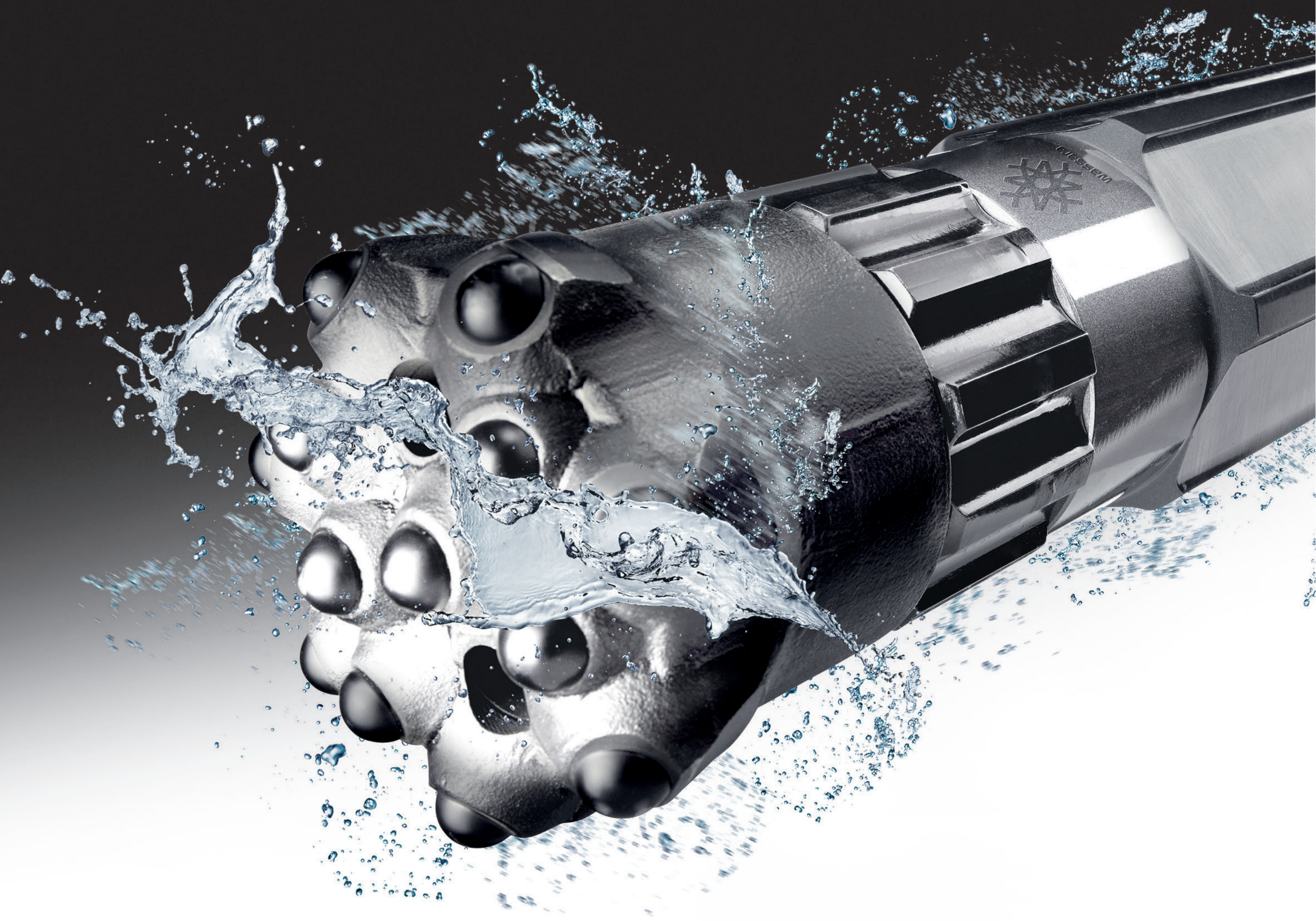
wassara



WATER POWERED DRILLING

The water hydraulic DTH technology

We are very proud of our water-powered DTH hammer. Intense development work through the years has given an absolutely unique product where water is used to power a drill system. The water-powered drilling has numerous features and benefits, proven by over 20 million meters of boreholes in LKAB mines alone.

Johan Jeansson, Senior Technical Specialist, LKAB Wassara

STRAIGHT FORWARD DRILLING

The Wassara technology uses water to power the down-the-hole (DTH) percussion hammer. This makes it the superior choice for many drilling applications where air-powered DTH hammer, top hammer or rotary drilling equipment are normally used.

Drilling technologies over the years

The mechanised drilling in mining operations started some 140 years ago with the invention of the pneumatic top hammer. Productivity demands have forced development in new technologies, and the possibility to drill long and straight holes gave a huge step in this direction. The most recent major innovation in drilling came with the water-powered DTH hammer from Wassara.

