Munich ringroad

A99 west section – Tunnel Aubing

SSF Ingenieure

History of planning

Already in the 1930s, considerations were made and finally at the beginning of the 80s things were put into practice: The west section of the Munich ringroad was planned to connect motorway A96 Lindau to motorways A8 and A99. This measure formed another part of the much frequented Munich ringroad which contributes to meet requirements of a modern infrastructure network in and around Bavaria's capital. Heart of this section of motorway A99 is the tunnel at Aubing – with 1,935 meters the longest tunnel in Bavaria.

Starting point

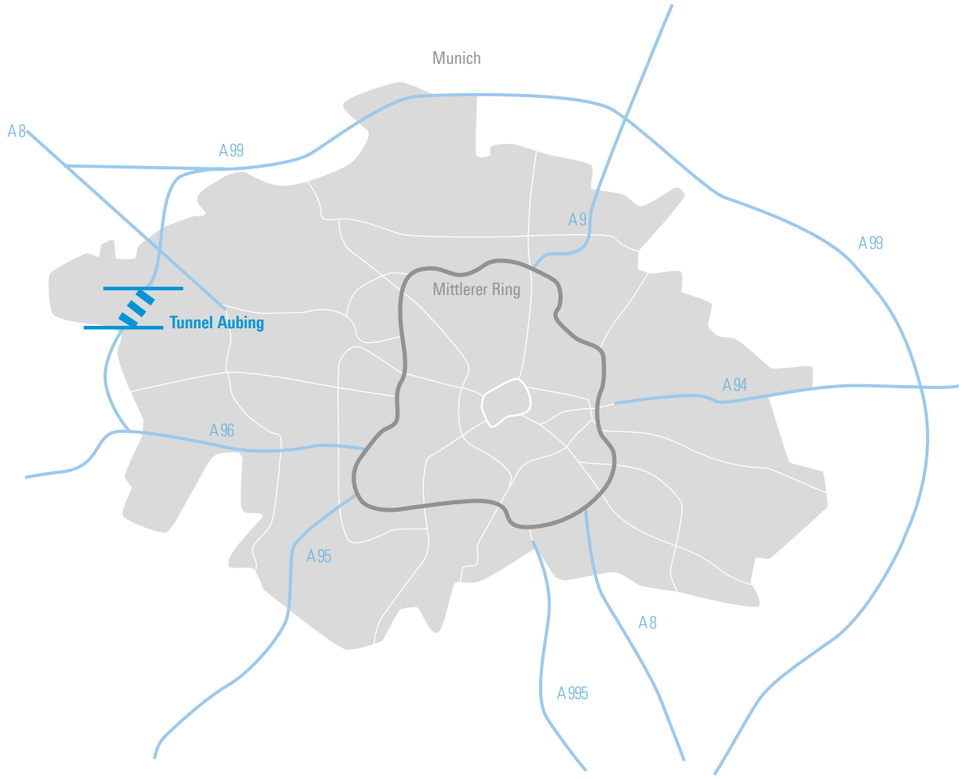
During the planning phase, the tunnel concept was modified several times also because of revised legislation for nature and environment protection. First, the approximately 1-km-long structure was extended to the north then also to the south. In this way, the wish of the City of Munich for an efficient noise protection of the newly planned city quarter Freiham was realized. The tunnel Aubing ranges over the whole section between the two railway lines from Munich to Augsburg and Munich to Lindau crossing motorway A99.

Purpose of the Munich ringroad is to take over traffic flows arriving on the motorways from Lindau, Stuttgart, Deggendorf, Nuremberg, Passau and Salzburg and to divert them around the city. This is especially important for long distance traffic: the connection between motorway A96 Lindau and the motorways in direction Stuttgart (A8 West), Deggendorf/Munich Airport (A92), Nuremberg (A9) and Passau (A94) presents an efficient distributing ring. Drivers in direction Salzburg (A8 East) use the A99 as effective alternative to the inner ringroad Munich.

