DESIGNING FLOOD PUMPING STATIONS

Welcome

When disaster strikes, a poorly designed pumping station is practically useless. However, we never learn until it's too late.

The medias are full of examples of poor pumping station design and the tragic consequences of it, including the tsunamis in Asia and Hurricanes on USA's east coast.

Today, flooding is the most common cause of disaster in the world and by far the fastest growing – and with it follows the need for properly designed and reliable pumping stations.

Based on our expertise within pump solutions, this handbook offers guidelines and recommendations to reliable pumping station design that will protect or limit damages to people and infrastructure.

We hope you will use the handbook in your work with pumping station design. For additional information or assistance, please contract your local Grundfos sales representative or the Grundfos Water Utility Competence Centres.

Jim Rise, Sales Development Manager, Flood Control

Mick Eriksen, Application Manager,
Grundfos Global Water Utility Centre, Copenhagen

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The design recommendations in this book are general guidelines that do not just apply to Grundfos pumps and solutions. However, Grundfos cannot assume liability for non-Grundfos equipment used according to these recommendations.

1. INTRODUCTION

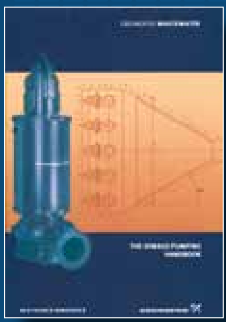
Who is this handbook for?

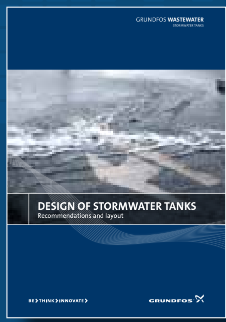
This book is intended to assist application engineers, designers, planners and users of sewage and storm water systems to incorporate axial and mixed flow pumps.

The guidelines in this book and especially the pumping station design can be used as they are, or be adapted to specific requirements and guidelines.

Additional information

If you need additional information that does not specifically concern flood pumping station design, perhaps the following Grundfos publications can be of help:





You can find all Grundfos publications in WebCAPS at **www.grundfos.com**

Based on the ANSI standard

Grundfos Chicago (formerly Yeomans Chicago Corp.) was on the ANSI standard working committee for the American standard for pump intake design. Therefore, many of the guidelines and recommendations in this book are based on the design standards of the American National Standards Institute (ANSI) that Grundfos helped define.

Grundfos Water Utility specialists

Grundfos specialists from our Water Utility Competence Centres, local Grundfos sales engineers, and our online publications are at your disposal and available to offer whatever assistance you need.

1.1 Introduction to Grundfos

Grundfos is the world's largest pump manufacturer and a full line supplier of pump solutions within water supply, wastewater, buildings services, and industry.

With Grundfos companies in more than 55 countries and more than 250 Grundfos partners, we offer local expertise and support wherever you are.

We support the planning, designing and commissioning of pumping systems, and we deliver the technology that can meet our customers' objectives.

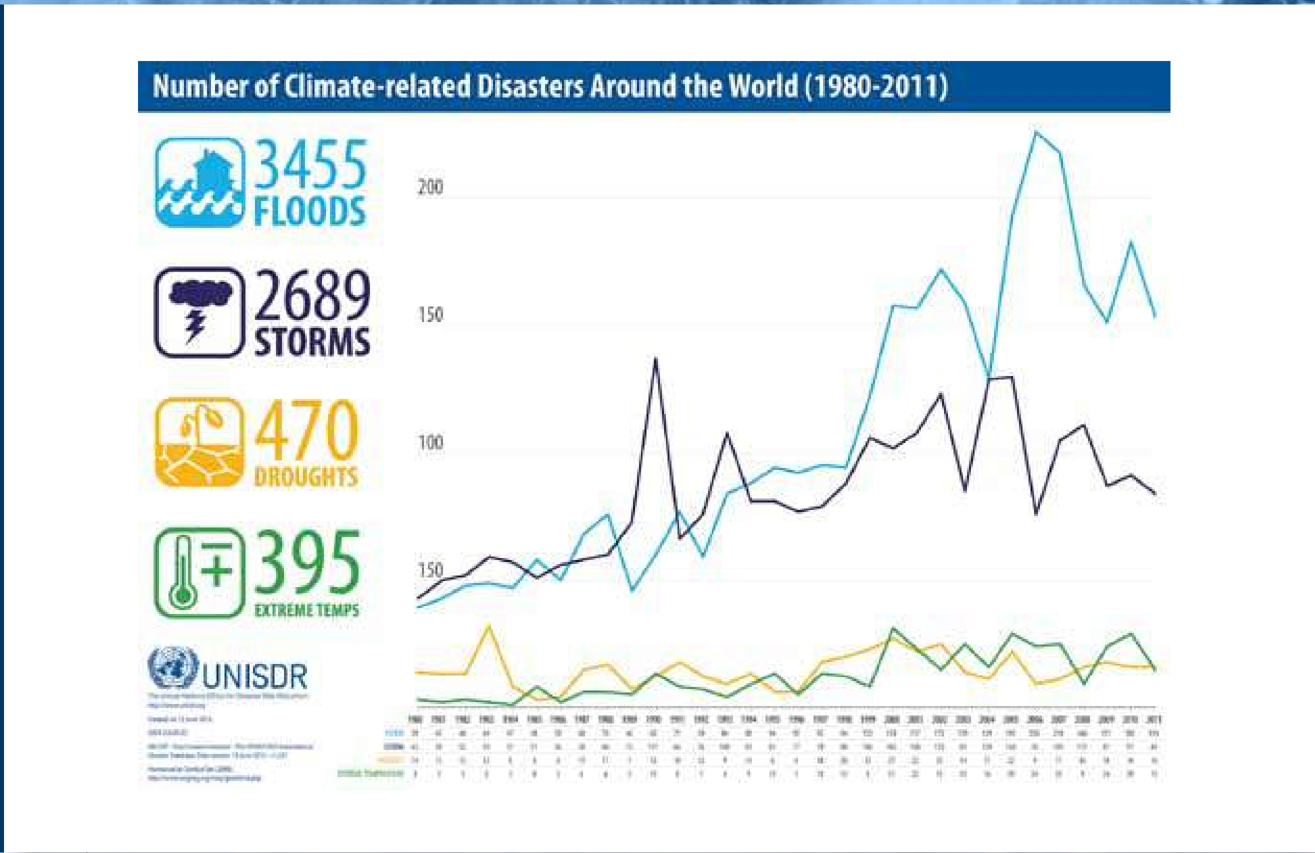
Experts in flood control

With our innovative and reliable flood control solutions we can go further than most to prevent flooding in a financially and environmentally sustainable way. Our insight can be applied to addressing the key issues of safeguarding people, crops, business and the entire infrastructure.

Over the years Grundfos has pioneered numerous innovations that have become or are becoming industry standards. And we will continue to be at the forefront in promoting and facilitating energy efficiency and sustainable technology.

It is these innovations that will enable us to meet future challenges, higher demand and stricter regulations within flood control. Our commitment is to play a strong part in the bigger picture, to prevent flooding or reduce the consequences of it. People worldwide depend on it.


Grundfos flood control installations worldwide



Source: UNISDR

1.2 Introduction to flooding

Flooding is not just the most common cause of disaster in the world; it is also by far the fastest growing.

However, not all floods are alike. Some floods develop slowly, while others, such a flash floods, can develop in just a few minutes even without visible signs of rain. Some floods are local, impacting a neighbourhood or community; others are very large, affecting entire river basins and multiple countries.

Inland flooding is the most common type of flooding event. It typically occurs when waterways such as rivers or streams overflow their banks either as a result of slow flooding due to sustained heavy precipitation like monsoons or snow melt.

Unexpected floods
But flooding can also hit where you don't expect it at all. Unusual weather patterns can – and do – cause unexpected storms and heavy rains in regions where historical data has offered no warning. Recent years have provided many examples of such unexpected floods in both Europe and Asia.

Coastal floods are also very common as a result of high tides after storms and increased sea water levels may occur quickly as a result of storms, hurricanes or even a tsunami.

Affected regions
Regions all over the world are affected by flooding. However, for countries with large overpopulated cities the consequences are the worst.

Major cities in Europe, the USA, and Asia, including Kuala Lumpur, Jakarta, Bangkok, and Shanghai, all have flooding problems. Indeed, any region faced with high annual rainfalls, increased populations, and expanding cities will be called upon to place increasingly great focus on flood control in cities.

1.3 Introduction to flood control

Common to all floods is that they cause catastrophic conditions for all people and animals affected by the flooding. Firstly, there is the physical damage of the infrastructure to actual casualties both to humans and livestock. Secondly, there is the contamination of the drinking water which can lead to diseases and the loss of crops and food supply.

