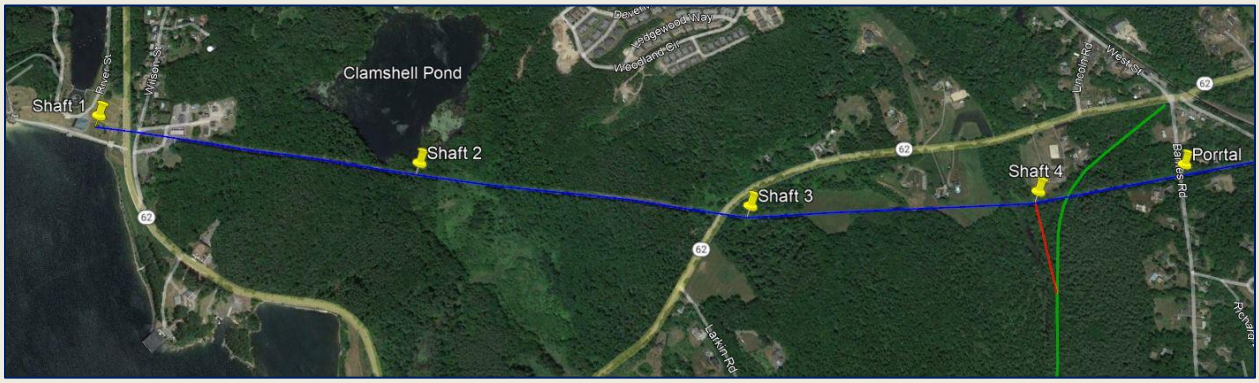
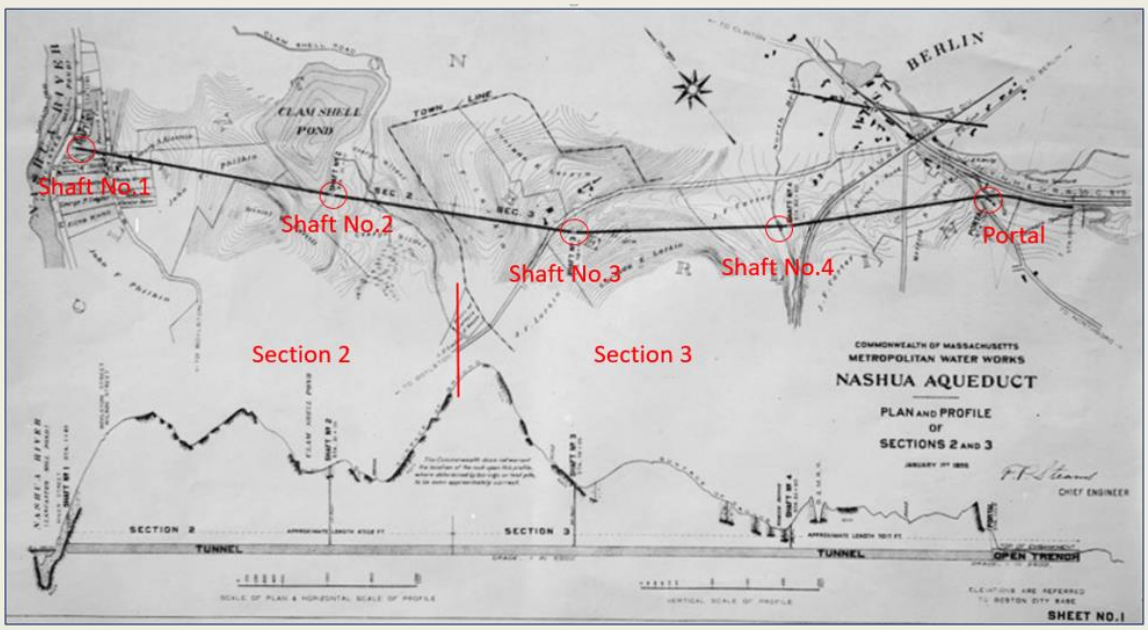
Wachusett Aqueduct

The Hard Rock Tunnel

Sections 2 & 3



The Tunnel through a Hill.



Wachusett Aqueduct, plan and profile of Sections 2 and 3.

The Wachusett Aqueduct would lead water from the Wachusett Reservoir twelve miles to mingle with that of the Sudbury Reservoir before continuing on to the metropolitan area.

The first leg of that journey would be in a hard rock tunnel traverse the two miles between the Lower Gate House (powerhouse) at the Wachusett Dam and a portal at the Derby Road area in West Berlin

Four vertical shafts (about 8-10 feet in diameter) were sunk along the path of the aqueduct with the tunneling excavation proceeding between them in two directions at once. It would be quite a feat of engineering to guarantee that the tunnel met at the midpoints between the shaft, but that is exactly the way it happened.

The shafts and tunnels.

Shaft No.1 – (50 feet deep) about a hundred feet away from the powerhouse
Shaft No.2 – (111 feet deep) at the south shore of Clamshell Pond
Shaft No.3 – (90 feet deep) about 300 feet easterly of Boylston Street in Berlin
Shaft No.4 – (34 feet deep) about 1,200 feet westerly of Barnes Road in Berlin
Portal – adjacent to Derby Road in Berlin

From the start date of the project in June 5, 1895 the aqueduct study and design process lasted eight months and a contract for the tunnel work was awarded on February 12, 1896 to the E.D. Smith & Company.

