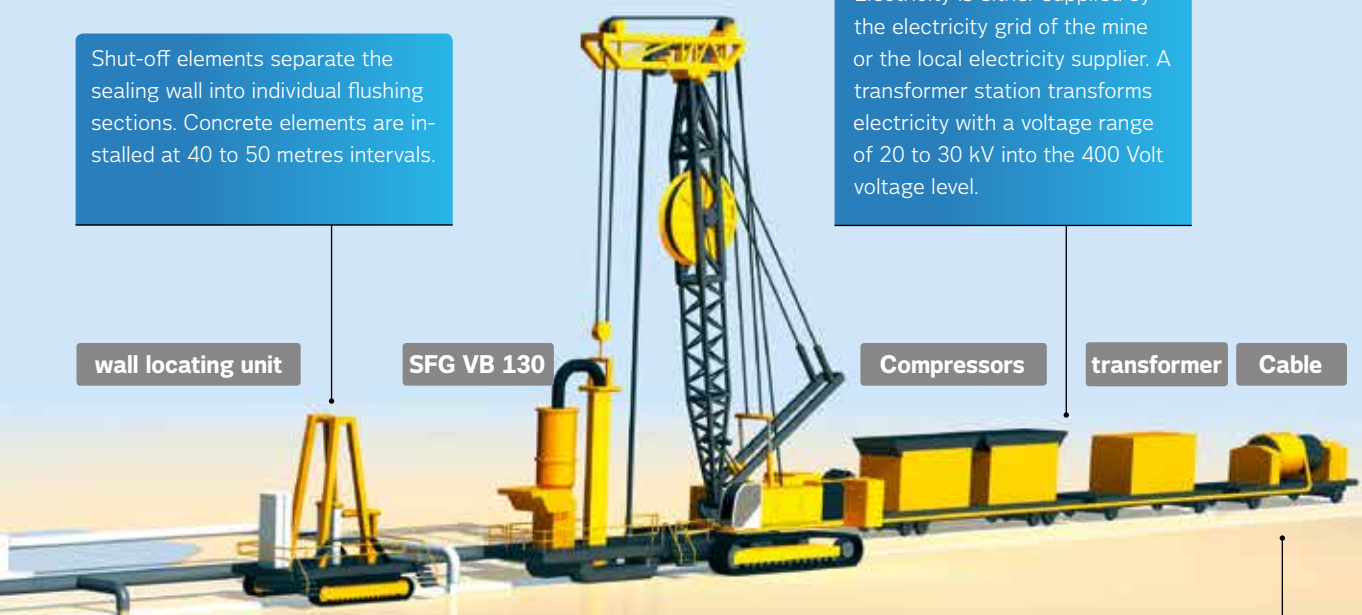
Generation of equipment	Year of manufacture	Model	Max. depth (m)	Annual capacity in 1 000 m²	Operational site	Partner
1	1970er	SF 50	50		Rüdersdorf/Berzdorf	
		SG 60	60		Berzdorf	
	1979	SG 73	84		Jänschwalde	Bergakademie Freiberg
2	1980	SG 100/01				
	1983	SG 100/02	100	18 - 25	Jänschwalde	
	1993	SG HW 852 HD	73	20 - 35	Berzdorf Cottbus-Nord	
3	1998	SFG LW 120	120	50 - 60	Jänschwalde Cottbus-Nord Reichwalde	Wirth Maschinen- und Bohrgeräte-Fabrik GmbH
4	2010 2012	SFG VB 130/1 SFG VB 130/2	130	50 - 60	Welzow-Süd	Bauer Maschinen GmbH


The complete equipment train for installing a sealing wall is 200 metres long.
It moves two to six metres per day.
After the sealing wall is built the area is recultivated. The owner decides upon the later use. The Cottbus-Nord sealing wall path is an example that restoration of the pre-mining landscapes is not always required: Today, the "Fürst-Pückler- Rad und Kutschweg" follow this path.
Blue clay from Friedland is supplied as dry powder and is processed directly in a stationery mixing plant on site. Depending on the geological conditions approximately 30 cubic metres are required per day..
Separation plant
Clay depot
The separation plant has to filter surplus sand material from the clay suspension. Thereafter, the cleaned suspension is flushed again; the separated sand is used for filling the surface.
The cut soil material (Air-Lift-Method) is used to refill the slots. The clay crust which formed beforehand remains intact.