Due to climate changes and an increase in the population and urbanisation the amount of flood scenarios has increased over the past decades and at the same time the population has also become more vulnerable due to an increased settlement in low-lying areas and near river deltas.

Counteracting flooding
Basic methods of flood control have been practiced since ancient times: reforestation, dikes, reservoirs and floodways (i.e. artificial channels that divert floodwater). These days, floodways are often built to carry floodwater into reservoirs where excess water is pumped into rivers.

With this handbook, we wish to use our expertise and experience to provide valuable design tips in connection with the considerations of designing new pumping stations for flood control.

We hope that the simple yet very important considerations when designing flood control solutions will benefit millions of people living in exposed areas all over the world.

Thinking ahead

Flood control strategies usually cover the whole city. In practical terms, the solutions typically involve multiple pumping stations at several locations to ensure sufficient flood management when nature bares its teeth.

However, the decision to implement a flood control strategy is often made when it is too late: when a flood has already happened, trailing major damage in its wake. In some cases, even a wake-up call of this kind is not sufficient; the flood is forgotten until, several years later, another incident occurs.

Flood control projects very easily become political bones of contention. There are, of course, financial and practical issues to be considered, and it will be tempting to focus on immediate problems rather than hypothetical disasters.

Even so, authorities should view flood protection as a vital aspect of ensuring a safe environment for everyone. Ultimately, lives can be at stake.

2 THE SOURCES OF FLOODING – AND THE SOLUTIONS

2.1 Can we prevent flooding?

History has repeatedly shown that there is no ultimate solution to forestall and prevent flooding and fully secure people, livestock and infrastructure.

Every year, nature and a changing climate set new records for the size of storms, rainfall intensity and tsunamis. This causes increasingly intense episodes and often in unpredictable geographical areas.

We cannot create a complete guard against these phenomena, but with the experience and knowledge gained from each episode, we can constantly improve our ability to withstand flooding. We can minimise the risk for populations and livestock, and with our ability to handle the situation before, during and after flooding, we can limit the damage to infrastructure.

2.1.1 Flood management

In an effort to address flooding, we will use the EU flood directive for inspiration. It identifies all the factors that should be taken into account and provides clear requirements for individual countries:

- Preliminary flood risk assessment.
- Flood hazard and risk mapping.
- Flood risk management.

Cooperation across borders

In this context, it is perhaps also important to understand that flooding knows of no borders as waterways and shorelines are coherent. Flooding is a common problem and must be solved in cooperation across borders.

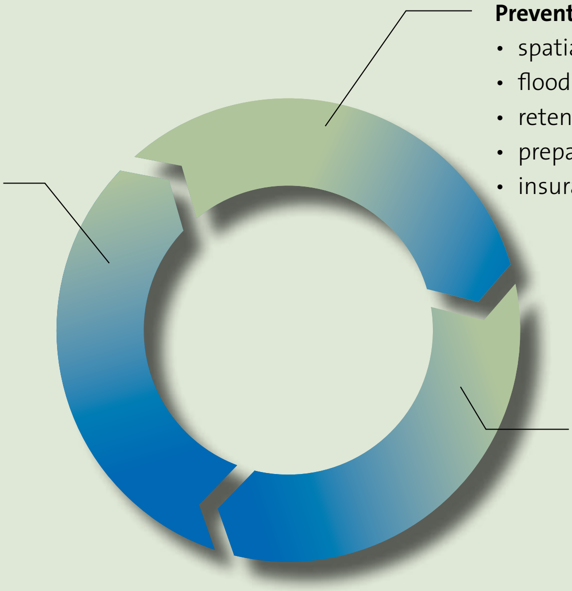
We start where nature stops

As a pump manufacturer, our contribution to the above relates primarily to flood risk management. Through new technology, constant product development, services and solutions, we continuously seek to meet the changing needs of the market and our customers. In terms of flood control: We start where nature stops.

2.1.2 The flood risk cycle

The concept of flood risk management is bulky and can hardly be regarded a stationary nature. Rather it is more like a cycle that continues to evolve.

To cover all elements, we use the following cycle to describe the concept.



Preventive flood risk management
Our contribution to flood defence extends from household solutions to large scale management of water flows:

- Household drainage pumping stations and storm water solutions.
- Network pumping stations handle rainwater in scattered settlements and urban areas.
- Main pumping stations in rainwater systems with associated stormwater basins
- Mega stations for handling water flows in tributaries to larger rivers and outlet to the recipient or the sea.
- Supporting the design and project management during the planning and execution and commissioning of systems and solutions.

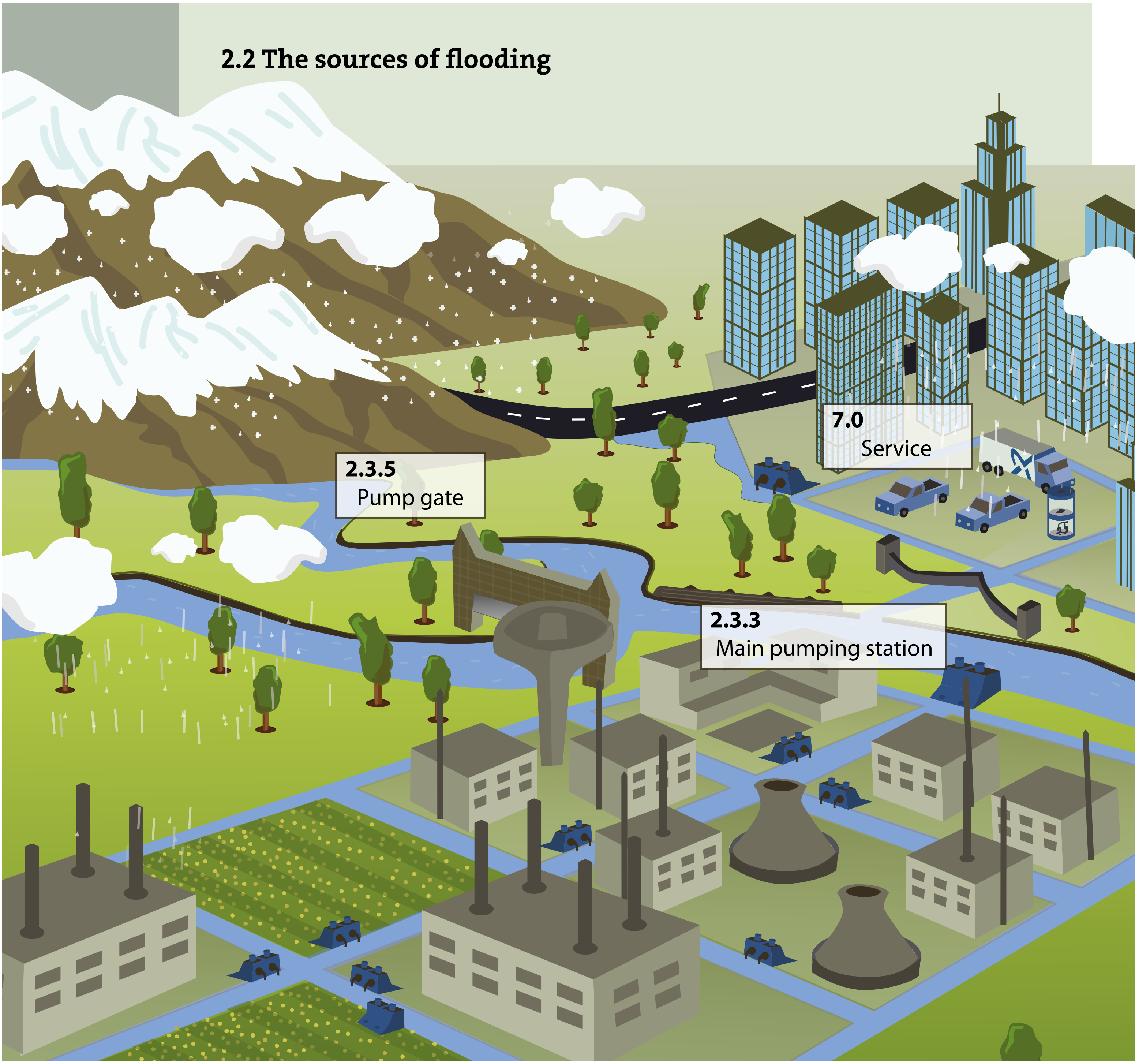
Flood event management
Grundfos has developed operational solutions and services to handle flooding and improve reliability. These include:

- Operation of installations.
- Concepts for service, preventive maintenance and preparedness for existing installations.
- Control and monitoring concepts for monitoring the status and alarm functions.