The Shafts

Shaft No. 4 (34 feet deep)

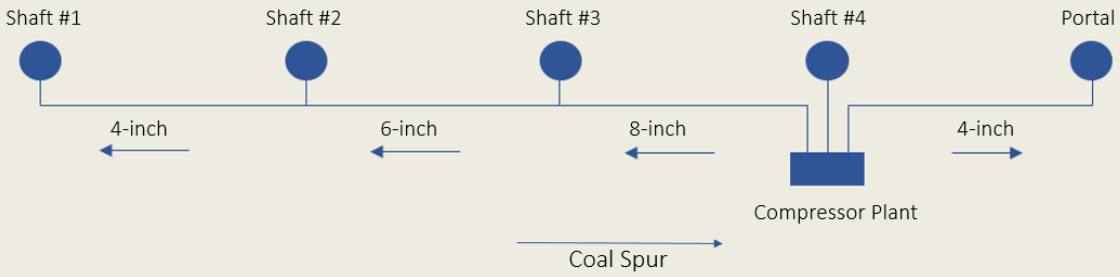
The work of the rock tunnel was first started at Shaft No. 4 because it was closest to a rail road and more central to the entire aqueduct tunneling. The work proceeded from there east and west to the other shafts.

The top priority for this contract was the power source (compressed air) required to run it. The installation of two large air compressors took about six weeks after which excavations at Shaft No. 4 in Berlin began March 31, 1896.

Plant and equipment in full operation at Shaft No. 4 in Berlin.

A side-track was put in from the Central Massachusetts Railroad to a point near Shaft No. 4. A very complete plant was provided for excavating the shafts and tunnel, the whole of the machinery, including drills, pumps and hoists, being operated by compressed air.

Air Compressors and Distribution Scheme



The compressor plant consisted of two double Rand duplex compressors, having cylinders 20 by 36 inches, the compressors being rated at about 250 horsepower each. Four boilers, of 100 horsepower each, were set up near the compressors at a point where coal could be unloaded directly into the boiler house.

From the compressors the compressed air was conveyed to shafts Nos. 3, 2 and 1 through wrought iron pipes 8, 6 and 4 inches in diameter, and to the portal by a pipe 4 inches in diameter. The most distant shaft is about 1.5 miles from the compressors, and the air is furnished to it with but little loss of pressure.

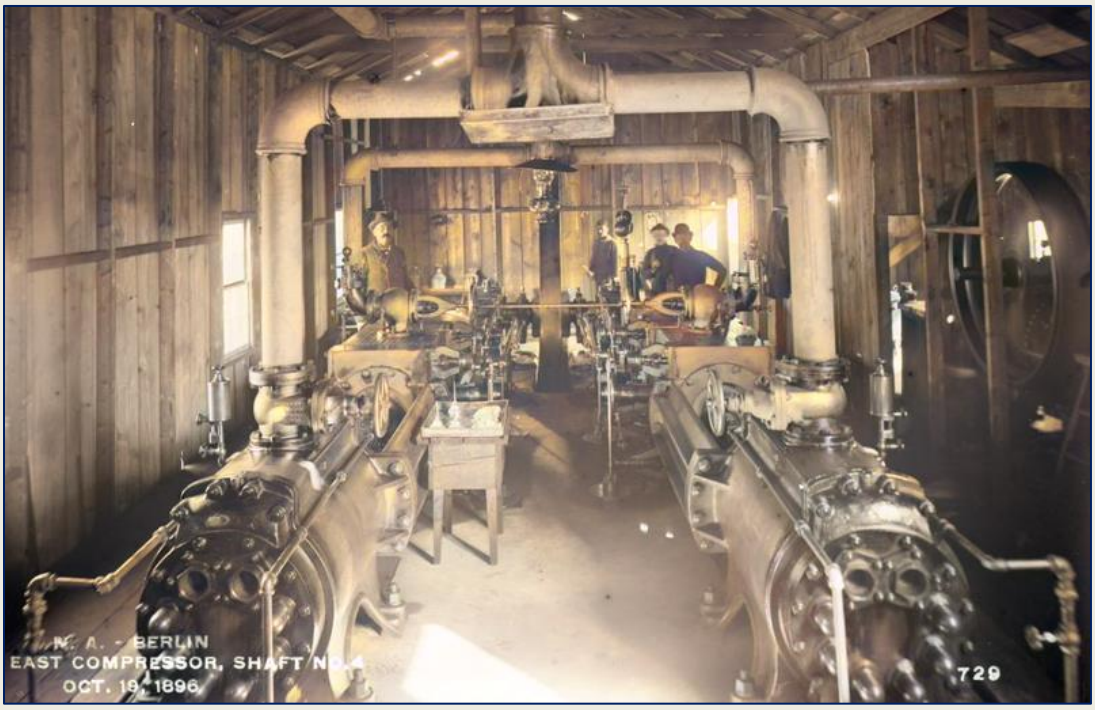
Annual Report of the Chief Engineer for the year 1896

Installing compressor flywheel at Shaft No. 4, from the east.

The water tower was there to provide water to the boilers.

Compressor at Shaft No. 4, from the east.

Note the sloping eight-inch airline in the foreground which will supply the other shafts.



East compressor plant.

West compressor plant.

Start of excavation for Shaft No. 2 (circled).

Railroad spur from the Central Massachusetts Railroad can be seen entering the site from the left. A steam derrick swings rock from the new shaft to the tailings dump. The hoisting platform is on the ground to the left. An eight-inch compressed air supply pipe leads off to Shaft No. 3, a half mile away.

Headhouse at Shaft No. 4.