Direction of operating path

Shut-off elements separate the sealing wall into individual flushing sections. Concrete elements are installed at 40 to 50 metres intervals.

Electricity is either supplied by the electricity grid of the mine or the local electricity supplier. A transformer station transforms electricity with a voltage range of 20 to 30 kV into the 400 Volt voltage level.



Guiding pile

The slot cutter continuously cuts a one metre wide slot.

A constant mixture of natural clay and water flows into the freshly cut slot in the earth. The clayey slurry "stabilizes" the earth slot and clay particles deposit on both sides of the slot simultaneously. This process is called colmation. The clay suspension penetrates the pore spaces of the soil layer. The first millimetres of a crust form within a few minutes. About three hours later an almost impermeable two to five centimetre thick filter crust has formed. After 20 hours the crust formation is almost complete.

trench cutter

Gravel
sand
silt
fine sand

The loosened soil material is transported within a guiding pile to the surface using the Air-Lift-Method.

Groundwater impermeable layer

Samples of the filter crust are taken regularly to check the impermeability. Directly after the cut a kind of self-healing or self-repairing process starts. The pressing wet clay-water slurry forms a new crust within a short period of time which closes the opening in a few minutes.

Underground Walls

They secure construction pits, protect against floods and enclose contaminated soil. For decades slot walls in civil engineering and sealing walls in mining industry have been used to protect buildings and landscapes.

Slot walls in civil engineering

The first underground pile walls were already built in the USA in 1903 and in Germany in 1905. The Austrian civil engineer for geotechnics Christian Veder is regarded as the inventor of the slot wall technology. In the 1930s he studied the properties of clay sludge and their ability to provide a supporting function. The slot wall technology developed later based on this. Concrete piles are cast into the soil transferring the loads into deeper lying stable layers. Bentonite, a mixture from water and clay, was used as supporting fluid.

In the 1950s an Italian construction company developed Veder's process for practical use. Under his management the first slot walls were built in Italy and Canada in the following decades. The slot wall technology was used at the Ponte Flaminio in Rome as well as for the construction of dam walls. A particularly deep slot wall with a depth of approximately 130 metres was built at the Manicouagan dam in Canada. The construction pit of the World Trade Center was also secured by a slot wall. This wall protected the World Trade Center against water from the Hudson River - and in addition held out on the day of the terrorist attack. What a stroke of luck for the rescue works. If it had been broken the southern Manhattan would have been flooded.

The slot wall of the World Trade Center withstood and protected the southern Manhattan from being flooded.

In use throughout the world

Enclosing contaminated soil material
In 2013 the contaminated site of a former gasworks in Detmold, Northrhine-Westfalia, which had already been closed down in the 50s was belatedly enclosed with a slot wall.

Securing construction pits
At the edge of the historic city centre, directly beside the Danube River, the Eurovea International Trade Centre Bratislava is built on an area of 230,000 square metres.
The construction pit is enclosed by a 34 metres deep slot wall.

Flood protection
The Sylventeich reservoir in Bavaria has a 60 metres deep slot wall in 2012.

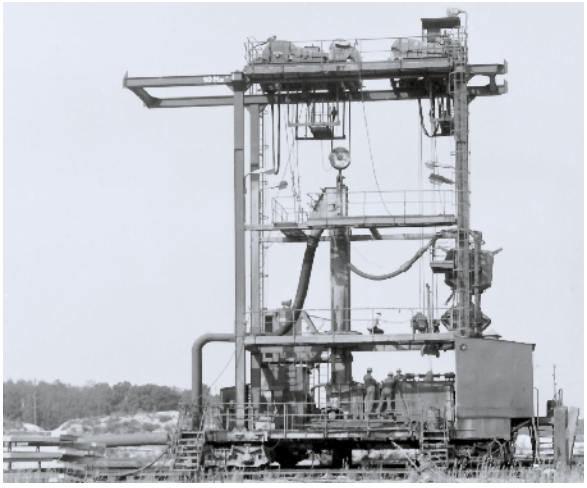
◂ SFG VB 130 Sealing wall equipment on the Welzow- Süd sealing wall route

Sealing walls in mining

Since the 70s underground sealing walls have been installed in Lusatia's mining industry. The initially used equipment for this world-wide unique technology was a machine originally developed for operator-free excavation of lignite. But inventions are rarely developing straight - also in this case: The slot cutter was supposed to produce two parallel slots down to the coal seam to extract the coal underground by means of an underground plough. But this never happened. What was left was a machine movable on rails which was able to continuously cut slots down to a depth of 50 metres.