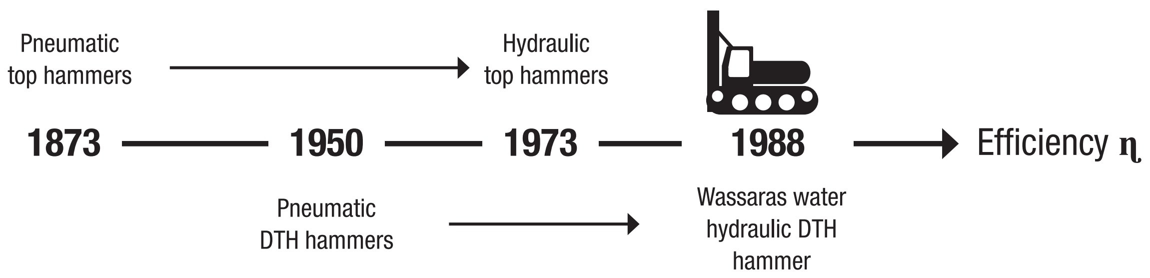
Wassaras water-powered DTH hammer is the most environmentally friendly percussion drilling method existing today. The DTH hammer is powered by water. No oil is used for lubrication, meaning no contamination of air or water. The water is effectively suppressing dust as well.

The incompressibility of water is a key factor allowing the features of the Wassara hammer system. It also gives a major energy cost saving compared to air DTH technology, and reduces the energy demand to power the hammer

Wassara applications

A selection of applications where drilling with Wassara makes a difference:

- Grout holes in dams and ground engineering
- Jet grouting
- Sensitive formations
- Casing advancing
- Precollaring in mineral exploration
- Long holes in underground mining

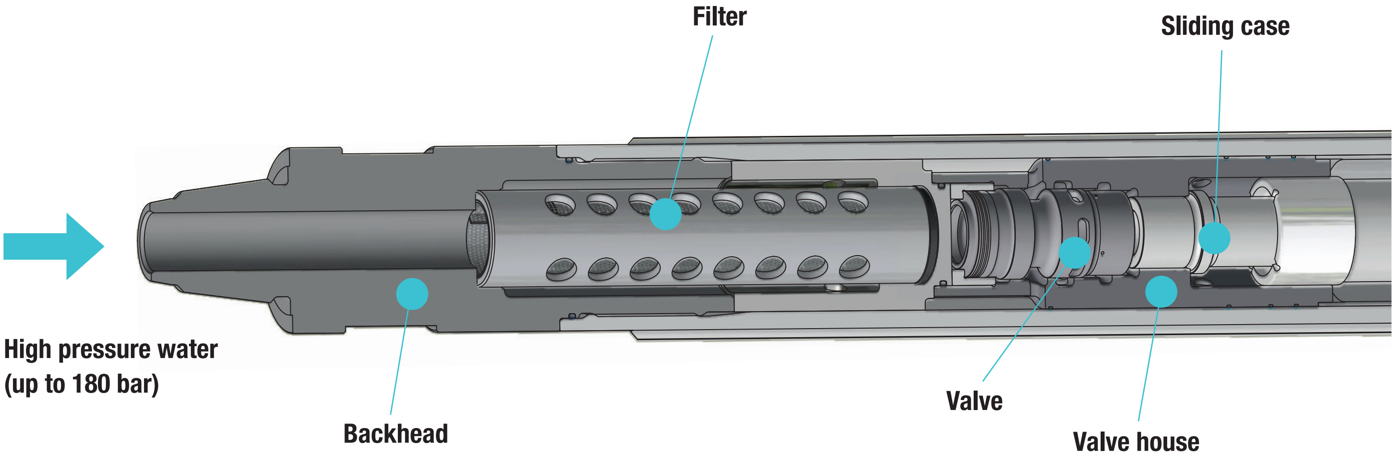


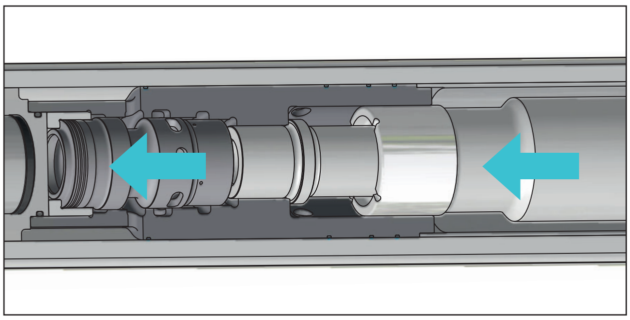
HOW WASSARA WORKS

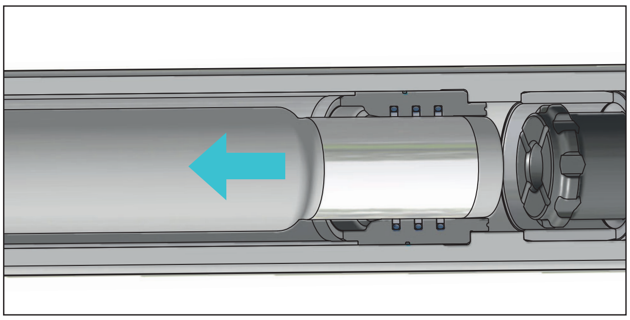
The DTH hammer

The Wassara hammer is ideal for use in hard, stable rock drilling applications and overburden drilling applications that require casing systems. Compared to conventional air-powered DTH hammers or top hammers, water-powered DTH hammers offer a wide range of advantages, including low energy consumption, a cleaner environment, minimal hole deviation, deeper drilling capabilities, a high power output ratio and minimal impact on the surrounding ground.