The four-inch line in the foreground supplies compressed air to the twin cylinders (near the shack door) which hoist a tracked platform by wire rope from the tunneling below ground. The horse then draws the mine car loaded with rock tailings along a track to a dumping ground. Total crew above ground is the hoist operator, the car switcher and a driver with the horse.

Tailings dump at Shaft No. 4.

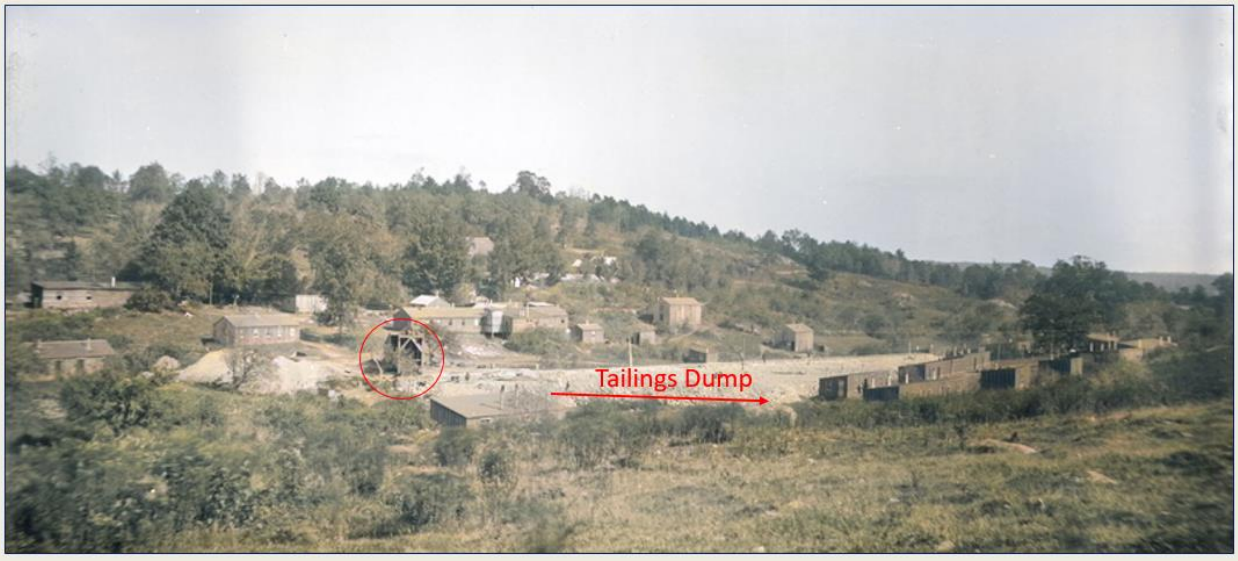
On the top of the shaft a small, circular gray brick house was built to facilitate access to the tunnel.

Final cleanup of Shaft No.4 site.

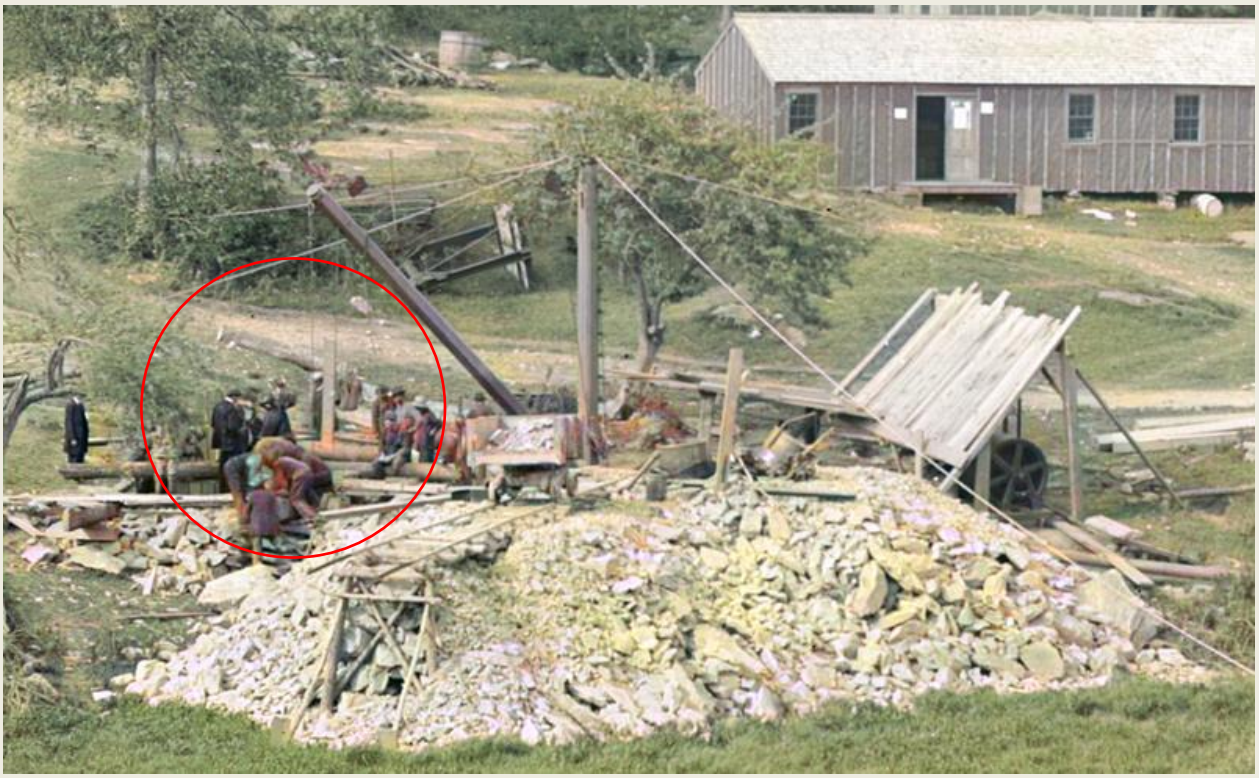
Shaft No. 3 (90 feet deep)

The contractor's administrative headquarters were located at Shaft No. 3 about 300 feet easterly of Boylston Street (Route 62) in Berlin. Here also was located housing for the 300 itinerant laborers who actually performed the work.