Several height positions of the tunnel Aubing were assessed. The very high groundwater level was opposed to the requirement of a low position. That is why this low position was only realized in the area of the crossing railway lines. At the middle, the tunnel was covered with earth and modelled in accordance with the surrounding landscape. Together with the two ramps which were built in water-tight concrete just as a part of the tunnel, the structure is in total 2,425 meters long. With respect to the groundwater, it was built in ten sections. These so called docks were encircled with sheet pile walls and have a length of 250 m.

Data and facts	
Client	Federal Republic of Germany represented by the Authority of Motorways of South Bavaria
Construction type	tunnel in cut-and-cover method Tunnel length: 1.935 km Tunnel length incl. ramps: 2.425 km Clearance: 2 x14.00 m Depth in the groundwater: up to 7.50 m Construction costs: approx. 91 m Euro
Description	Tunnel Aubing, part of west section of federal motorway BAB A99 - ramp north (groundwater trough) - northern low-lying tunnel with undercrossing of railway line Munich - Augsburg - near-surface tunnel - low-lying tunnel with crossing of railway line Munich – Lindau - ramp south (groundwater trough) - operation room with pump stations - underpinning of railway bridges above the tunnel
Services SSF	project planning: preliminary design, draft design, final design, preparation and evaluation of tenders Structural engineering: preliminary design, draft design, preparation of tenders for tunnel and preliminary measures on railway bridges
Total length of structure	2.425 m
Ramp north	200 m
Northern low-lying tunnel	1.090 m
Near-surface tunnel	510 m
Southern low-lying tunnel	335 m
Ramp south	290 m
Lane width	2 x 12.25 m, 2-lane: 2 x 3.75 m and hard shoulder (lay-by)
Regular clear width tunnel	2 x 14.00 m
Headroom	4,80 m
Width of structure	30,40 m

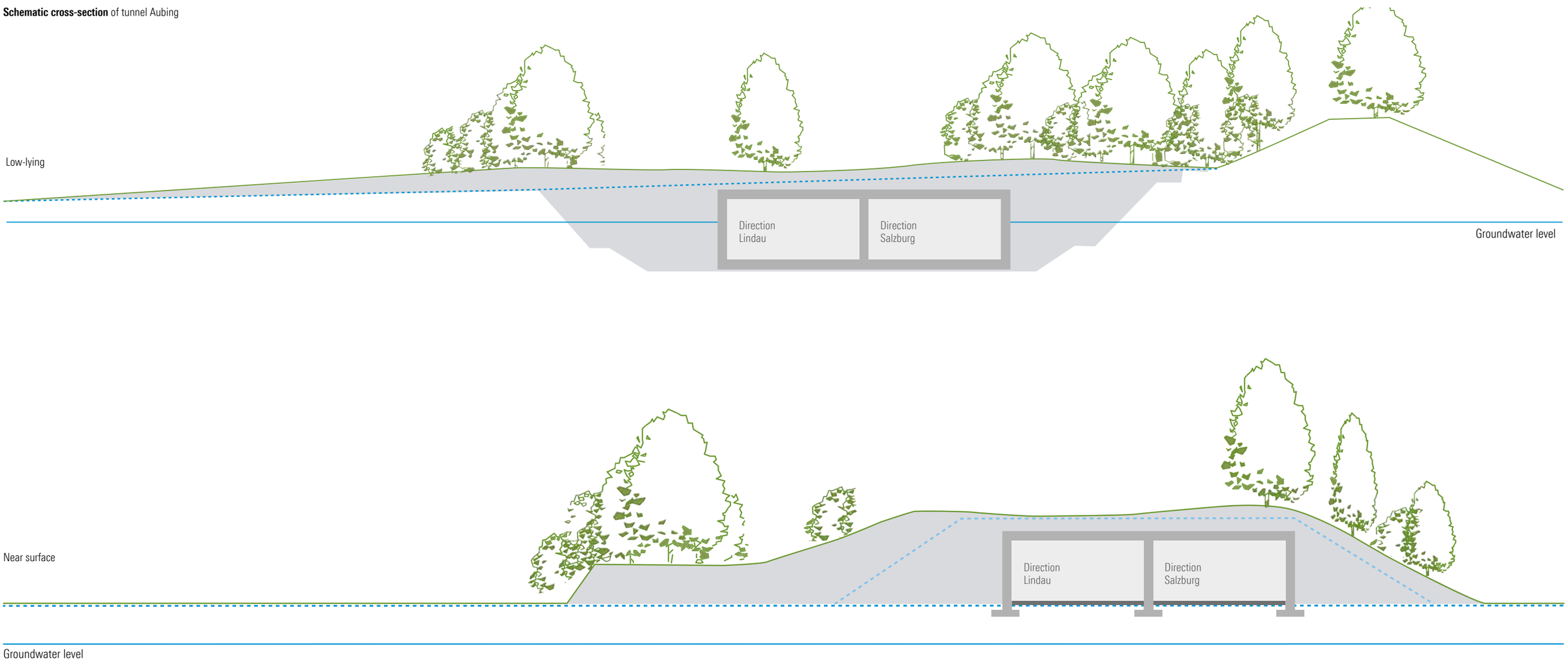
Picture credit: SSF Ingenieure GmbH / Florian Schreiber fotografie