Wassaras DTH hammer consist of only two moving parts: the piston and the valve. With so few moving parts, the smart solution delivers reliable high performance drilling in the most challenging conditions. Water, at up to 180 bar delivery pressure, is used to power the impact mechanism of the hammer at a high frequency rate. When the water leaves the hammer, it loses the pressure and keeps a low flush velocity. This however is still adequate to bring any cuttings to the surface and clean the borehole. Additionally, the hydrostatic column, which is created above the hammer, helps to keep the hole stable while preventing potential collapse. This also prevents water from being drawn into the borehole, which increases hole stability and prevents potential environmental issues.







1 The valve is opened and the piston moves back from its striking position.

2 The piston gets in position, ready to strike.

Unrivalled performance

The piston in a DTH hammer always strikes directly on the drill bit. A top hammer, on the other hand, loses approximately 4-6 % of impact energy at each drill rod connection, as the percussion unit is located on the drill rig.

When comparing an air-powered DTH with a water-powered DTH, which, in principle, work the same way, there are significant differences. The energy per blow can be expressed as follows:

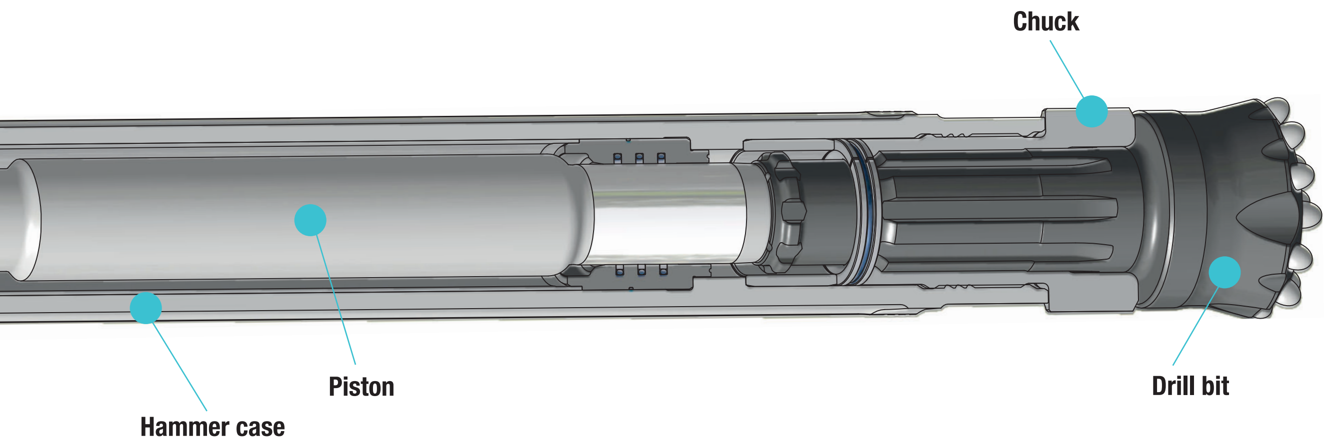
$\mathbf{E}$ equals the piston mass, $\mathbf{m}$ times the piston impact velocity, $\mathbf{v}$ squared and divided by 2.

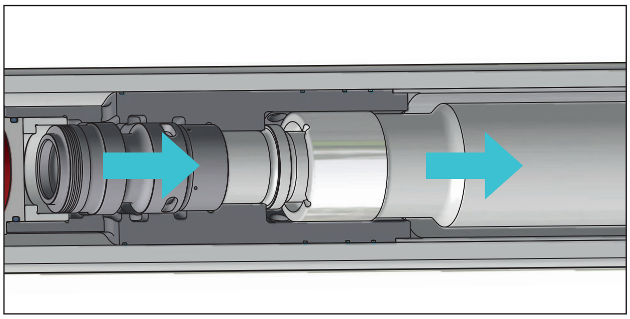
$$\mathbf{E} = \frac{\mathbf{m} * v^2}{2}$$

The output power $\mathbf{P}$ equals the pressure $\mathbf{p}$ of the medium powering the piston, times the pistons pressurized area $\mathbf{A}$, times the piston impact velocity $\mathbf{v}$, all divided by 8.

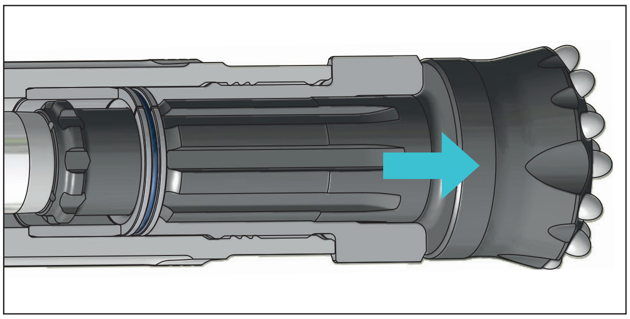
$$\mathbf{P} = \frac{\mathbf{p} * \mathbf{A} * \mathbf{v}}{8}$$

The piston mass and the pressurized area are determined by the diameter of the hammer case and are therefore rather fixed. The impact velocity depends on the piston material characteristics and is therefore also a parameter which cannot be significantly improved. But the pressure of the medium powering the DTH hammer is a parameter that can be considerably increased/ improved, for a hydraulic hammer.