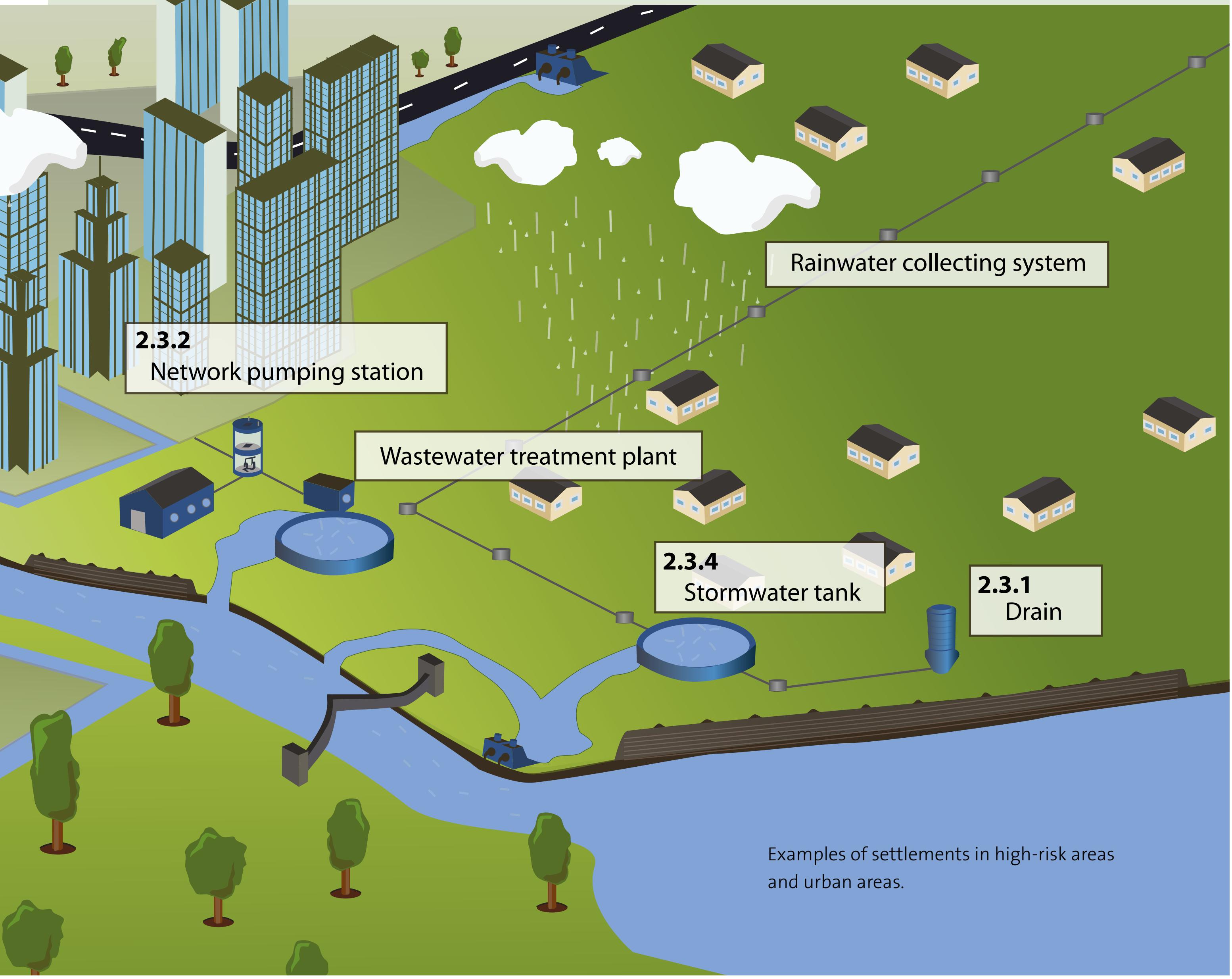
Post-flood measures
Immediately after a flood, a community faces great challenges. The population is at risk, as drinking water supplies may be infected. To get the infrastructure back on track, sewage must be removed and entire areas cleaned up.

- Pump preparedness for pumping of excess water – portable pump solutions
- Stationary and mobile disinfection solutions to maintain a drinking water supply.

2.2 The sources of flooding



There are as many causes of flooding as there are natural phenomena. However, others are man-made causes that increase the risk of flooding, triggered by the way we establish and organise our society.



Examples of settlements in high-risk areas and urban areas.

Despite the many causes, we will break down flooding occurrences into the following:

1. Inland flooding
Primarily related to precipitation, either prolonged rain or intense local rain. Depending on the geographical location, it can also be precipitation in the form of snow and accelerated melting.

2. In deltas
Where rivers or waterways meet, bottlenecks develop and block the water flow towards the recipient or the sea.

3. In coastal areas
Hurricanes and climate change can cause elevated water levels with the risk of flooding from the sea which can also be caused by undersea earthquakes followed by tsunamis.

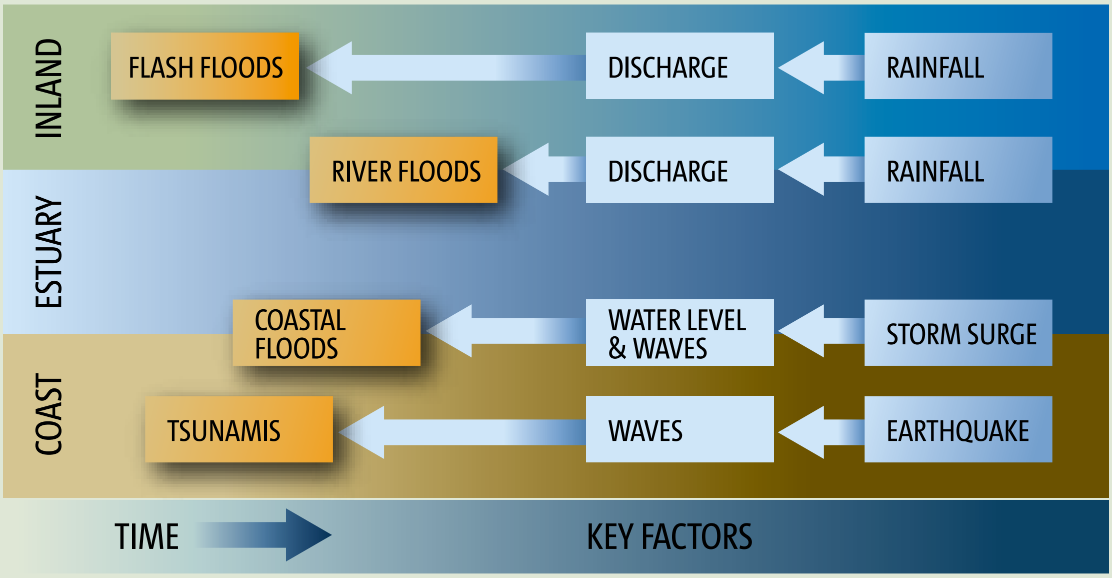
Regardless of the source, a flooding threat is virtually always a combination of these sources.

Often heavy inland rainfall and elevated sea levels are connected, and elevated sea levels will affect inland river flows.

2.3 Flood control solutions

Grundfos offers a wide range of flood control solutions – from small solutions for private households to large-scale solutions that protect mega cities.

In the following, we will introduce some of the most common solutions and their natural applications.



2.3.1 Drain/rain water station

Application
Excess water is collected in the well and pumped away from the house.

Grundfos solution: We offer solutions with integrated control and external control as complete units with inlet and outlet, and as single components.

Flow: 5-10 l/s
Head: 10 m

Benefits
- Safety: Surveillance and alarm
- Reliability

Products
Pumping stations: PUST
Pumps: AP/KP/CC/DP/DWK/EF/DW/ AUTO*ADAPT*

www.grundfos.com/flood-control

2.3.2 Network pumping station

Application
Collects and distributes rainwater and storm-water.

Flow: 10-100 l/s
Head: 70 m

Benefits
- Flexible extension -> less piping and gravitation -> reduced depth of main pumping station
- Intelligent control between pumping stations
- Combined with stormwater tanks
- Surveillance and alarm

Products
Available as pre-fabricated units or customised solutions adapted to the existing infrastructure.

Pumping stations: PUST
Pumps: SE/SL/S/DPK/DWK/ AUTO*ADAPT*
Drives: CUE
Monitoring: GRM
Controls: LC/LCD/DC
Accessories: Pipes/valves

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2.3.3 Main pumping station

Application

Receives rainwater from pumping stations and gravitation systems. Capable of handling large amounts of rainwater and distributing it in large pipe systems.

Flow: 100-2,000 l/s
Head: 120 m

Benefits

- Independent of gravity -> reduced construction costs
- Intelligent control in combination with network pumping stations, stormwater tanks and other pumping stations
- Minimising the environmental and human consequences of overflow

Products

Submersible or dry installed pumps: SE/SL/S/ AUTO*ADAPT*
Controls: LC/LCD/DC
Drives: CUE
Mixers: AMG/AMD
Monitoring: GRM
Accessories: Pipes/valves

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2.3.4 Stormwater tank with installations

Application

The concept of storm water detention is to temporarily store excess storm water runoff. This is to avoid hydraulic overload of the sewer system, which could result in the flooding of roads and buildings with untreated wastewater or its release directly into the environment, causing pollution.