In 1970 dewatering activities for the Jänschwalde opencast mine north of Cottbus started. After the first filter wells were put into operation the Polish authorities suspected that the groundwater level on the other side of the Neisse River would soon drop over a large area. The demands for compensation were growing and therefore the pressure on the engineers. It was necessary to find a solution to counteract groundwater lowering in the catchment area of the Neisse River. The engineers remembered the unused slot cutter for operator-free coal mining. With the scientific assistance of the Mining Academy of Freiberg the prototype for the first equipment generation for the installation of underground sealing walls in the mining industry was developed.

In 1979 the construction of the first sealing wall started at the edge of the Jänschwalde opencast mine. With a length of almost 11 kilometres it is among the longest sealing walls world-wide to date. Annual measurements on both sides of the border river confirm: The sealing wall lives up to its name.



Slot cutter SG 73 late 70s

Slot cutter SG 100 beginning of the 80s

Sealing walls in the Lusatian Mining Area

1 | Sealing wall Jänschwalde opencast mine

Location:	from Bohrau to Taubendorf, along the Neisse River
Constr. period:	1979 to 2000, 2007 to 2009
Dimensions:	depth 52 to 85 metres | length 10,740 metres
Goal:	protection of wetlands east of the Jänschwalde opencast mine, especially in the Neisse floodplain and the adjacent area to the Polish Republic
Equipment:	SG 73; SG 100/1; SG 100/2; SFG LW 120
Noteworthy:	World-wide first sealing wall for mining