3 The valve closes and the high-pressure water forces the piston to strike.



4 The piston strikes the bit. The valve opens to release the water through the bit. A new cycle starts.

WATER-POWERED DRILLING – SAFE AND BENIGN

High performance drilling

Water is a non-compressible medium. This means the same volume of water is required regardless of the desired pressure. Air, however, is a gas and therefore compressible. Practically this means that we need (x) times more flow if we want (x) times higher pressure. The two can be expressed as follows:

Water: $\mathbf{V}_a = \mathbf{V}_c$

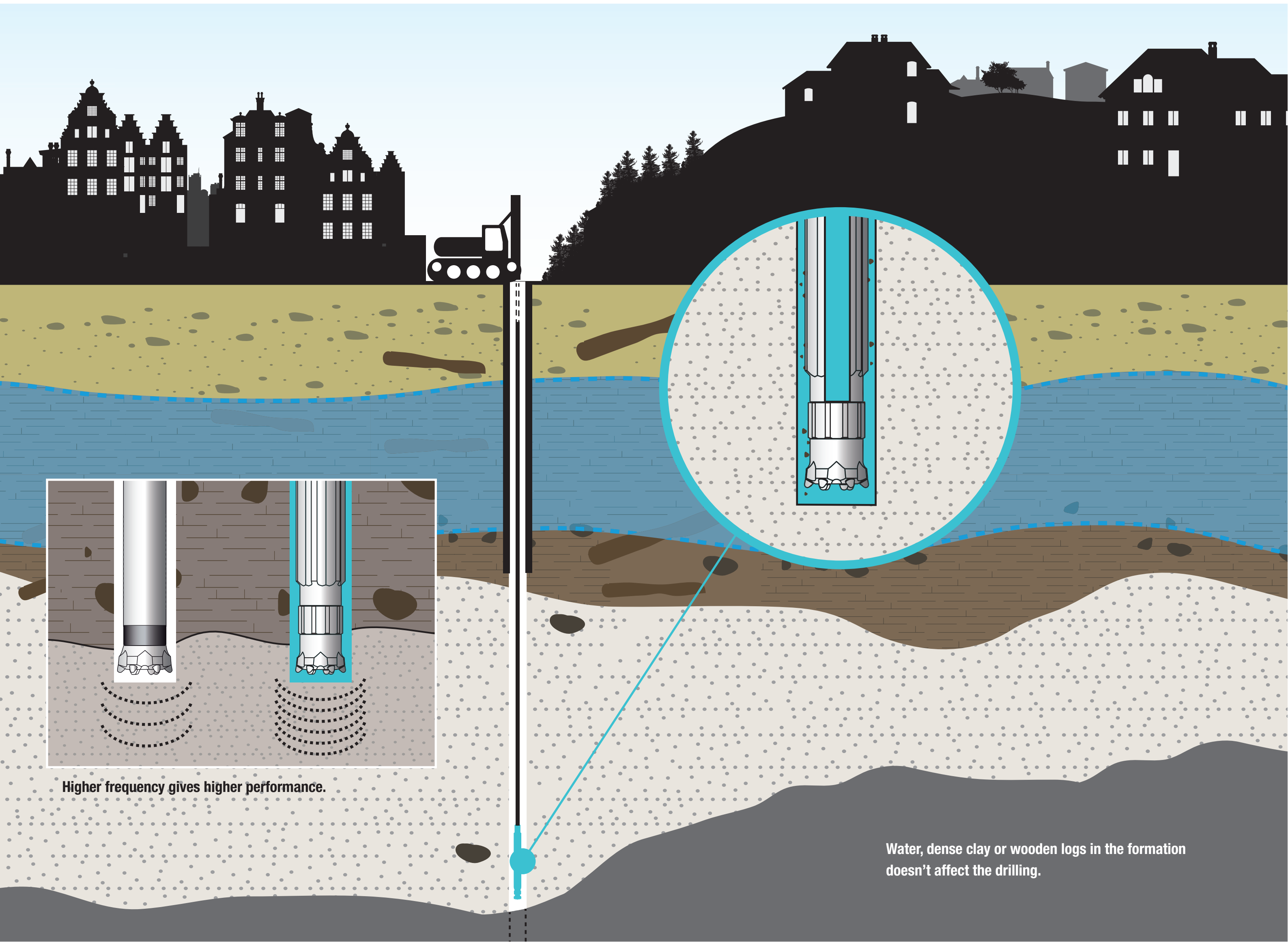
Air: $\mathbf{V}_a = \mathbf{V}_c (p_c / p_a)$

Where $\mathbf{V}$ is the volume, p is pressure, a is atmospheric state, c is compressed state

The result of the higher pressure is a higher striking frequency, i.e. more blows per minute. As a comparison, a 4 inch water-powered hammer (W100) at 180 bar (2611 psi) will generate 3 600 blows per minute, consuming only 3-6 liter per second (48-95 USgpm).

A 4-inch air hammer, powered with 30 bar (435 psi) compressed air, will generate approximately 2 000-2 700 blows per minute and consume approximately 100 times more, 350-450 liter of air per second (618-794 cfm).

Another big difference occurs when drilling below the water table of a borehole exposed to inflowing water from the surrounding formation. A 200 m (650 ft.) deep borehole full of water is equal to a 200 m (650 ft.) water column. When drilling with an air-powered DTH system, this water column must be lifted, generating a 20 bar (290 psi) pressure loss. A water-powered DTH system will not suffer from this since there is water both on the inside and the outside of the drill string. The only pressure losses that need compensating for are inside the drill string and the differences in density (water vs. slurry).



Higher frequency gives higher performance.