Flow: 100-500 l/s
Head: 20 m

Benefits

- Reducing peak flow and equalising flow rates
- Better utilisation of the existing sewer system
- Allowing for intelligent management of stormwater flows
- Savings on infrastructural investments

Products

Pumps: SE/SL/S/Flushjet/ AUTO*ADAPT*
Controls: LC/LCD/DC
Drives: CUE
Mixers: AMG/AFG/AMD
Monitoring: GRM
Accessories: Pipes/valves

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2.3.5 Pump gate pumping station

Application
Pump gates may be a reliable option if a pumping station and reservoir are not an option due to lack of space. If the outside water level is low, the pump gates and screen will be open and discharge the inside water by gravity flow. Once the outside water level gets higher, blocking the back flow, the pump gates close and block the rising water level. If the inside water reaches a certain level, the pump and screen will start operating to forcibly discharge the water inside.

Once the outside water goes down to a certain water level, the flood gate and screen open and discharge the inside water by gravity flow.

Flow: 150-100,000 l/s
Head: 10 m

Benefits
- Serves as a flood gate and pump simultaneously
- Equipped with submersible pumps, the gates can be installed on an existing waterway. May in some cases eliminate the need for a reservoir and pumping station

Products
Pump gates
Pumps: KPL/KWM
Drives: CUE
Monitoring: GRM
Accessories: Pipes/valves

www.grundfos.com/flood-control

2.3.6 Flood control pumping station

Application
A flood control pumping station manages extremely large amounts of water flowing in open canals at low heads. This solution demands a good infrastructure because of the large inlet channels or pump sumps. Also, the power supply comes from a power plant, a dedicated power structure, or a combination of them.

Flow: 150-100,000 l/s
Head: 10 m

Benefits
- Typically low operating hours -> high reliability
- Protects large areas from flooding
- Allows for settlements in areas that are exposed due to climate changes
- With or without water gate to the sea

Products
Pumps: KPL/KWM
Accessories: Pipes/valves
Drives: CUE
Monitoring: GRM

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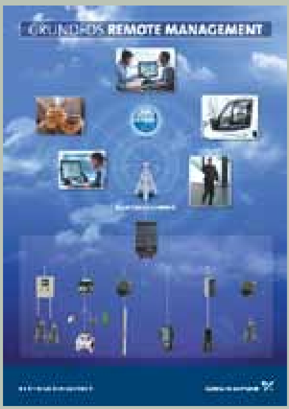
2.3.7 Grundfos Remote Management System



Application

Grundfos Remote Management is a secure, internet-based system for monitoring and managing pump installations in commercial buildings, water supply networks, wastewater plants, etc.

Pumps, sensors, meters and Grundfos pump controllers are connected to a CIU271 (GPRS Datalogger). Data can be accessed from an Internet PC, providing a unique overview of your system. If sensor thresholds are crossed or a pump or controller reports an alarm, an SMS will instantly be dispatched to the person on duty.

Features and benefits

- Complete status overview of the entire system you manage
- Live monitoring, analysis and adjustments from the comfort of your office
- Trends and reports
- Plan who receives SMS alarms with easy-to-use weekly schedules
- Plan service and maintenance based on actual operating data
- Share system documentation online with all relevant personnel

2.4 Flooding – then what?

The solutions presented so far have all been preventive. In other words, they have been designed to prevent flooding completely. However, if a flood occurs, either due to the absence of a suitable solution or because the weather phenomenon was so extreme that a flood was unavoidable, there are also several solutions to minimise the consequences of it.

2.4.1 Water-borne illnesses and water contamination

During a flood we hear about the deaths, displacements, economic losses, and causes associated with the flood. Less common immediately after a flood event, however, is attention to water-borne illnesses and water contamination.

Depending on location and sanitation conditions, infectious diseases are often spread through contaminated drinking-water supplies. This includes:

- Flood water can contaminate drinking-water supplies, such as surface water, groundwater, and distribution systems.
- Groundwater wells can be rendered useless from inundation of water laced with toxins, chemicals, animal carcasses, septic seepage, and municipal sewage.
- Surface water sources are impacted in similar manners.

To reduce the consequences of an actual flood, it is vital to have emergency systems ready to take over when disaster strikes. And immediate access to clean drinking water is essential to prevent a dangerous sanitation situation that often exceeds the consequences of the actual flood.

To secure clean drinking water supplies during and after a flood, Grundfos offers a wide range of solutions tailored to the specific situation and location.

2.4.2 Drainage pumps and service trucks

Application
The Grundfos drainage solution ranges from small portable drainage pumps for private housing, farms and small industries to large-scale drainage solutions for drainage of areas.

Despite their difference in size and application, they have all been designed for pumping drain water and are therefore ideal for flood-relief applications.

Flow: 5-10 l/s
Head: 10 m

Benefits
- Portable/movable
- Plug and pump solutions
- Easy to get to inaccessible disaster areas

Products
Pumps: Unilift CC /KP/DP/DW/DWK/Pomona
Drives: CUE
Monitoring: GRM

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2.4.3 Filtering and disinfection

Application
Mobile filter units for cleaning drinking water can be transported by car or helicopter to disaster areas, where immediate access to clean drinking is essential to prevent a dangerous sanitation disaster.

Benefits
- Complete removal of suspended solids
- Partial removal of dissolved matter (TOC, COD, BOD)
- Removal of micro-organisms:
  - Log 6 removal of bacteria (99.9999)
  - Log 4 removal of viruses (99.99)
- Superb quality as RO feed water (low SDI15)
- Certified for use in potable water

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3 DESIGNING A FLOOD CONTROL PUMPING STATION

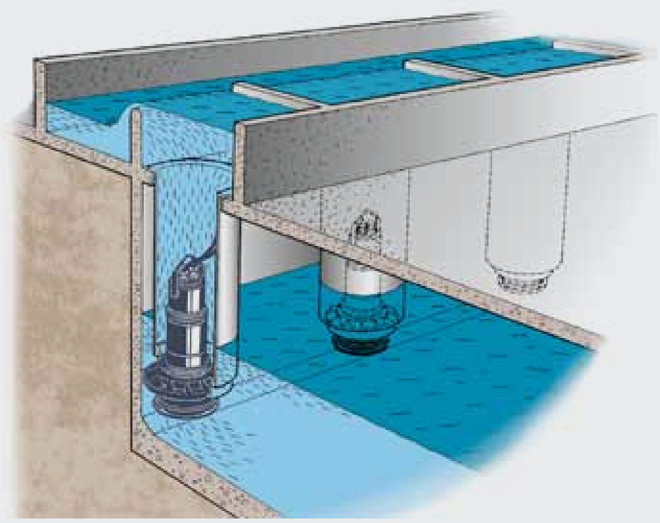
3.1 General considerations

Good sump design
The sump design has a crucial impact on the pump's total lifespan. It relies on an intake structure that allows the pumps to achieve their optimum hydraulic performance under all operating conditions.

The fundamental condition of a good sump design is optimal flow into the pumps – which is a uniform flow, free of submerged or surface vortices and excessive swirl.

Poor sump design
A less-than-optimal sump design could potentially result in poor performance and/or mechanical strain due to vibrations and cavitation at the inlet to the pump(s).

A poor design can easily lead to sedimentation of sand and rags, which in turn can cause additional cavitation and vibration problems and excessive noise and power usage.



Sump design no go

The following phenomena should be prevented or reduced to a minimum in a properly designed pump sump:

- **Non-uniform flow at the pump intake:**
  Results in excessive noise and vibrations, and reduced efficiency
- **Unsteady flow:**
  Can cause fluctuating loads
- **Swirl in the intake:**
  Can create vortices and unwanted changes to the head, flow, efficiency and power
- **Submerged vortices:**
  Can cause discontinuities in the flow and can lead to noise, vibration and local cavitation
- **Surface vortices:**
  Can draw harmful air and floating debris into the pump
- **Entrained air:**
  Can reduce the flow and efficiency, causing noise, vibration, fluctuations of load, and result in damage to the pump.

The negative impact of each of these phenomena on pump performance depends on the speed and the size of the pump.