2 | Sealing wall Cottbus-Nord

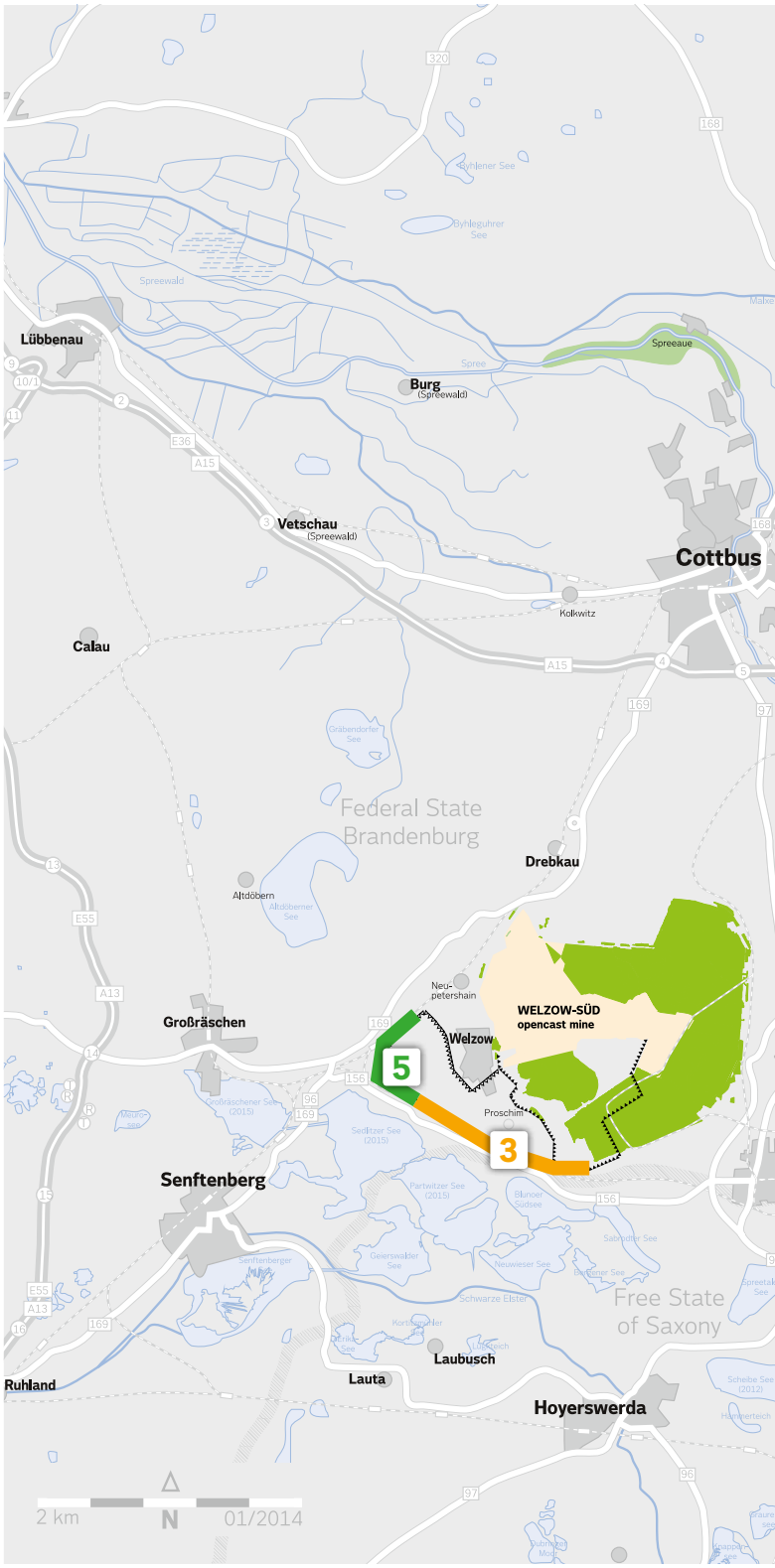
Location:	from Merzdorf via Lakoma to Neuendorf
Constr. period:	1993/94 until 2007
Dimensions:	depth 51 - 72 metres | length 7,071 metres
Goal:	protection of FFH areas "Peitzer Teche", "Spreeaue" and "Nordstadt Cottbus"
Equipment:	excavator HS 852 HD with rope grab SWG 3,2 SFG LW 120
Noteworthy:	1993 – 1998 slot grabbing method | 2001 – 2007 slot cutting method