Water, dense clay or wooden logs in the formation doesn't affect the drilling.

Safer drilling in sensitive formations

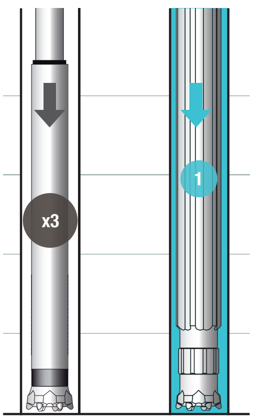
A significant change occurs when the medium (air/water) leaves the hammer and changes function – from powering the DTH hammer to acting as a borehole cleaner and bringing the cuttings up to surface. As soon as water – which is not a compressible medium – leaves the drill bit, the pressure drops considerably and reaches the state of hydrostatic pressure.

Air, however, expands as soon as it leaves the drill bit and enters the surrounding formation. The air starts expanding, accelerating the cuttings up towards the surface at a speed of up to 80 meter per second (179 mph). This exposes the drill string and, even more importantly, the surrounding formation to high levels of stress. Unstable soft formations are at even greater risk, as compressed air will always find the "easiest" way out. This can be through the formation rather than up through the borehole. Accordingly, drilling in sensitive formation, such as close to a dam or in an inner city environment, can result in severe damage to the surrounding infrastructure.

Urban areas are usually "sensitive" in the sense that they have a limited capacity to absorb movements and/or changes in groundwater levels due to drilling operations. Furthermore, the injection of air or oil into the ground is typically prohibited. Due to the incompressible nature of the water flush, and its low "up-hole velocity", over-pressurization risks are minimized. This is not the case with compressed air.

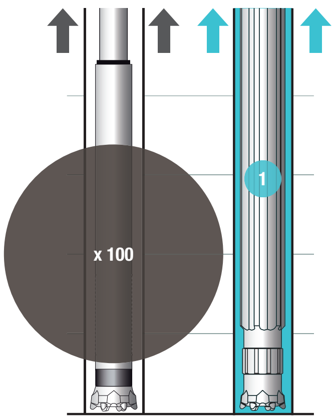
Water-powered DTH's do not create dust and do not require any lubricants, the water used to power the hammer is the lubricant.

Incoming volume



Air **Water**

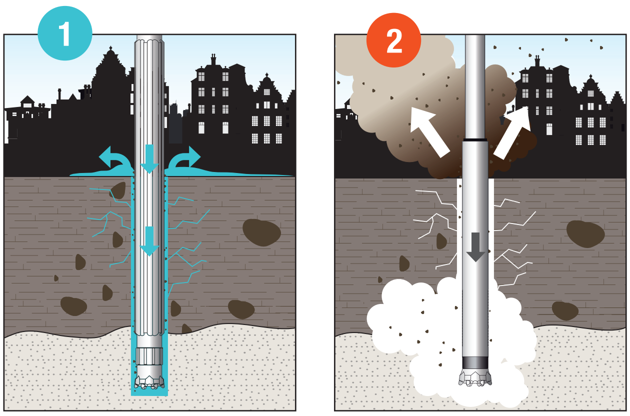
Outgoing volume



Air **Water**

No pressurising of the formation

1 Wassara 2 Air



Water-powered drilling (left image) minimises the risk of pressurising the formation

Better borehole quality and accuracy

The main difference between air-powered and water-powered DTH drilling is the fact that the water hammer has stabilizer ribs along the hammer case. The diameter created by the ribs is matched with the drill bit diameter and can be as tight as Δ 1-2mm to ensure that the hammer is straight aligned in the borehole. The reason this set up is feasible for the water hammer and not the air hammer is the multifold lower flow and up-hole velocity. The air hammer requires much more annulus space to evacuate the expanding air that is about 100 times greater in volume. The expanding air causes a "cutting up-hole velocity" of 50-80 meter per second (111-179 mph) (in relation to 0.5-2 meter per second (1-5 mph) for water). This wears out the guide ribs in virtually no time.

The energy E in every particle flushed to the surface is equal to the particle mass m times the square of the velocity v divided by two:

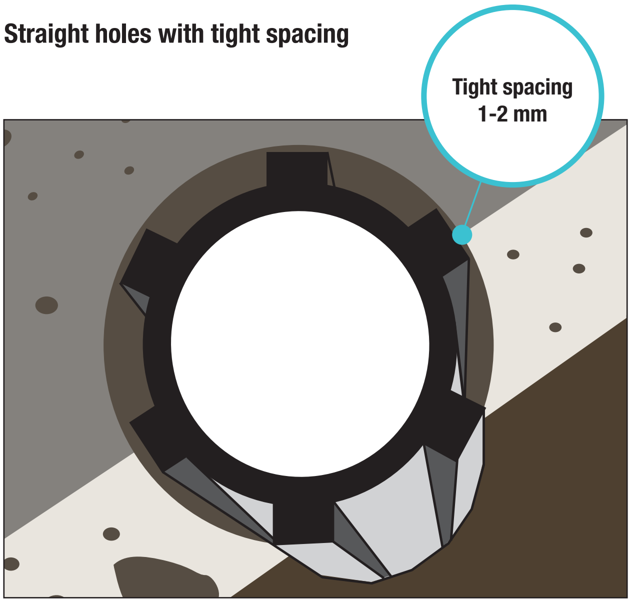
$$\mathbf{E} = \frac{\mathbf{m} * v^2}{2}$$

This results in approximately 3000 times higher energy (*J*) per particle, which causes severe wear on the drill string.