Excavations at Shaft No. 3 in Berlin were started on April 20, 1896, three weeks after the start at Shaft No.4.

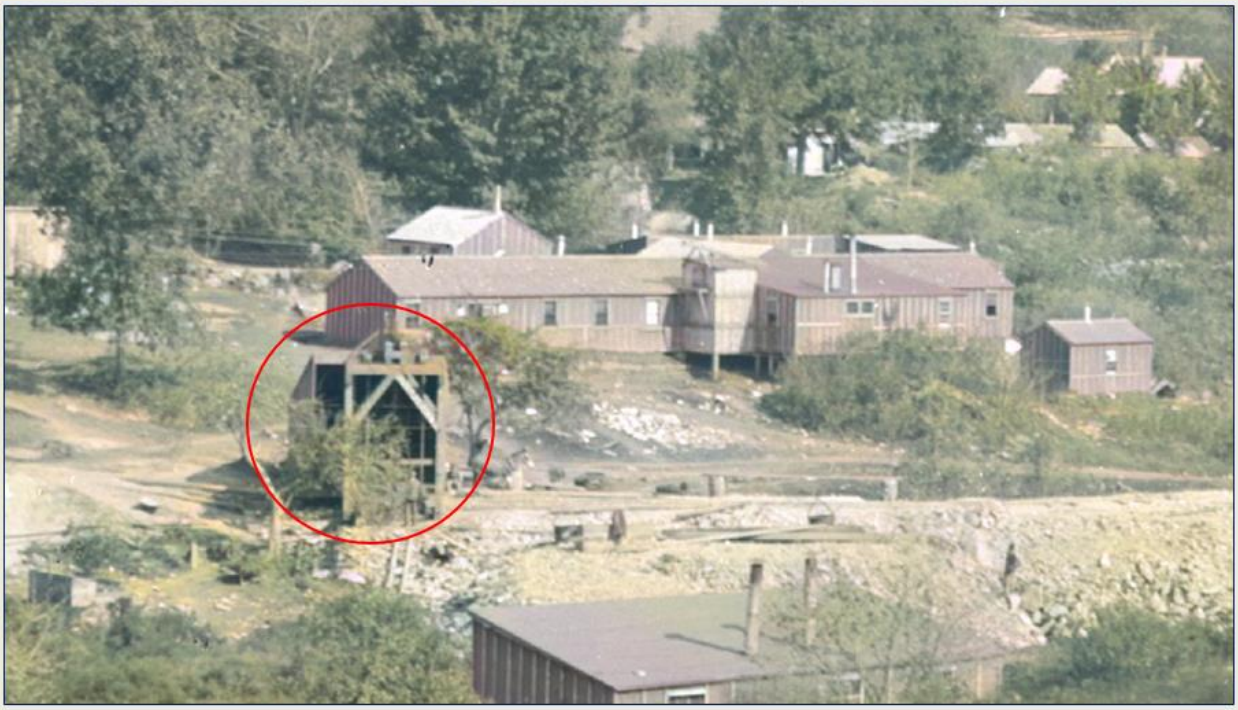


Shaft No. 3, contractor's headquarters and labor camp.



Start of excavation at Shaft No. 3 (circled).

The derrick is lifting tailings onto the mine car.