Picture credit: ediundsepp

right above: Tunnel portal south
right below: Site plan Tunnel Aubing

Schematic cross-section of tunnel Aubing



Preliminary measures

First of all, railway bridges for the crossing lines were built in top-down construction. The covers were produced next to the railway line and inserted during breaks in operation. Pile caps and framing corners were then added; the same procedure was carried out for tunnel base and walls during tunnel construction.

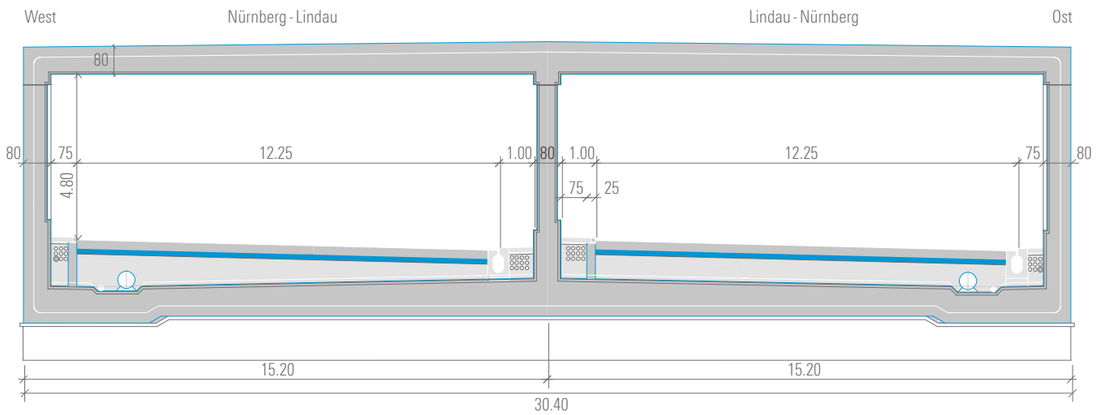
The concept

The tunnel Aubing was constructed according to the design of SSF Ingenieure in cut-and-cover method in several sections. Construction permission under water law stipulated water-tight pit lining. Construction methods where sheeting walls remain in the ground were not permitted. Starting with ramp north in form of a groundwater trough with 200 m length, the structure continues in direction south with the northern low-lying part of the tunnel (1,100 m long) and the undercrossing of the railway line Munich – Augsburg. Comes next the near-surface tunnel part (about 500 m), the southern low-lying part (undercrossing of the railway line Munich – Lindau, about 300 m) as well as ramp south, again built as groundwater trough with a length of 300 m.

The tunnel cross-section with 2 x 14.00 m clearance results from two 12.25 m wide carriageways with two lanes each, a hard shoulder and emergency paths on both sides. The smallest clearance of the tunnel structure was set at 4.90 meters according to the draft design approved by the German Ministry for Transport, Construction and Town development.