Using water as a flushing medium also has a secondary effect in terms of borehole cleaning. This is important if the purpose of the borehole is for injection of cement (grouting) for ground improvement. Dust (compressed air + cuttings) clogs cracks, while the water cleans the borehole. This increases both productivity and quality in the grouting process.

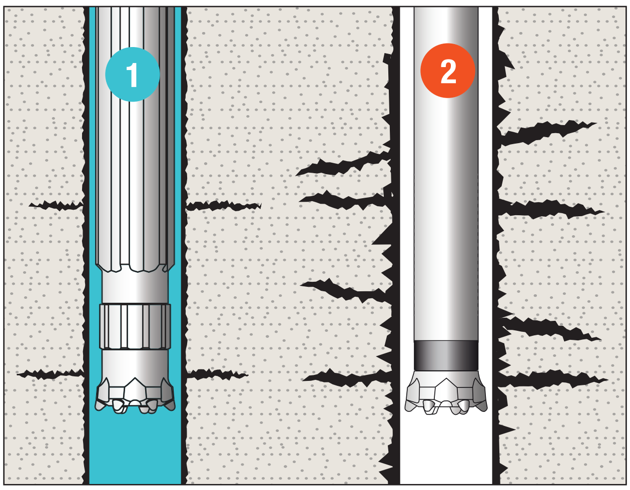
Drilling performance suffers in top-hammer drilling because the percussion unit is mounted at surface on the drill rig. Striking further and further away from the drill bit not only affects the performance negatively when drilling deeper, it also, in combination with a thinner drill string, interferes with borehole deviation. Top hammer drilling is prone to a deviation of 5 % - 10 % of the length of the borehole with excessive deviation after > 20 m (66 ft.). Water-powered DTH is extremely accurate when compared to top hammers as the percussion unit is placed in the bottom of the borehole.

Straight holes with tight spacing



The low velocity of the return water minimizes the wear on the hammer guide ribs, making it possible to keep a tight clearance between hammer and borehole.

Clean borehole surface

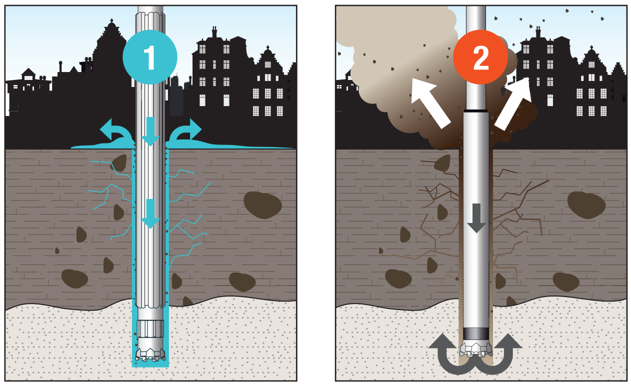


The water-powered drilling doesn't erode the borehole (left)

1. With Wassara **2.** With air-powered DTH

Less environmental impact

Water-powered DTH requires a power source with less than half the installed power, compared with air-powered DTH. This is despite the fact that a water-powered hammer runs at significantly higher operating pressure. This equates to 3-5 times less diesel consumption for water power versus air power for a similar size DTH hammer. Obviously, the CO_2 emissions are directly correlated to this. If taking into account the possibility of running with an electric pump, we will find a reduction of 99% in CO_2 emissions in comparison with the diesel powered compressor setup.



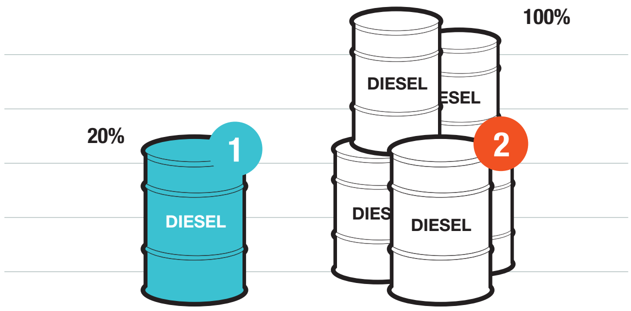
Wassara gives no introduction of oil or dust to the ground or to the air

Better working conditions

All mechanical machines need some kind of lubrication to operate over their lifetime. A water-powered hammer uses the pressurized water for more than just powering the hammer and bringing the cuttings to surface. Water also acts as a lubricant and eliminates the need for any oil. This means that the ground is not polluted and workers or people in the vicinity are not exposed to oil mist or dust caused by the drilling process. This is particularly important in underground work sites where ventilation is limited.

With an air-powered DTH hammer, the lubrication is usually done by continuously adding oil to the drill string. The oil not only lubricates the hammer mechanism, it also follow the air through the hammer and out into the rock formation and environment.

Water-powered hammers are also considerably quieter than top hammers, as the percussion unit is down the borehole. The sound level is also significantly lower compared to air DTH, since the borehole is almost always full of water, dampening the noise.

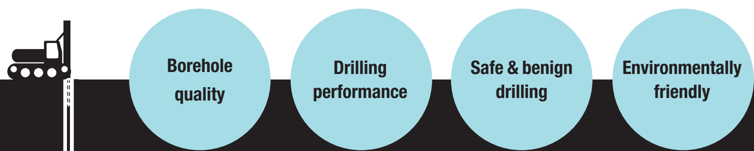


There is a clear difference in power consumption

Cost efficient

Total project costs

Calculating total costs for a drilling project all aspects needs to be considered.