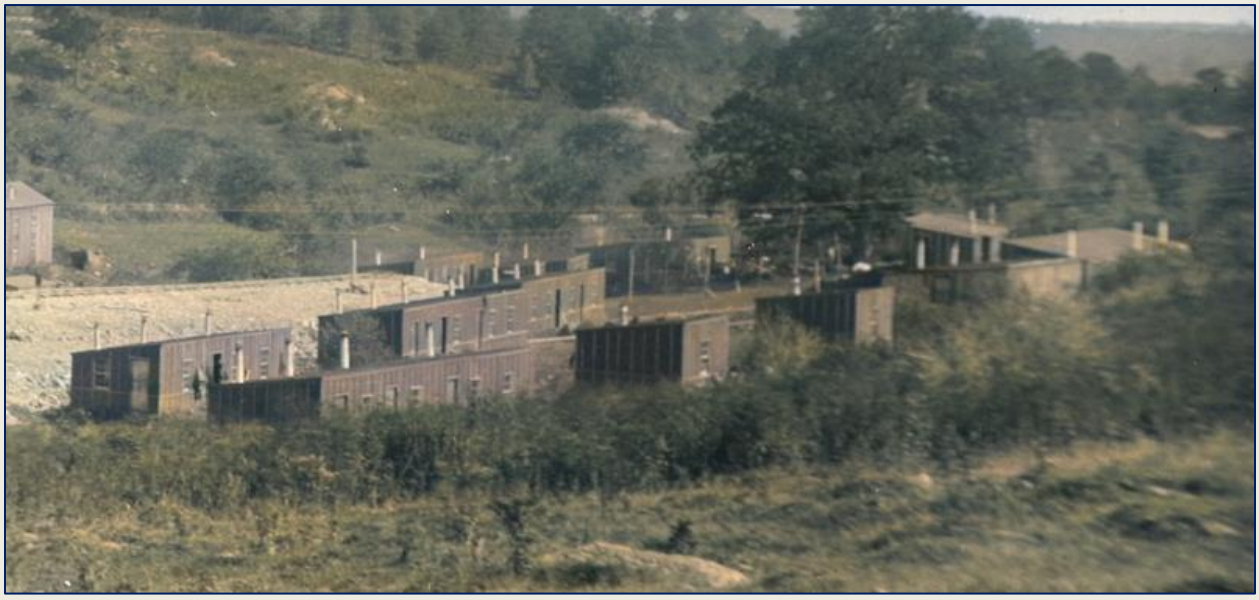


Shaft No. 3 and headquarters buildings.

Headhouse at Shaft No. 3.

Here two surveyors watch as a tender positions a mine car on the lift platform for return to the tunnel while the driver and his horse await the next car. Inside the building the lift operator prepares to lower the platform to the tunnel 90 feet below.

The eight-inch airline passes near the horse's hooves and continues up the slope (six-inch) to Shaft No.2.



Well maintained labor barracks.

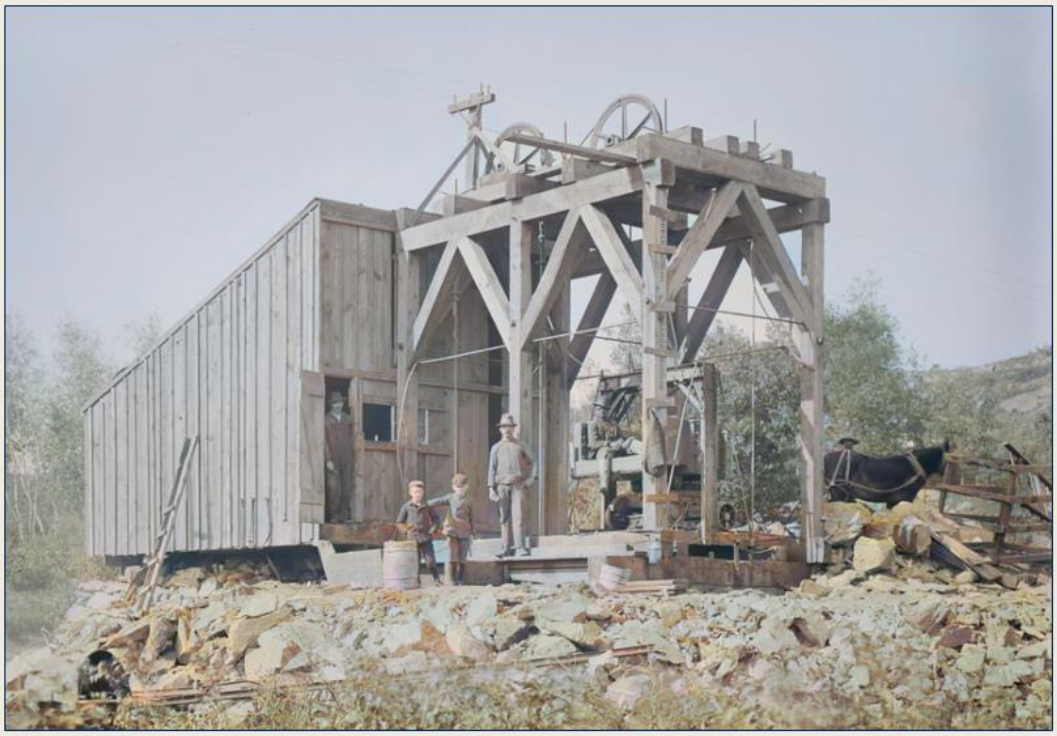
Shaft No. 3 was plugged and filled after the completion of the work and is not readily observable today.

Shaft No. 2 (111 feet deep)

Shaft No. 2, situated on a narrow high ridge on the southerly shore of Clamshell Pond in Clinton, was the deepest of all the shafts at 111 feet. Excavations here began on May 5, 1896 after the 2,745 foot long, six-inch airline reached it.

Start of operations at Shaft No. 2

The six-inch airline was reduced to a four-inch line and extended to Shaft No. 1 adjacent to the dam.



Headhouse at Shaft No. 2.