Picture credit: eduundsepp

Schematic cross-section of low-lying tunnel



Construction type	
ramps (troughs)	water-tight concrete tank, mostly with projecting foundation for anti-buoyancy effect
low-lying tunnel	water-tight closed double-cell frame (anti- buoyancy by dead weight)
near-surface tunnel	2-cell frame on strip foundations
Depth in the groundwater	up to 7.50 m
Length of concrete docks	10 m with inner joint tapes
Construction period	2002 – 2005 tunnel 2000 – 2001 preliminary measures of railway bridges

DThe gradient was planned very close to the surface due to the high groundwater. Constraint points were the two railway lines at the tunnel ends and road St 2345. In these areas the structure lies in the groundwater. Both ramps and the adjoining tunnel areas were design as water-tight concrete constructions. Between the railway line Munich – Lindau and the crossing road, which could only be lightly lifted thus necessitating a low position of the tunnel gradient, the enclosure could only be implemented on a length of 520 m near the surface above the groundwater without base slab. Crossing roads were lifted consequently.

A main sewer of the city of Munich, crossing the railway line north of the road directly under the tunnel, was another constraint point to the gradient. The 4.30 m wide and 1.63 m high concrete channel has 3 separate flow sections lying next to each other.

Construction

After pre-excavation, most parts of the construction pit were sloped. The excavated wet gravel was utilized for the later following road constructions. On the embankment shoulder, a sheet pile wall as simple sealing wall was built. This wall was inserted in tertiary groundwater-accumulating soil layers which seal the construction pit from below. To avoid soil heave within the pit, the confined groundwater – e.g. in gravels in the tertiary sands – in the pit was discharged by wells. The design of SSF

Picture credit: SSF Ingenieure GmbH

Picture credits: Autobahndirektion Südbayern/Authority of Motorways South Bavaria