The total project cost is often affected by the drilling operation

- Cost of fuel and compressor rentals – Water-powered drilling has 3-5 times less power consumption.
- Project time – When drilling in difficult formations, water-powered drilling has proven to be a versatile method effectively coping with hard, soft and water rich formations. This ensures the projects stays on time.
- Efficiency – In many applications water-powered drilling is several times faster than conventional methods. The Wassara method has similar accuracy as core drilling, still 2-5 times faster. When drilling longer holes, Wassara maintains speed over total length.
- By using the unique Wassara Jet grouting technology, several steps in the process can be eliminated.
- Wear on hammers and drill string is often considerably less due to the low up-hole velocities, hammers can also be repaired with service kits to maximise lifetime of equipment.

COMPARING DRILLING TECHNOLOGIES

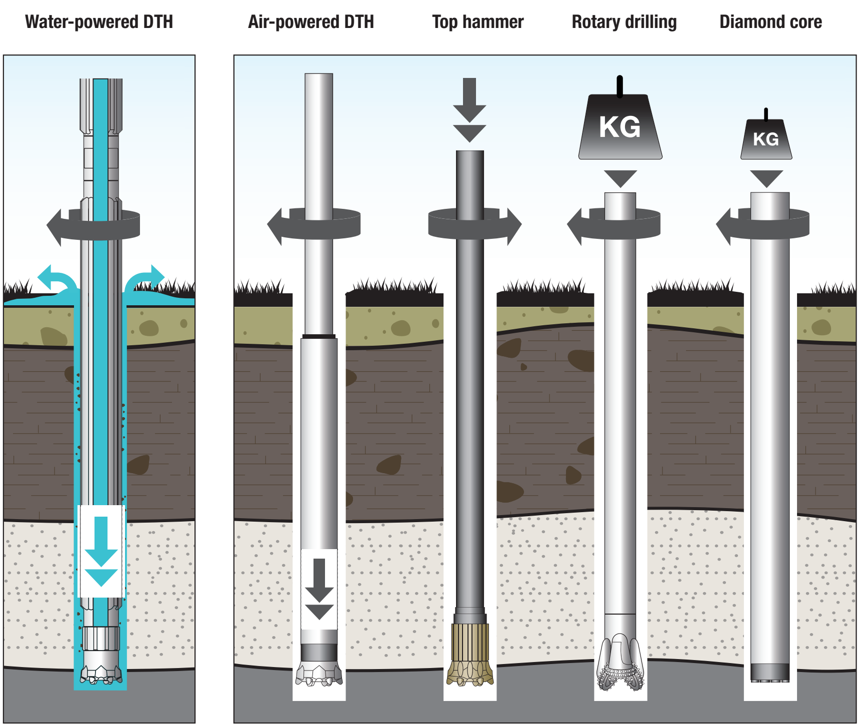
The information in the table below is intended to give an overview of the different drilling technologies. Please note that the stated facts are general and very much depending of the formation.

	Water-powered DTH	Air Powered DTH	Top Hammer	Rotary Drilling
Rate of Penetration (ROP)	High (High frequency)	High (dry holes, normally <200m)	High (short holes, normally <20m)	Low (non-percussive)
Formation limitations	Formation independent	Dense clay, water rich formation	Fractured ground	High compressive strength
Risk of pressurizing the formation	Low (outgoing water at hydrostatic pressure)	High (expanding air)	Low/High (water / air flush)	Low/High (water / air flush)
Risk of contaminating the formation	Low (water flush)	High (Oil added for lubrication)	Low (water flush)	Low (water flush)
Working environment	Good (Water flush bind dust, no-oil mist)	Poor (dust + oil-mist)	Medium (oil-mist from drifter, dust if air-flush)	Good
Total energy consumption per meter	Low (High efficiency pump)	High (high losses compressing air)	Low	Low
Sound emission	Low (Water column dampening the DTH)	Medium (large compressor, evacuating air at rod change)	High (percussion unit on surface)	Low
Hole accuracy	Good (Stabilized hammer)	Medium (Not stabilized hammer)	Low (thin drill string, percussion unit at surface)	Good (tight spacing)
Deep hole drilling capability	Good (Not affected of water in the formation)	Medium (Restricted in water rich formations)	Low (4-6% energy loss per drill rod)	Good