Generally, large pumps and axial flow pumps (high speed) are more sensitive to adverse flow phenomena than small pumps or radial flow pumps (low speed)

For special applications beyond the scope of this book, please contact your local Grundfos Water Utility sales engineer, who will be more than happy to provide the expertise and experience you need to meet your specific needs.

www.grundfos.com/flood-control

90% OF ALL PROBLEMS WITH PUMPS ARE BASED IN THE INSTALLATION AND THE FLOW CONDITIONS AROUND THE PUMP

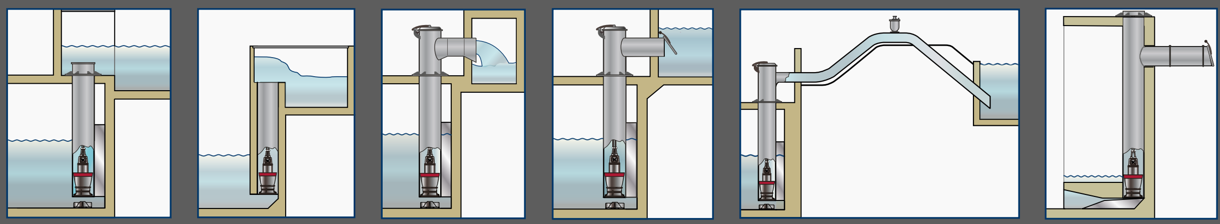
3.1.1 Design sequence

When designing a pumping station, the design sequence is essential.
Below, we present the typical progression in the design phase and what to consider.

1	Flow patterns and boundary geometry (see 3.2)	1. How much water? (Flow) 2. Coming from where? 3. Going where? (Head)
2	Pump size and quantity (see 3.3)	Determine the number and size of pumps required to satisfy the range of operating conditions likely to be encountered.
3	Pump selection (See 3.3)	Identify the column pipe diameter
4	Placing the pumps (see 3.3)	Determine the distance from pump bell mouth to floor
5	Minimum water level (See 3.3)	Determine the minimum submergence of the pump and by that the minimum water level. Check NPSH at minimum water level.
6	Determine slope (See 3.4)	Check the bottom elevation in the inlet channel and determine if it is necessary to slope the floor upstream of the pump bay entrance. Maximum slope 10°.
7	Velocity (See 3.4)	Check the pump bay velocity for the maximum single-pump flow and minimum water depth with the bay width set to 2D. Max velocity 0.5 m/s.
8	Cross-flow velocity (See 3.2.6)	Compare cross-flow velocity (at maximum system flow) to average pump bay velocity. If cross flow velocity exceeds 50% of the pump bay velocity, a CFD study is recommended.
9	Dimensions (See 3.4)	Determine the dimensions of the pumping station.

Source: Adapted from ANSI/HI 9.8-1998 table 9.8.2.

3.2 Design conditions



Depending on the specific condition of the area and the location of the station, you can choose a pumping station design that meets your specific requirements.

Ask us for installation recommendations. We can often help you create a more efficient and durable system.

Choose the installation set-up that suits you
With the Grundfos KPL and KWM pump solutions, the individual installation has the same scope for customisation as the pumps themselves.

Installed directly in the column pipe, KPL and KWM pumps seriously reduce the need for construction works – so they can even save you money before they prove their efficiency in day-to-day operation.

ZONES OF STAGNATION SHOULD BE AVOIDED WITH FILLETS.
USE CFD MODELLING TO DETERMINE WHERE THE ZONES OF STAGNATION ARE

COMBINING DIFFERENT PUMP SIZES ALLOWS YOU TO OPTIMISE THE OPERATION AND PUMP TO A LOWER LEVEL WITHOUT DAMAGING THE PUMP INSTALLATION

3.2.1 Flow patterns and boundary geometry

Before you can select the right station design, you need to identify where the water comes from:

- Rain
- Melting water from mountains
- High water/tsunami
- Screening

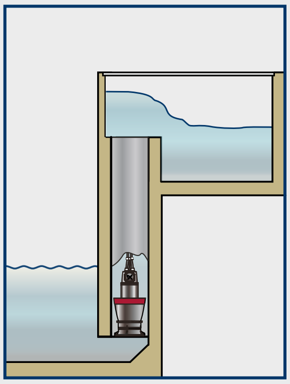
And equally importantly: where the water should be pumped to, based on the following conditions:

- Installation type
- Discharge conditions

3.2.2 Types of installation

Grundfos offers turnkey solutions for site-specific installation. In the following, we will go through the most common solutions.

All accessories and components can of course be adapted to your specific requirements.

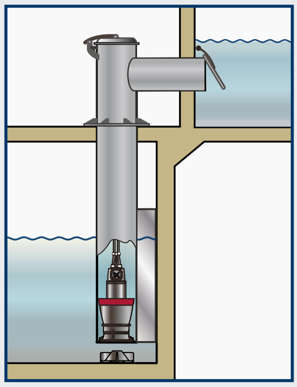


Type Open 1
Suitable where the liquid is pumped to a tunnel, channel or basin – and where the water level is nearly constant so that shut-off devices are not required.

Pros:
This arrangement involves the smallest number of steel components; it consists of a circular concrete tube and a short pipe grouted in place as a base for the pump. Because the top of the tube is placed at a level slightly above the maximum water level in the outlet channel, water cannot run back to the sump when the pump is shut off.

Cons:
This design demands a higher pump head.

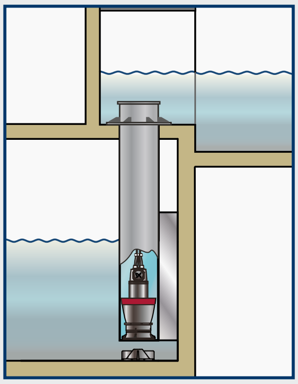
In case on rising water level above outlet, backflow may occur.



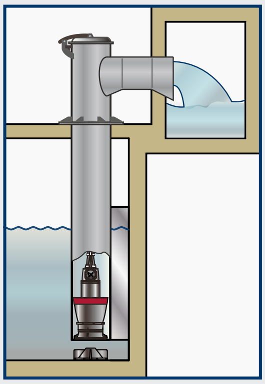
Type Open 2
If the water level on the outlet side of the pump varies considerably, flap valves can be installed. Normally the pump works against the head in the discharge channel or basin.

Pros:
When the pump is not in operation, the water is prevented from running back to the sump by the automatic closure of the valve.

Cons:
This design has a built-in risk of water hammer, which can be countered with controlled non-return valves, i.e. a motor valve or a valve type with hydraulic dampener.

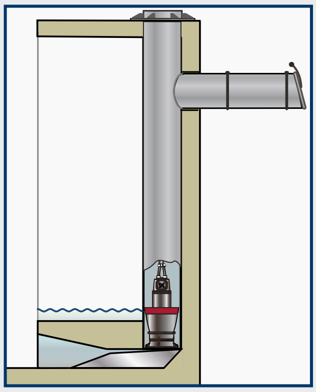


Type Open 3
Basically a steel version of Open 1.



Type Open 4
Apart from the free discharge, this type is quite similar to Open 2 with discharge to a closed channel.

Pumping to a closed channel can be necessary to avoid accidents or reduce odours.



Type FSI 1
A Formed Suction Intake can be constructed in steel or concrete. It improves the inlet flow conditions to the pump and enables a lower minimum water level.

Pros:
This type reduces the risk of surface vortices and allows a lower minimum water level. Therefore, it provides a better defined flow to the pump. In addition, a lower minimum water level can reduce the size, the depth, of the pumping station.

Cons:
If you pump to a lower level, you have to consider the NPSH required by the pump.

3.2.3 Water flow (Q)

When dimensioning pumping stations there are many conditions to consider, such as climate change, 10, 30 and 100 year's rain, urban development and planning. General recommendations are therefore virtually useless, as all calculations depend on your specific priorities.

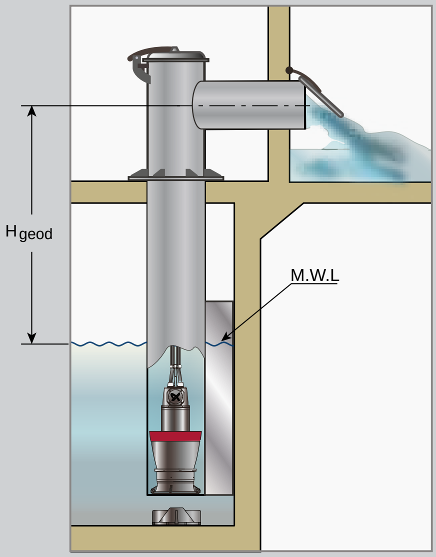
Instead, we recommend that you follow the national standards and legislations using the latest tools, such as MIKE URBAN and MIKE FLOOD from DHI.