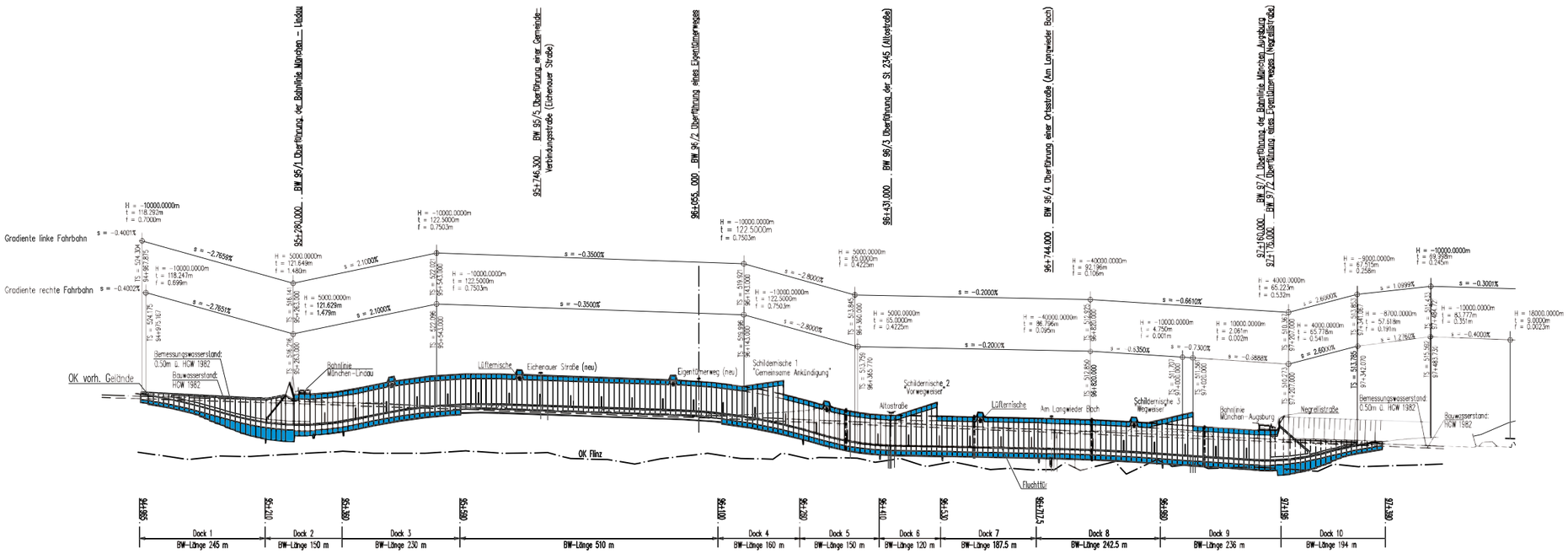
1

2

3

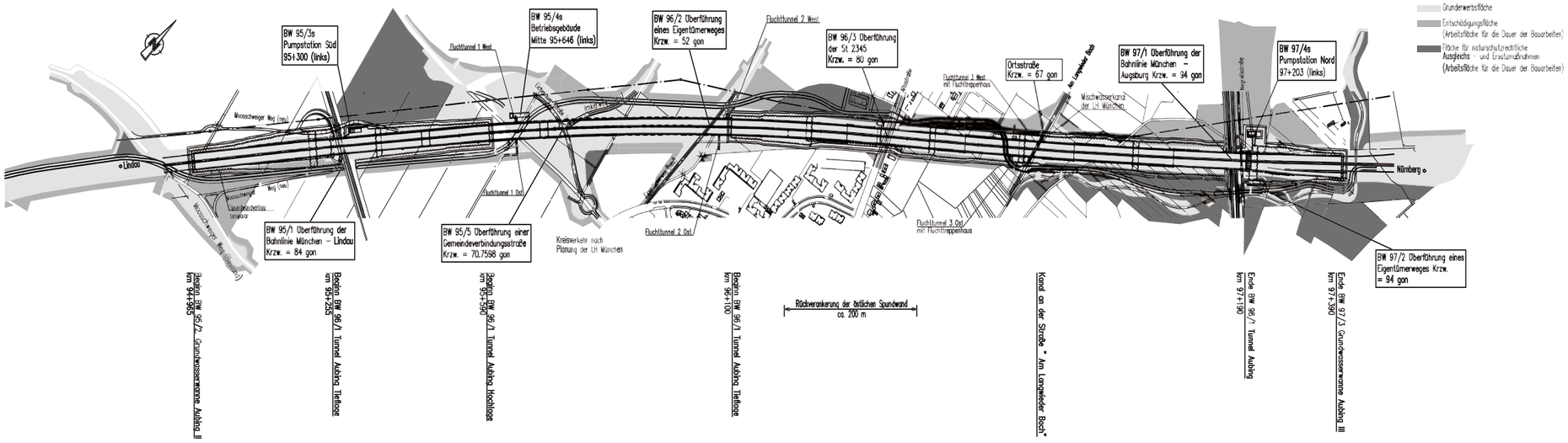
4

1 **Pre-excavation** in the northern low-lying area
2 **Plugging** of bulkhead between docks
3 **Concreting** of dock 4
4 **Operation** room central



Ingenieure planned in total ten docks separated by bulkheads. Between the water-tight, at maximum 250 meter long sheeting sections one dock was left as "gap" enabling the groundwater to flow freely during construction. Today this function is fulfilled by four pipes diverting the groundwater. These pipes are concreted into the tunnel base. A groundwater siphon consisting of a pipe DN 300 crosses the tunnel and leads into a concrete shaft at the external tunnel walls. Around 50 to 60 m long horizontal drainages (DN 300), which run parallel to the tunnel, are connected to these shafts. Their vertex lies approximately 0.5 m underneath the height of low groundwater levels. This drainage system collects the groundwater flowing in a wide stream at one side of the tunnel and then siphons it by a pipe underneath the tunnel and drains it to the other tunnel side.

The low-lying tunnel was built as closed double-cell frame according to the principle of waterproof concrete tanked slab with a length of 10 m per section in the regular areas. Tunnel base and external walls were concreted in one go in order to avoid shrinkage cracks. The area of the near-surface tunnel was implemented as double-frame on strip foundations, the ramps are water-tight, buoyancy-proof troughs.