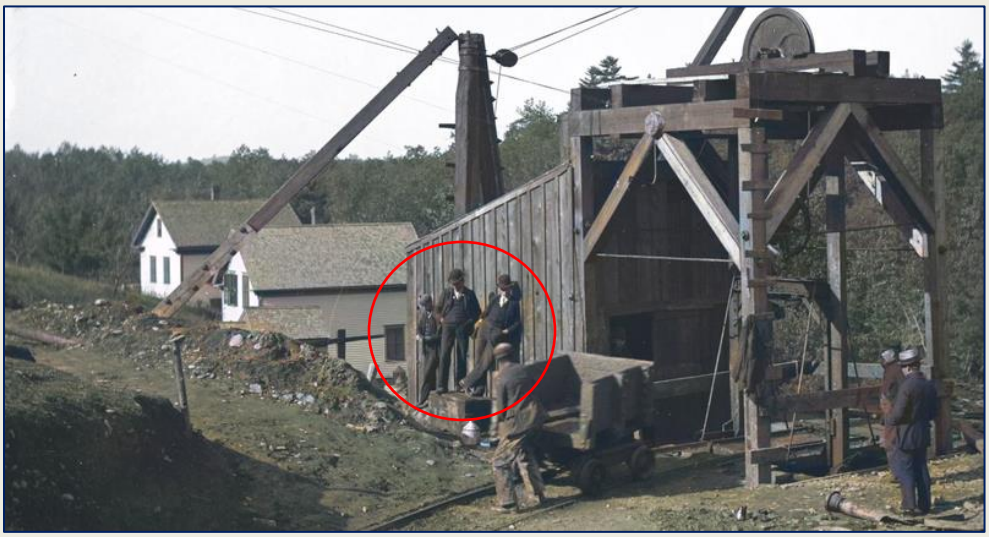
The mine car on the hoisting platform is being returned to the tunnel far below. That is Wilson Hill in the distance to the right in the direction of the dam site. On this day, a Saturday, one worker has brought his two sons with him to work.

Shaft No. 2 at Clamshell Pond.

Shaft No. 1 (60 feet deep)

Shaft No. 1 was located at the westerly terminus of the contractor's tunnel. Work was started there on June 27, 1896, four months after the contract award, after the four-inch airline finally reached it from Shaft No. 4 about a mile and a half away.

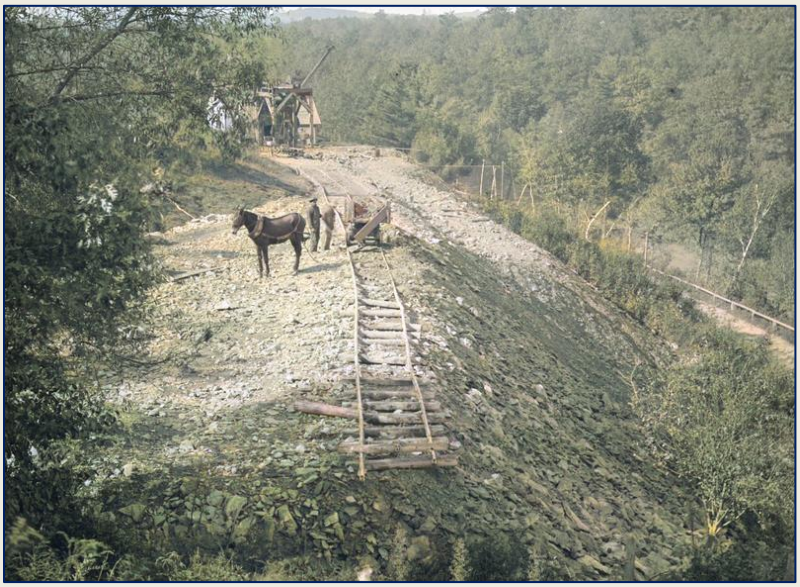
This shaft was the one closest to the dam and just 21 feet of tunnel were excavated beyond it. Final connection to the Lower Gate House (powerhouse) would not be made for until five years later in 1902.



Shaft No. 1 in Clinton, adjacent to the proposed dam.

A mine car is being loaded onto the lift platform for return to the tunneling below.

The boys observing might be waiting for the Worcester streetcar, in operation from 1903, to arrive at a local stop at Boylston Street about fifty feet up the slope to the left.



Driver and horse dumping tailings along a track.

Shaft No. 1 tailings dump along River Street.

Shaft No. 1 was not filled in, as were the others, so the connection to the Lower Gate House (powerhouse) might be made at a later date.

The aforementioned Worcester streetcar can be seen passing on Boylston Street above Shaft No. 1.

The Portal

The Portal, located at the extreme easterly end of the rock tunneling at Derby Road in Berlin, had no vertical shaft. Rather, it was started at grade as a horizontal entrance to the tunnel.

Excavation of the approach to the Portal was started on July 27, 1896 after 2,178 feet of four-inch airline reached it and after work at all of the other shafts and tunnels was well underway.

The Portal approach excavation to the tunnel.

Driver and horse dumping tailings from the Portal, April 27, 1897.

The Portal, August 3, 1897.

The tunnel Portal at Derby Road.

The Tunnels

Once the vertical shafts had been excavated to the correct elevation horizontal drilling and blasting was started between them in both directions simultaneously.

In tunnel work, a "heading "is first excavated, which comprises only the upper half of the tunnel, and the lower half, or "bench," is excavated subsequently.

The Surveyors

The surveyors had great responsibility to ensure that the tunnels, under excavation from two directions at once, aligned exactly when they met at the midpoints between the shafts.

Surveyor in the tunnel with rubber boots, hand lamp and pipe.