3.2.4 Head (H)

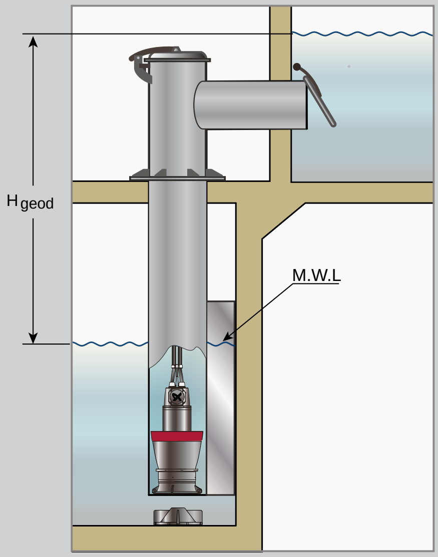
Any dimensioning consists of a static and a dynamic head.

The dimensioning head $H = H_{geod} + H_{losses}$ (losses in pipes, valves, bends and flaps etc).

TO SECURE SUFFICIENT HEAD IT IS IMPORTANT TO INCLUDE THE DYNAMIC HEAD, VELOCITY HEAD



Free outlet from non-return flap



Submerged outlet from non-return flap

Velocity head

Discharging to an open canal where the water flows over a weir requires a special calculation. In this case, it is important to include the head contribution H_W from the increased water level created by the flow velocity:

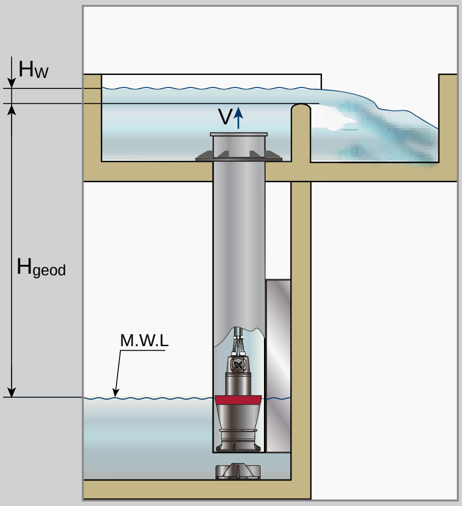
$$H \approx H_{geod} + \frac{V^2}{2g} + H_W$$

$$H_W = 0{,}6 \cdot \left(\frac{Q}{b}\right)^{0{,}7} \quad \textit{weir edge rounded}$$

$$H_W = 0{,}8 \cdot \left(\frac{Q}{b}\right)^{0{,}7} \quad \textit{weir sharp edged}$$

g = 9, 81 [m/s²]
v = Flow velocity [m/s]
Q = Flow [m³/s]
b = Weir width [m]

For more detailed information on this topic, please see Appendix 1: Head loss calculations, page 90.



3.2.5 Net Positive Suction Head (NPSH)

Net Positive Suction Head (NPSH) describes conditions related to cavitation. Cavitation should always be avoided as it causes inefficient operation and is harmful to the installation.

What is cavitation?

Cavitation is the creation of vapour bubbles in areas where the pressure locally drops to the fluid vapour pressure. The extent of cavitation depends on how low the pressure is in the pump. Cavitation generally lowers the head and causes noise and vibration. It first occurs at the point in the pump where the pressure is lowest. Most often, this is at the blade edge in the impeller inlet.

NPSH explained

The NPSH value is absolute and always positive. NPSH is stated in metres [m] like the head.

Two different values

A distinction is made between two different NPSH values: $NPSH_R$ and $NPSH_A$.

$NPSH_A$ stands for NPSH **Available** and expresses how close the fluid in the suction pipe is to vaporisation.

$NPSH_R$ stands for NPSH **Required** and describes the lowest NPSH value required for acceptable operating conditions. You should always consider worst case scenarios or the full operating range, when you use $NPSH_R$ and not only the specific duty point.

NPSH calculations

$NPSH_A$ can be calculated as:

$$NPSH_A = \frac{(p_{bar} + \rho \cdot g \cdot H_{geo} - \Delta p_{loss,suction\ pipe}) - p_{vapour}}{\rho \cdot g} \ [m]$$

Pbar – atmospherical pressure depends on your altitude.

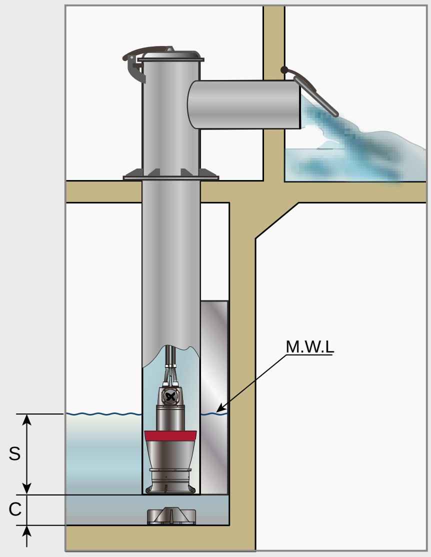
Example:

In practical terms for column installed axial flow pumps the calculation looks like this:

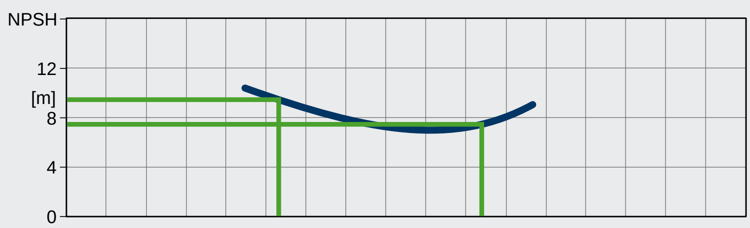
$NPSH_R$ + safety margin ≤ $NPSH_A$ (in all duty points)

⇳

$NPSH_R$ ≤ (S_{min} + 10 - safety margin) = S_{min} + 9,5 [m]



REMEMBER TO ALWAYS CONSIDER $NPSH_R$ FOR THE FULL OPERATING RANGE, AND NOT ONLY AT THE SPECIFIC DUTY POINT. A MINIMUM SAFETY MARGIN OF 0.5 M IS RECOMMENDED, BUT DEPENDING ON THE APPLICATION, A HIGHER SAFETY LEVEL MAY BE REQUIRED

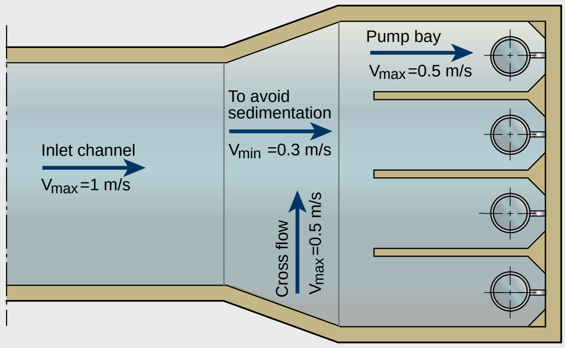


For more information and specific pump curves, please see the KPL & KWM data booklet.

3.2.6 Water velocity

Appropriate water velocity is essential for the reliability and the efficiency of a pumping station.

To avoid sedimentation and build-up of obstructions it is important to maintain sufficient velocity. However it is equally important to keep the velocity low enough to prevent pressure losses and vortices in the pump bay.



Velocity guidelines

- The velocity and distribution of the fluid flow in the inlet channel should be uniform. The angle of the bottom should have an inclination of 10 to 15 degrees.
- The velocity of the water in the inlet channel should be less than 1.2 m/s.
- The overall velocity of the water in the pumping station should be between 0.3 and 0.5 m/s.
- If cross-flow velocity exceeds 50% of the pump bay velocity, a CFD study is recommended.
- The effects of flow disturbances should be dissipated as far as possible from the pump intake.
- Stagnation regions should be avoided. If the design has stagnation sections, they should be filled with concrete before operation commences.

In the column pipe

If water velocity is too high =>pressure loss causing excessive energy consumption.

If water velocity is too low => sedimentation or up-concentration of solids makes the water heavier and causes the motor to trip on overload.