Alignment and top view

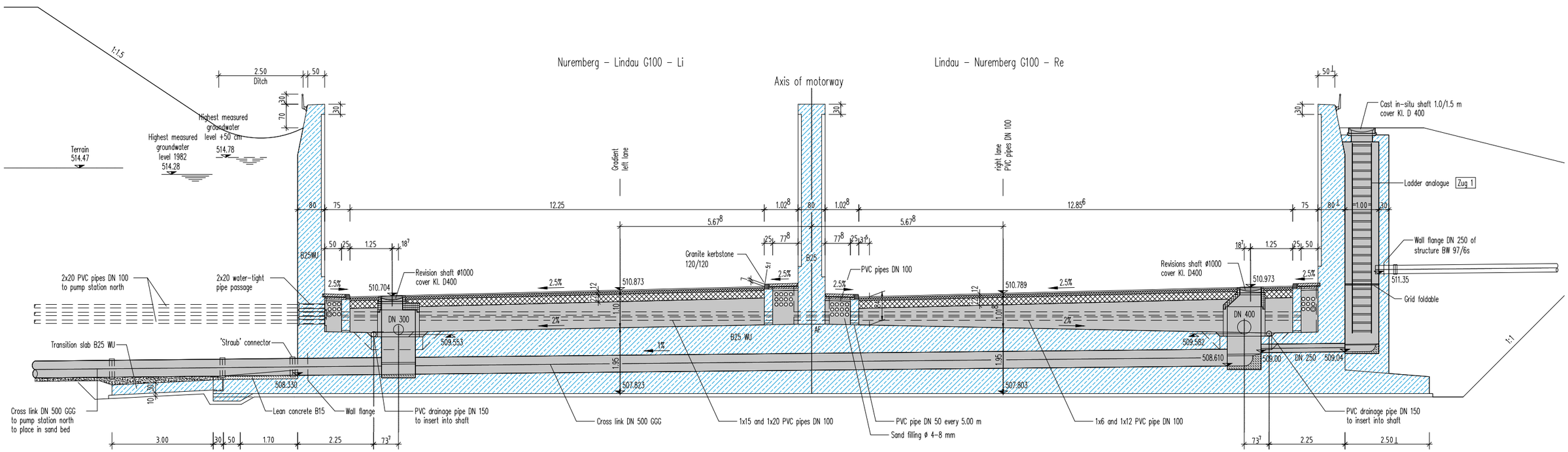
Picture credit: SSF Ingenieure GmbH

The entire tunnel was constructed in cut-and-cover method. In the areas of the ramps in low-lying position and at the transitional areas to the near-surface parts, groundwater-protecting, water-tight sheet pile walls were utilized which were inserted in the sufficiently large construction fields next to sloped pits without back-anchorage, otherwise with back-anchorage. They were inserted by jetting assisted vibrating and if needed by pre-drilling supports. They reach at least 1 m in the tertiary soil. For construction of adjoining sections, additional bulkheads were installed. The sheet pile walls are inserted into a depression in the tunnel base of the finished section and remain in the ground. After concreting onto lateral extensions of the tunnel walls, the relevant bulkhead was removed.

The upper side of the tunnel ceiling has a light pitch of 1.1%, the bottom view is horizontal. The base slab's upper side is, in transversal direction starting from the middle axis, inclined by 2% to the outside to divert seeping water from the carriageway. At the transitions to the near-surface parts, upturned edges in form of an apron reach underneath the binder course of the continuous road to avoid infiltration of groundwater at the end of the low-lying