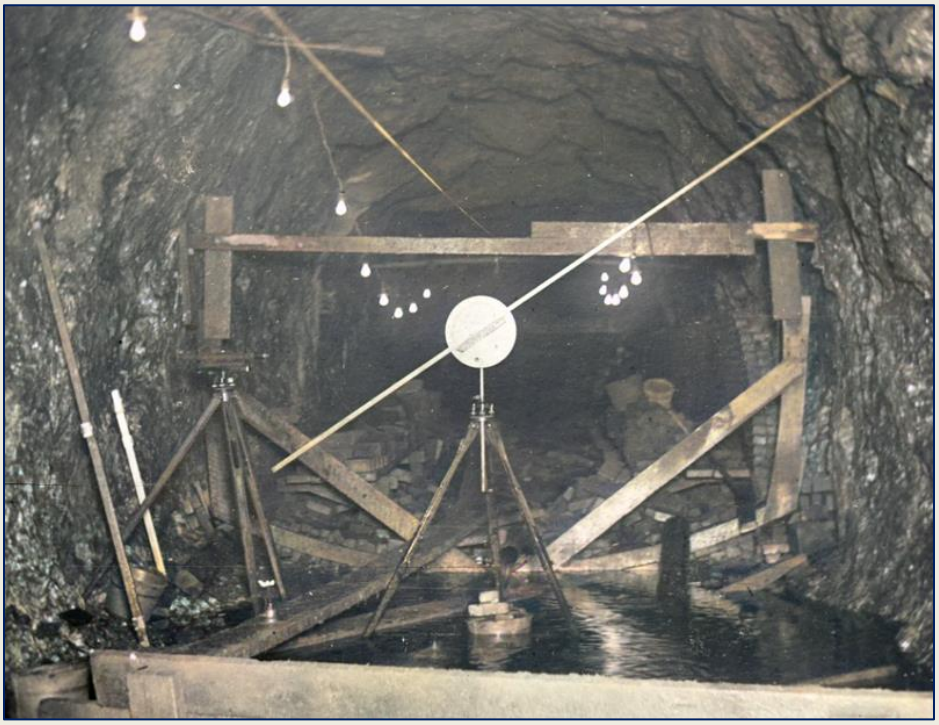
Surveyor with transit inside a partially completed tunnel.

Here, the tunnel heading has been temporarily reinforced with heavy timbers to prevent collapse. About half the length of the rock tunnel would require permanent reinforcement.

Precise alignment apparatus below Shaft No. 1.

This device transferred the horizontal alignment from surface to the tunnel below.

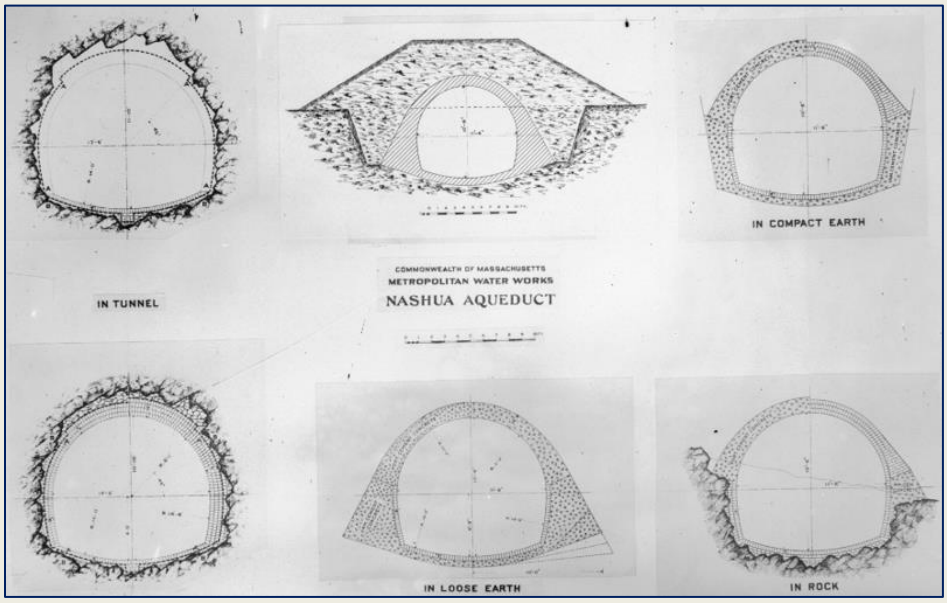
Note the air cylinders to the left there to raise and lower the hoisting platform and power the rock drills. The four-inch airline (all the way from the compressors at Shaft No. 4) powered this equipment as the work proceeded along the tunnel.



"Sunflower" cross-section machine in tunnel.

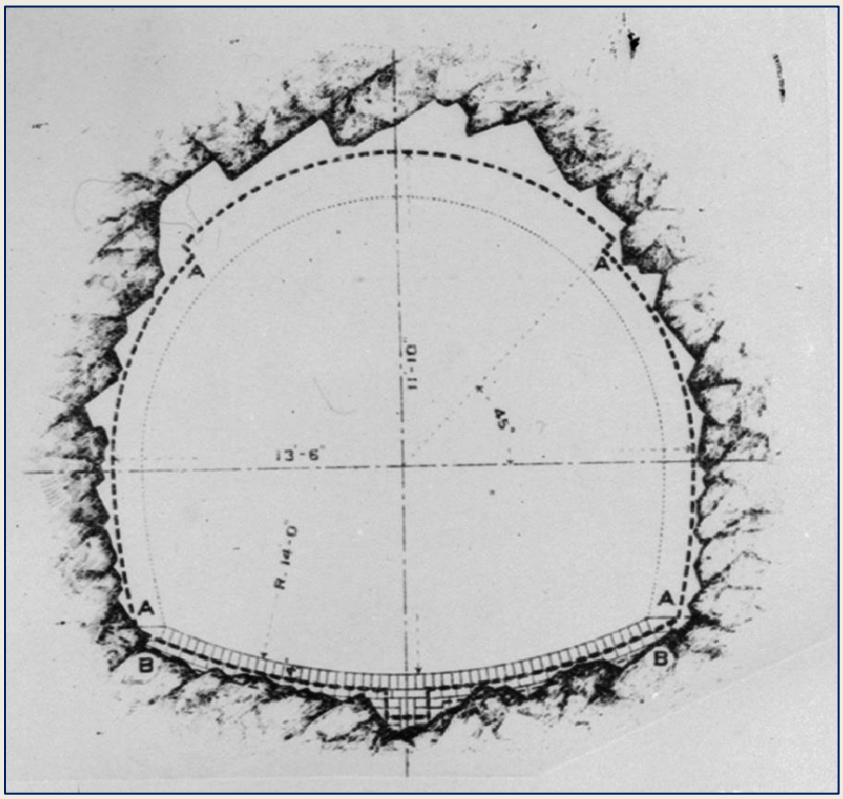
The adjustable arm measured the correct distance from the tunnel centerline to the rock face.