3.2.7 Power supply and backup

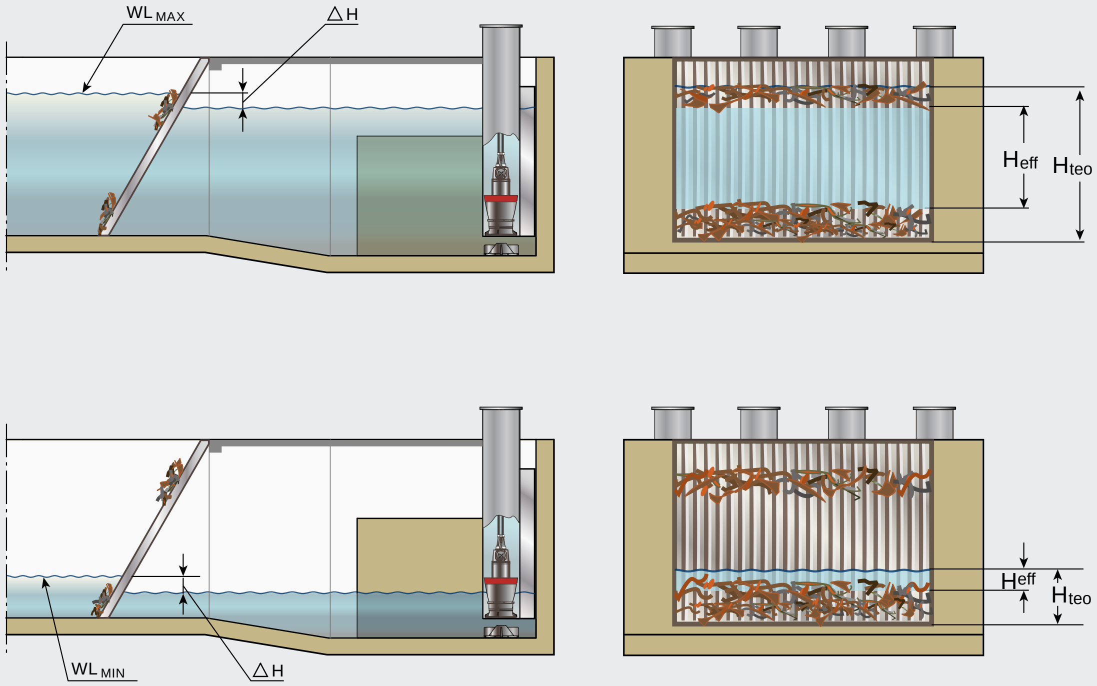
In some parts of the world, electrical grids are unstable and power failures are common. Although Power outage is rare in others parts of the world, they do occur and can be downright dangerous if you're not prepared.

Therefore, it is important to consider emergency situations where the regular power supply fails. A common solution is to install a backup diesel generator that can eliminate the headaches of long-term power outages.

Please refer to EN752 and local legislation.

ALTHOUGH RARE IN SOME PARTS OF THE WORLD, POWER FAILURES DO OCCUR AND MUST BE CONSIDERED WHEN DESIGNING A PUMPING STATION

3.2.8 Trash racks and screens



Partially clogged trash rags or screens can result in very uneven flow patterns and head increases.

Especially at low water levels, a screen clogged by sediments, floatation layer etc. can result in a considerable pressure drop over the screen, reducing the water level at the pumps. This can contribute to vortices and cavitation in the pumps.

Reduce dead zones

One way of preventing clogged rags and screens is frequent inspection and cleaning. However, minimising scraper travel by reducing the size of the dead zones in the screen design can also reduce the problem significantly.

Screen support

Screens should be divided into several vertical panels and supported by vertical piers; they should never be supported horizontally, as this may create velocity jets and severe instability near the pump.

A general guideline is that a screen exit should be placed a minimum of six bell diameters from the pumps. Observing these guidelines will maximise the flow channel, thereby eliminating potential head increases and making it easy to clean and maintain the screens.

3.2.9 Handling sludge

During dry seasons, water levels recede. When this happens, the sludge in the remaining water settles in the sump and the problem is escalated by a slow inflow.

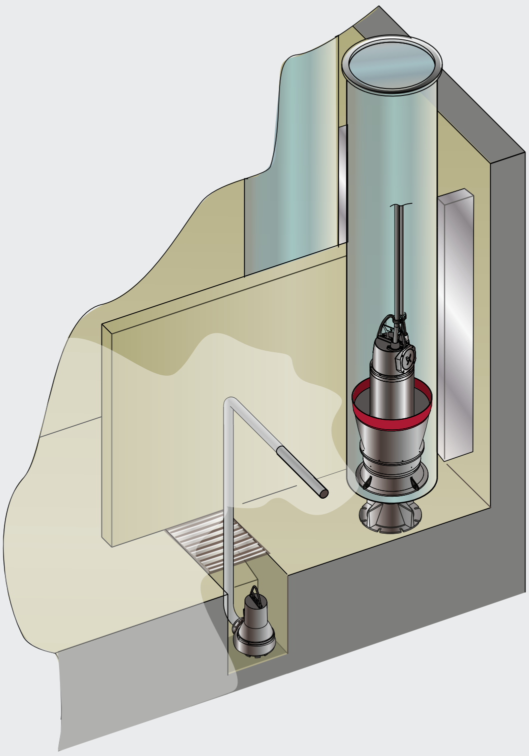
Sludge settlement

In this situation, additional sludge builds up in the sump and eventually the water evaporates.

The end result may be that the impeller is buried in silt when the pump needs to start.

Install a sludge pump

To keep the sump clean at all times, it is recommended to install a small sludge pump in a separate, small pump sump within the main sump. This sludge pump is used to empty the main sump in periods with less or no inflow to the main sump.

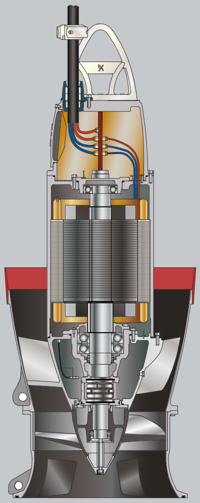


AVOID DEAD ZONES AND OBSTACLES WHERE SEDIMENTS AND RAGS CAN BUILD UP. ESPECIALLY AT THE BOTTOM OF THE SCREENS, FREE PASSAGE IS CRUCIAL

SCREENS ARE MADE FROM VERTICAL PANELS, SUPPORTED BY VERTICAL PIERS – NEVER HORIZONTAL PIERS

TO REDUCE CABLE SIZE YOU COULD CONSIDER A HIGH VOLTAGE MOTOR.

GRUNDFOS SUPPLIES MOTORS FROM 220-6,600 VOLT



3.3 Pump selection

Grundfos provides a full range of pump solutions for virtually any purpose. Although, the solutions are versatile and flexible and easy to place in a wide range of different installations, selecting the right solution requires access to the conditions and relevant data.

With the right data available, we can optimise the optimal pump solution according to your exact demands and specific installation.

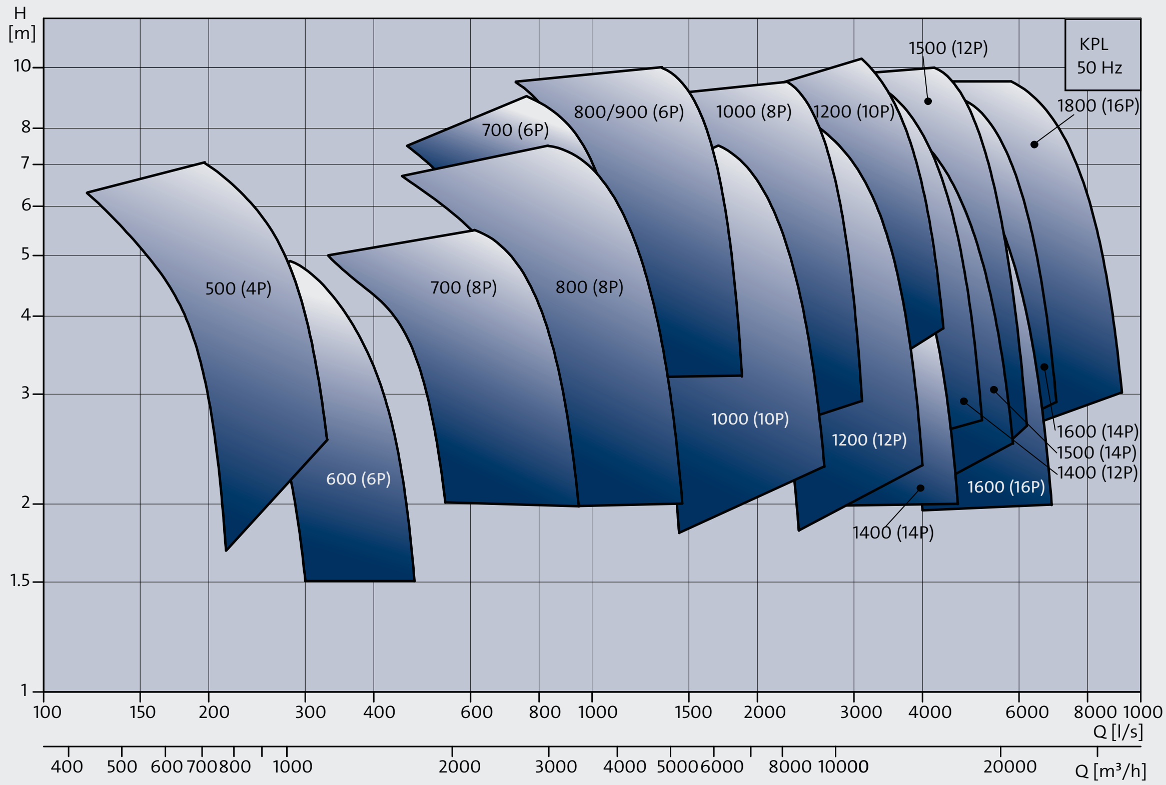
3.3.1 Axial flow propeller pump or mixed flow pump?