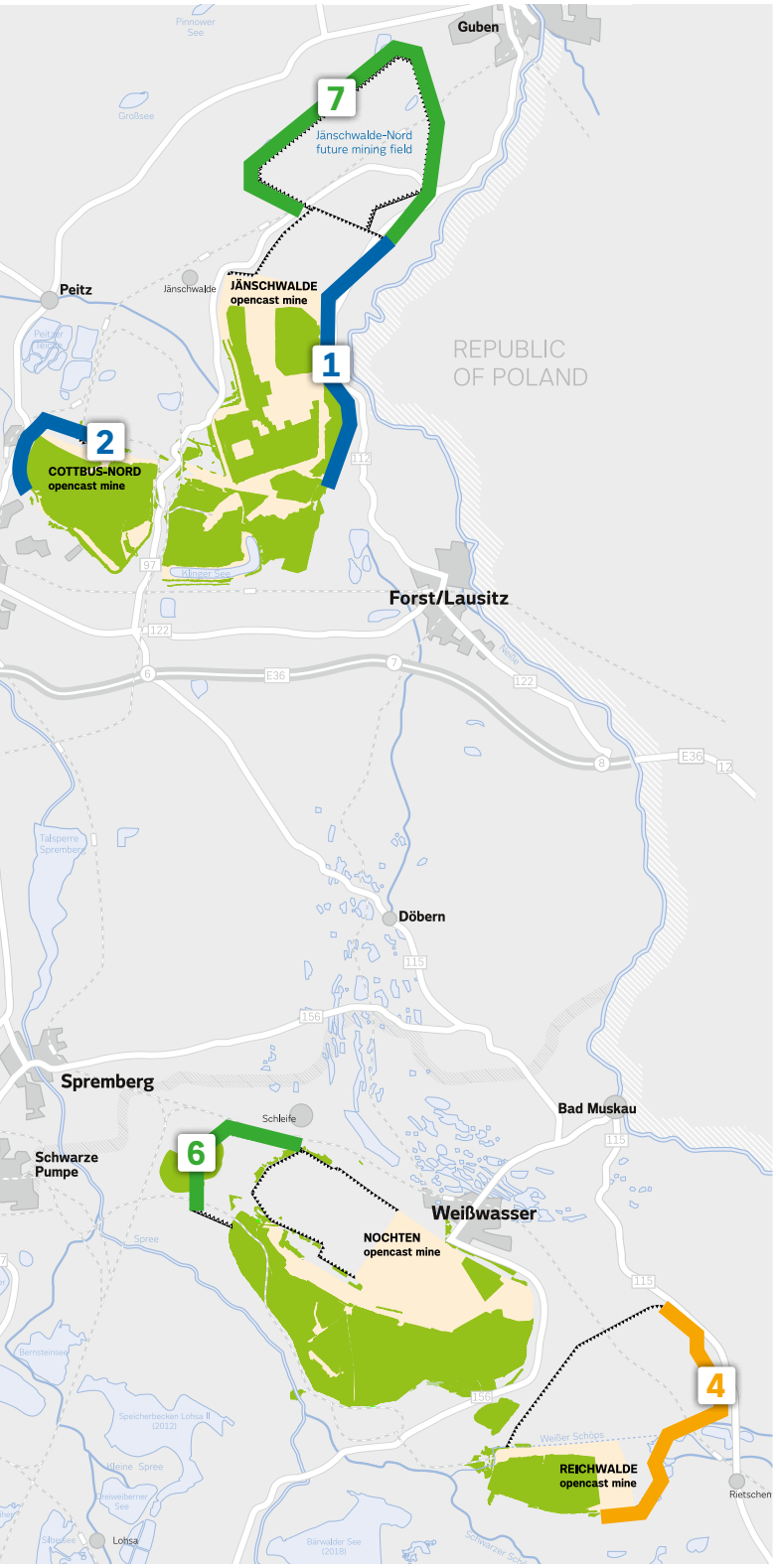
3 | Sealing wall Welzow-Süd

Location:	from Lieske to Bluno
Constr. period:	December 2010 to 2022 (planned)
Dimensions:	depth 95 to 120 metres | length 10,630
Goal:	protection of Lusatian lakeland region and environs of Welzow-Süd opencast mine
Equipment:	SFG VB 130/1, SFG VB 130/2
Noteworthy:	largest sealing wall construction so far with a depth of up to 120 metres and a length of more than 10 kilometres, the route runs across a glacial depression with strongly varying geological layers

4 | Sealing wall Reichwalde

Location:	1st stage of construction (BA 1) eastern margin near Hammerstadt; 2nd stage of construction (BA2) Weißer Schöps to Weißkeißel military training area
Constr. period:	BA1 2009 to 2014, BA 2015 to 2024 (planned)
Dimensions:	depth BA1 37 to 50 metres, BA2 50 to 90 metres, length BA1 4,200 metres, BA2 7,700 metres
Goal:	protection of FFH area "Hammerstädter Teiche", SPA area "Oberlausitzer Teiche" and Neisse floodplain
Equipment:	SFG LW 120 and SFG VB 150
Noteworthy:	crossing of a pond area and an active military training area





5 | Sealing wall Welzow-Süd (TA 2)

Location:	from Lieske to Bahnsdorf
Dimensions:	depth 90 to 110 metres | length 6,000 metres
Goal:	protection of Lusatian lakeland region
Equipment:	SFG VB 130
Noteworthy:	approaching a FFH area

6 | Sealing wall Nochten (Mining Field 2)

Location:	northwest of the Nochten opencast mine
Dimensions:	depth 115 to 150 metres | length 7,500 metres
Goal:	protection of FFH area "Reuthener Moor" and the drinking water protection area for the Spremberg "Kuthen" waterworks
Equipment:	SFG VB 130 and SFG VB 150 (in planning); up to three devices at the same time
Noteworthy:	crossing of a very deep glacial depression; for the first time 150 metres depth to be achieved.