Typical Tunnel and Aqueduct Details



Typical aqueduct geometry. All sections followed a common centerline.

Self-supporting Tunnel Sections



Tunnel cross-section in rock.

In self-supporting sections like this the only brick used if for the flow line, or invert.

Rock drilling by lamplight.

Excavating the heading beyond electric light and in wet conditions. The airline powers rock drills while heavy steel jacks help keep the heading in place. Once blasted, the loose rock will be manhandled into the mine cars on tracks and drawn back to the vertical shaft and hoisting platform.

Excavating at a typical rock face.

Here, the heading is self-supporting and bench has been extended as far as possible for loading.

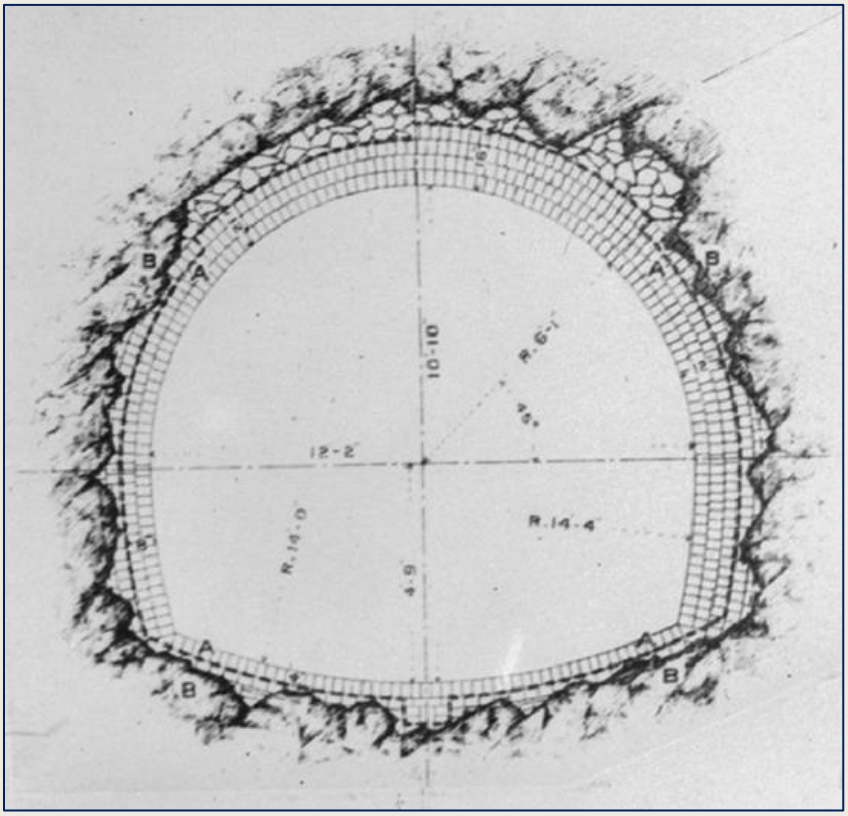
These men are loading drilled and blasted rock into a mine car. Note the airline on the left. The horse will haul the car back to the vertical shaft and hoisting platform.

A note on the horses:
Horses were kept stabled in the tunnels but were likely rotated periodically with those above ground. The horses were also the reason for ten-foot shaft diameters as they, like everything else, had to be lowered into and hoisted out of the tunnel through them from above.

Section of tunnel below Shaft No. 2, in rock with brick invert.

Section of tunnel in rock with brick invert.

Reinforced Tunnel Sections



Section of tunnel showing details where brick lining was required.

Loose blasted rock at tunnel heading.

Brick liner on entire perimeter.

Arched forms were installed below the timbering to support the brick lining. A minimum of three rings of brick (12 ½ inches) was installed with mortared rubble filling the space above that. The top timbering could not be safely removed and was left in place but the side lagging was generally taken out.

In such cases, as much timbering was removed as possible, and cement grout was pumped in behind the brick rings and behind the timber, to thoroughly fill all vacant spaces

Typical completed section of brick lined tunnel.

The invert of the tunnel, the side lining for 12 1/2, inches from the interior of the tunnel and the arch, were built of brick masonry, laid in mortar. The backing behind the 12 1/2 inches of brickwork at the sides was generally made with stone from the tunnel, laid in mortar.

Transition from unlined rock to brick lined tunnel.

The contractor finished its work on the hard rock tunnel late in 1897.

Initial opening of the Wachusett Aqueduct.

On March 7, 1898 in Clinton the pure waters of the Nashua River were first turned into the Wachusett Aqueduct (with all of its sections completed) and delivered to the newly completed Sudbury Reservoir.

The engineers had met their responsibility for providing water to the metropolitan area in just over two years thereby relieving the anticipated shortage.