Picture credit: SSF Ingenieure GmbH

Cross section trough



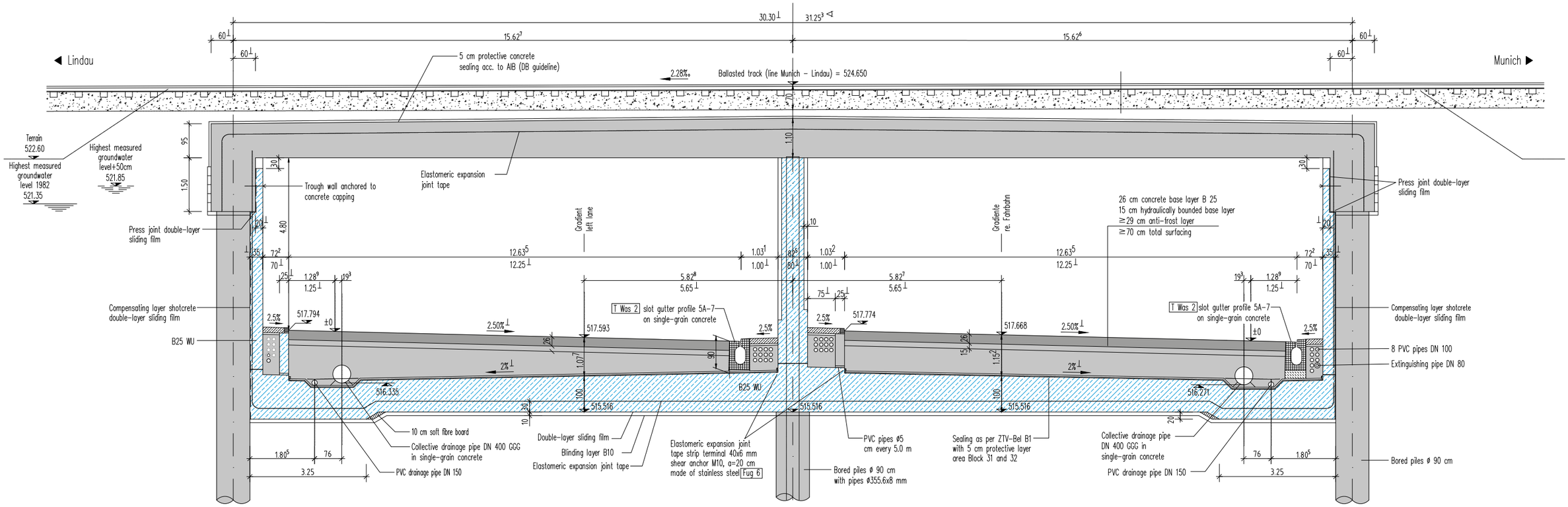
Picture credits: Autobahndirektion Südbayern/Authority of Motorways South Bavaria

tunnel sections. A joint was formed in the covering layer. In the area of the crossing of the main sewer, the tunnel base had to be lifted because of the height position within the antifreeze area.

Above the dimensioned water level, the tunnel was implemented without water-tight base slab as frame on two spans, founded on strip foundations. The strip foundations were executed continuously without expansion joints in order to avoid different settlements; in larger sections construction joints were implemented staggered to the expansion joints of the walls. On the foundations, emergency paths are arranged within the tunnel underneath of which run the cable ducts and slot gutters on the sides. Slot gut-

1 **Aerial photograph** during construction
2 **Formwork traveller** in the near-surface area
3 **Concreting** of dock 4
4 **Construction of new** carriageway structure
5 **Final state** without road marking

Cross-section Tunnel in the area of railway bridge 95/1



ters and cable ducts are protected from infiltrating groundwater by a small water-tight reinforced concrete wall connected to the foundation. At the transitions from near-surface to low-lying sections, each time the first bloc was constructed outside of the low-lying tunnel docks with a closed base slab such as a low-lying dock. For operational reasons, it was necessary to construct first of all the parts near the surface. Between near-surface and low-lying sections a 10 m wide gap remained for transversal sheet pile walls of the neighbouring dock. Only after completion of the low-lying section and removal of the sheet pile wall, was it possible to close the gap. Here, one bloc was completed with a continuous base slab with a limited groundwater lowering. By this construction method, soil pressures were minimized and differential settlements to the adjoining already consolidated blocs reduced.

Picture credit: SSF Ingenieure GmbH

The ramps were constructed as trough cross-sections, partially with middle wall, made of water-tight concrete without construction joints. The length of the troughs is determined by the dimensioned water level (1982 + 0.50 m).