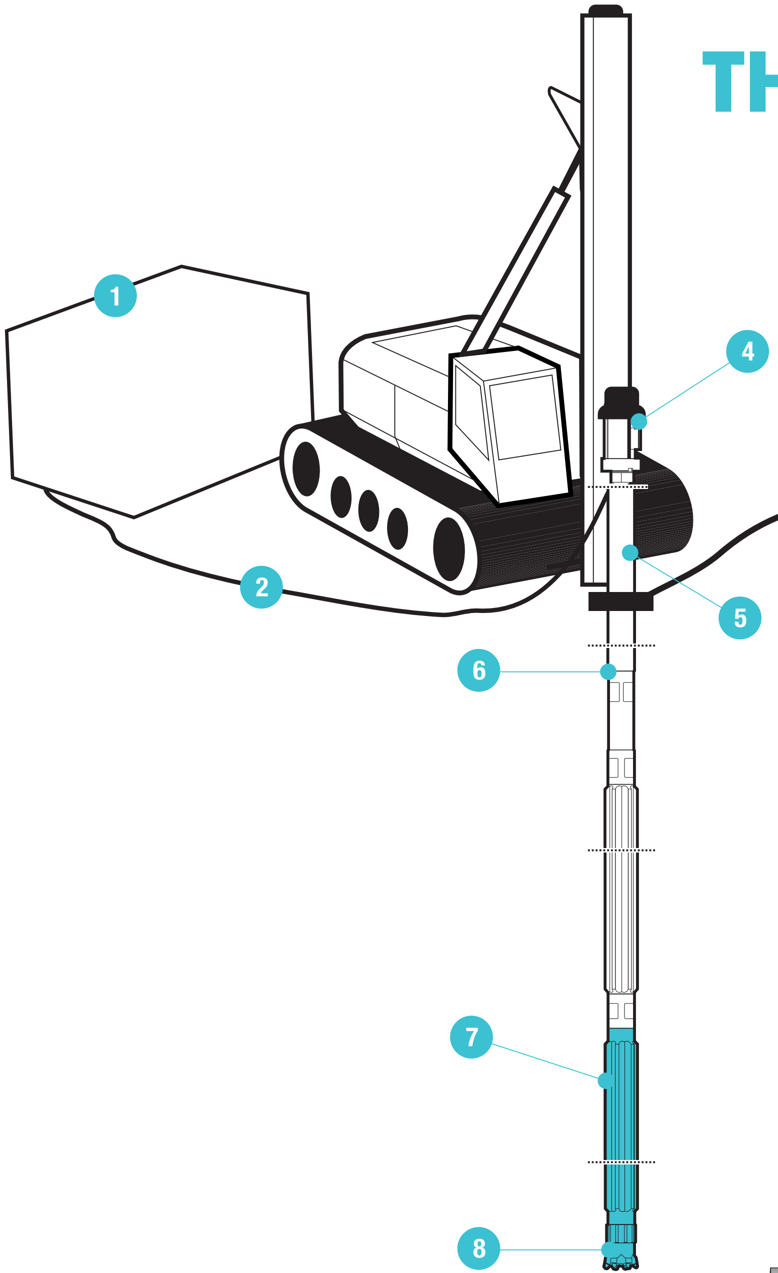
How Wassara works

The Wassara technology uses high-pressure water to power the DTH hammer. Water enables a high frequency and high power output. When the water leaves the hammer it has a sufficient velocity to bring the cuttings and debris to the surface and clean the hole.

Besides clean and straight holes with a minimum of deviation, Wassara offers superior benefits like high productivity, borehole quality and minimum impact on the formation you are drilling in.



THE WASSARA SOLUTION



1. High-pressure pump
2. High-pressure hose
3. Water handling system
4. Swivel
5. Drill tubes
6. Check valve
7. Wassara DTH hammer
8. Drill bit

Hammer range

Hammer	Ø Drill bit	Water consumption	Max operating pressure
W50 (2”)	60mm, 64mm (2 ⅜'', 2 ½”)	45-150 l/min (12-40 USgpm)	170 bar (2500 psi)
W70 (3”)	82mm, 89mm (3 ¼”, 3 ½”)	70-270 l/min (18-70 USgpm)	180 bar (2600 psi)
W80 (3.5”)	95mm, 102mm (3 ¾”)	70-270 l/min (18-70 USgpm)	180 bar (2600 psi)
W100 (4”)	115mm, 120mm, 127mm (4 ½”, 4 ¾”, 5”)	130-350 l/min (35-95 USgpm)	180 bar (2600 psi)
W120.G3 (5”)	130mm (5 ⅛”)	240-500 l/min (63-130 USgpm)	180 bar (2600 psi)
W150 (6”)	165mm (6 ½”)	270-570 l/min (70-150 USgpm)	180 bar (2600 psi)
W200 (8”)	216, 254mm (8 ½”, 10”)	280-744 l/min (73-197 USgpm)	150 bar (2200 psi)
W280 (12”)	305mm, 311mm (12”, 12 ¼”)	1 200 l/min (317 USgpm)	150 bar (2200 psi)

Hammer range – Jet grouting

Hammer	Ø Drill bit	Water consumption	Max grouting pressure
W100JG	153mm, 165mm (6”, 6½”)	130–350 l/min (34-93 USgpm)	150 bar (2200 psi)
W120.G3 with JG Monitor	152mm (6”)	240-500 l/min (63-130 USgpm)	500 bar (7 250 psi)

Wassara – cost-efficient and environmentally friendly drilling

LKAB Wassara is a Swedish company developing and manufacturing unique water-powered drilling systems for high performance in surface- as well as underground drilling operations. The heart of the Wassara drilling system is the world patented water-powered down-the-hole hammer.

The drilling systems have been used for more than 30 years in various applications within many industries; mining, exploration, ground engineering, dams, geothermal, marine, oil & gas storage. Our experience covers more than 30 million drilled metres working in different locations around the world. Reference studies can be found on our website.

LKAB Wassara was founded in 1988 and is owned by LKAB. LKAB is an international high-tech minerals group that produces iron ore products for the steel industry and other mineral products for many other industries and applications.

Explore more at www.wassara.com

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