7 | Sealing wall Jänschwalde-Nord

Location:	around the Jänschwalde-Nord mining field
Dimensions:	depth 65 to 120 metres | length 20,000 metres
Goal:	protection of FFH areas "Gubener Fließtäler" and "Neisseaue" as well as the adjacent area of the Polish Republic; protection of the drinking water protection area for the "Schenkendöbern" waterworks
Equipment:	Type SFG LW 120; up to three devices at the same time
Noteworthy:	up to 80 % of the mining field is surrounded by a sealing wall

(south east of the map section is not shown)

Sealing Wall Berzdorf opencast mine

Location:	south of Görlitz to Hagenwerda, along the Neisse River
Constr. period:	1983 to 1993
Dimensions:	depth 25 to 65 metres | length 5,500 metres
Goal:	protection of Neisse River and the adjacent area to the Polish Republic
Equipment:	SF 50; SG 60, rope grab K60
Noteworthy:	strongly varying depth of impermeable soil layer. The dam from the construction period was kept as flood protection dam for the Neisse River.

Dichtwand

Built | **being built** | **planned**

Glossary

Air-Lift-Method
The process uses the physical properties of air in water. Compressed air blown into a water-sand-mixture flows rapidly to the top carrying sands and other soil material to the surface.

Floodplains
Floodplains are areas of land adjacent to a stream or river which topography and biotic communities are characterized by alternating high and low water levels. As part of the river landscape they permanently interchange with the river. In floodplains new habitats for pioneers in fauna and flora are continuously developing.

Wetlands
Transfer area between dry and permanently wet ecosystems. The term comprises various habitat types like floodplain, marshland forest, wet meadows moor, marsh or swamp which are adjusted to excess water year round. Wetlands are of great ecological importance because they serve as resting places or winter quarters for water- and shore birds.

FFH areas
Special European protected areas in nature and landscape protection identified in accordance with the Fauna-Flora Habitat Directive, serving the protection of plants (Flora), animals (Fauna) and habitats (habitat types) listed in several annexes to the FFH-Directive.

Filter wells
Boreholes for pumping up groundwater; equipped with filter pipe and filter gravel and fitted with a submersible motor pump.

Cone of depression of groundwater
Area in which the natural groundwater level has lowered due to mining activities for many years In Lusatia, the cone of depression of groundwater caused by mining activities will be reduced step by step by protective measures like building of sealing wall and a specially developed flooding concept.

Colmation
The process of reducing water permeability of soil layers. It results from the introduction of finer material, e.g. suspended matter.

Gauge
Boreholes in which the groundwater level is measured.

Recultivation
Shaping of landscape after mining Recultivation aims at creating land for multiple uses and economically valuable landscape.

Slot cutter
A mobile piece of equipment for various uses specially developed to produce an earth slot. Consists of the basic equipment, superstructure with drilling equipment, guiding pile and cutting device.

Suspension (lat. suspendere: to suspend)
Heterogeneous material mixture from a fluid and finely distributed solid matter in it which are elutriated in the fluid and held suspended. For constructing sealing walls a suspension is used from natural clay (20%) and water (80%).

Opencast mining
In this process the overlying soil above the seam is removed. The inflowing groundwater is pumped out. Lignite is then mined and the mine is refilled and recultivated. In Lusatia lignite is mainly mined in opencast mines.

Watershed
A drainage divide between two adjacent catchment areas whereby the water flows into two different directions, e.g. mountain ranges. However, there are also watersheds which lie underground.

Photos: Archive Vattenfall (S. 10, 13), Andreas Franke (S. 2, 3, 10, 11, 17), Rico Hofmann (S. 7, 17), Andreas Neuthe (S. 7, 17), Peter Radke (title), Rainer Weisflog (S. 4, 7, 17), Fotolia (S. 12), layout and graphics: wallat & knauth

Vattenfall Europe Mining AG
Vom-Stein-Straße 39
03050 Cottbus

Geotechnik
Dr. Stephan Fisch

T 0355 2887 2112
F 0355 2887 2188

www.vattenfall.de

VATTENFALL

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