At the ends upturned edges in form of aprons reach underneath the binder course of the continuous road. At a distance of 10 m, dock joints were formed. There was no safety against buoyancy in the low-lying section caused by the permanent loads of the construction when the thickness of the base slab was to be maintained. In addition to a thicker base slab, lightly dimensioned lateral projections of the base slab were used to activate loads of the earth above against buoyancy. The earth was planned as overload up to 1 m under the top edge of the ground.

Operation and Safety

After only 34 month of construction, the tunnel carcass was finished in mid-2005. Afterwards, all installations for operation and safety in the tunnel were assembled – of course according to the latest state-of-the-art. To keep the tunnel operational at all times, two pump stations and one operation room were built. Basis for planning of the operational technical equipment was the German directive for equipment and operation of road tunnels (RABT) from 2003. Energy supply of the tunnel consists of two independent (redundant) inputs by transformer stations supported by an uninterruptible power supply (UPS)

Entry lights as well as fire emergency lights and escape route markings are assembles as well as emergency lighting in case of fire and escape route marking. Jet fans are switched on automatically in case of need. Emergency call units, fire detection systems, radio and loud speaker installations as well as continuous video surveillance and a traffic control system complete the technical safety devices. The whole system is of course integrated into a master control system. Also from a structural point of view, priority was given to safety. Two tunnel shafts separated by directions with each time continuous hard shoulders and emergency paths on both sides assure best possible safety together with the emergency exits at a distance of 60 m entering into the neighbouring shaft and into the open at a distance of 450 m and 12 walkable emergency niches with fire extinguishers and emergency telephones.

Visualisation Tunnel Aubing

Visualisation: edundsepp

Technical equipment and safety installations

Basis for planning of the operational technical equipment was the German directive for equipment and operation of road tunnels (RABT).

Overview of technical equipment:

- energy supply of the tunnel consists of two independent (redundant) inputs by transformer stations supported by an uninterruptible power supply (UPS)
- entry lights as well as fire emergency lights and escape route marking.
- ventilation control automatically switches on the emergency call system
- fire call installation
- loud speakers and radio telephone system
- continuous video surveillance is assured by automatic incident detection
- traffic management scheme
- master control system

Special security measures:

- two tunnel shafts separated by directions with each time continuous hard shoulders and emergency paths on both sides
- emergency exits at a distance of 60 m entering into the neighbouring shaft and into the open at a distance of 450 m
- a redundant, failsafe energy supply with separated supply units
- the most important safety relevant installations are supplied by uninterruptible power supply (UPS)
- a fire detection system with heat-sensitive detection cables and additional push button alarm in the emergency telephone niches
- a comprehensive video surveillance with automatic incident detection in case of congestions, pedestrians, stopping vehicles or vehicles driving in the wrong direction as well as generation of smoke
- 12 walkable emergency niches at distance of 130 m in each tunnel shaft with each time 2 fire extinguishers and telephones
- radio installations for rescue workers and continuous VHF radio distribution with voiceover possibility in case of emergency
- 24 jet fans per shaft for elimination of smoke and flue gases in case of fire and supply of fresh air
- so called quenching water niches at a distance of 60 m with hydrant connections, hose reels with 30 m hose and also fire extinguishers and push button alarms for the fire detection system
- slot gutters to conduct leaking liquids from the tunnel to the retaining basins
- a master control system to inform the monitoring personnel at the traffic control centre in Munich Freimann but also the police department Munich West and the responsible motorway authority in Inning round the clock about all relevant operation and emergency alerts as well as deliver images from the video surveillance
- continuous optical guidance by LED on the emergency paths
- self-luminescent escape route marking with distance indications
- emergency lighting at ca. 1 m height (escape orientation for persons in the tunnel in case of smoke)
- traffic control installation of the A99 west also in the tunnel Aubing
- tunnel barriers for block-off

above: Tunnel portal North
below: Tunnel portal South

SSF Ingenieure

SSF Ingenieure AG
Consulting Engineers

Munich
Berlin
Halle
Cologne

www.ssf-ing.de

Title: SSF Ingenieure GmbH / Florian Schreiber Fotografie