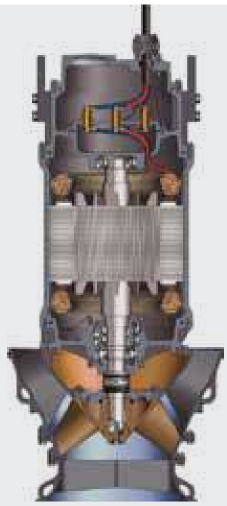
With a motor range from 15 kW up to 1000 kW, both Grundfos KPL and Grundfos KWM solutions are designed for high-volume water handling.

KPL:	Axial flow propeller pump
KWM:	Mixed flow pump

KPL

Axial flow propeller pump, max flow 700 m³/min, max head: 9 m.

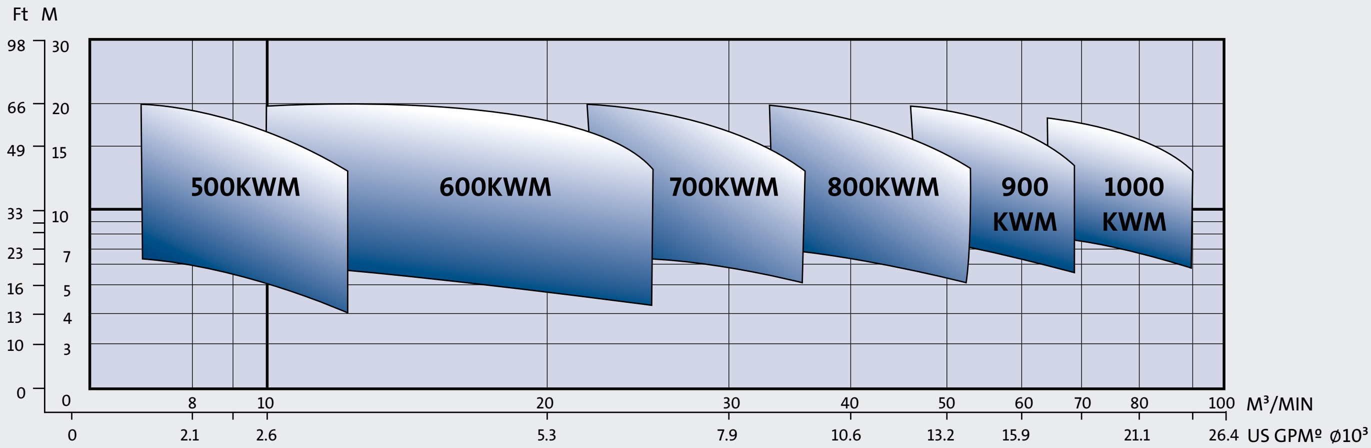


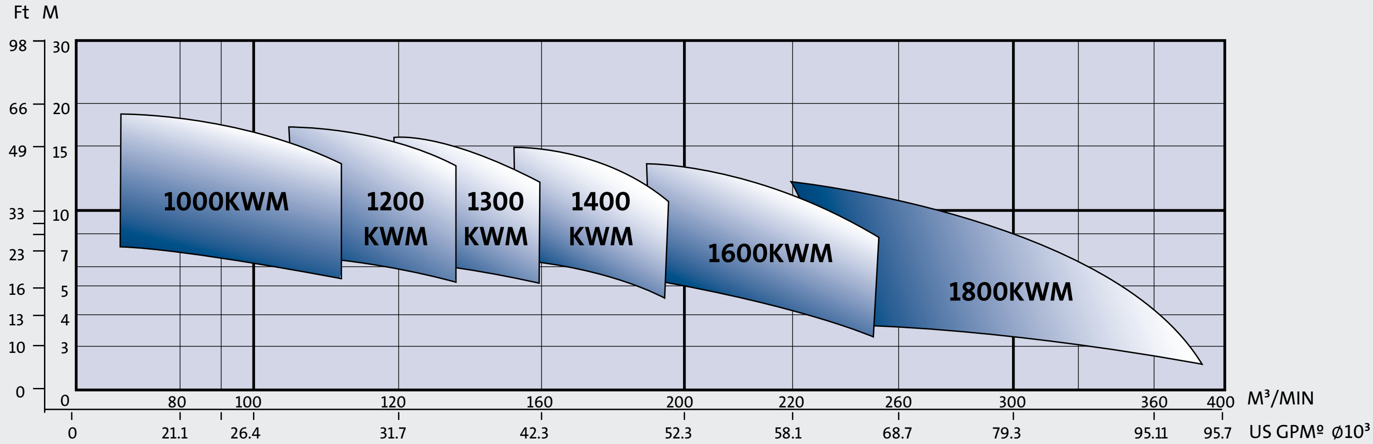


RULE OF THUMB:
HEAD BELOW 9 METRES=> KPL AXIAL FLOW PROPELLER
PUMP HEAD ABOVE 9 M=> KWM MIXED FLOW PUMP

KWM

Mixed flow pump, max flow 400 m3/min, max head: 50 m.

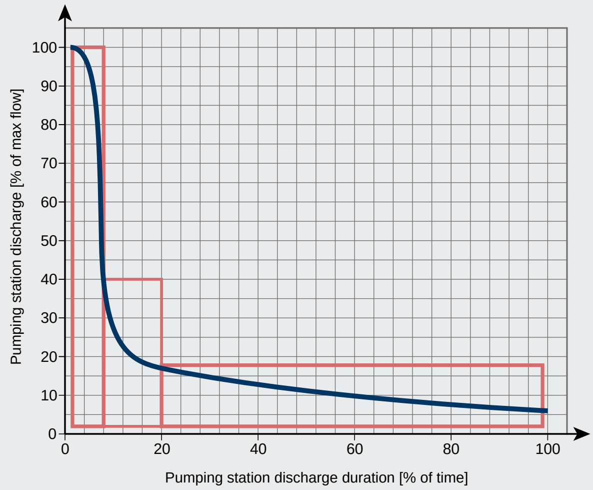




3.3.2 Number of pumps

Selecting the right pumps and the right quantity of pumps depends on the load profile: Q/H/time. In short, the ideal solution combination is where the individual pump operates as long as possible close to best efficiency point.

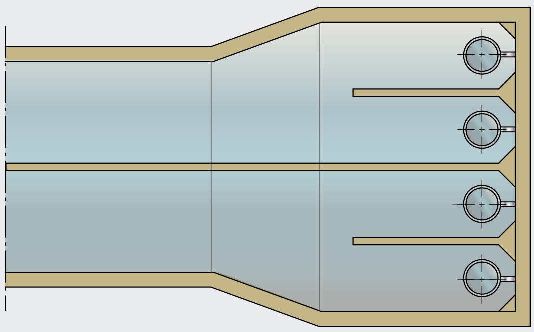
A minimum of two pumps are required: one duty and one stand-by pump. However, by installing more, but smaller pumps you gain a more reliable and easier controllable solution.



RULE OF THUMB:
Flow below 100 m3/min => 3 pump installation
Flow below 800 m3/min => 4 pump installation
Flow above 800 m3/min => 5-10 pump installation

Depth of the structure

Considering the depth of the pumping station at the design phase is vital, as smaller pumps can pump to a lower level than larger pumps. Consequently, smaller pumps can reduce the required depth of the pumping station.



A sufficient water velocity enables self-cleaning design.

High flow ensures self-cleaning and vice versa

Any pumping station design should consider the benefits of self-cleaning. By ensuring high flow/ a sufficient water velocity the design will prevent sedimentation and the need for regular cleaning.

If operation varies much (e.g. with the seasons), dividing the forebay and pump bays into two halves should be considered. Thereby, you use only one half of the station in low-flow seasons.

The dividing walls with an overflow gate allows the water to flow from one half to the other in high-flow seasons and in case of emergency.

3.3.3 Pump selection/determine column diameter

When Q and H have been established, use the pump curve below to select the right pump. Select a pump with best efficiency point as close to the nominal duty point as possible.

How to select a pump

- Select a pump based on the required duty point, operating range and safety range.
- Use the curve charts in the KPL & KWM data booklet.
- Select pump hydraulics first and motor size afterwards.

Example of how to choose:

1. Duty point (H = 5 m and 1910 l/s), specified by customer.
2. Operating range (1750 l/s to 2000 l/s), specified by customer.
3. Q-H curve is obtained at a propeller angle of 19 °.
4. P2 at duty point 115 kW.
5. P2max in operating range 128 kW (at a flow of 1750 l/s).

SELECT THE PUMPS AND THE NUMBER OF PUMPS BASED ON LOAD PROFILE AND HIGHEST EFFICIENCY

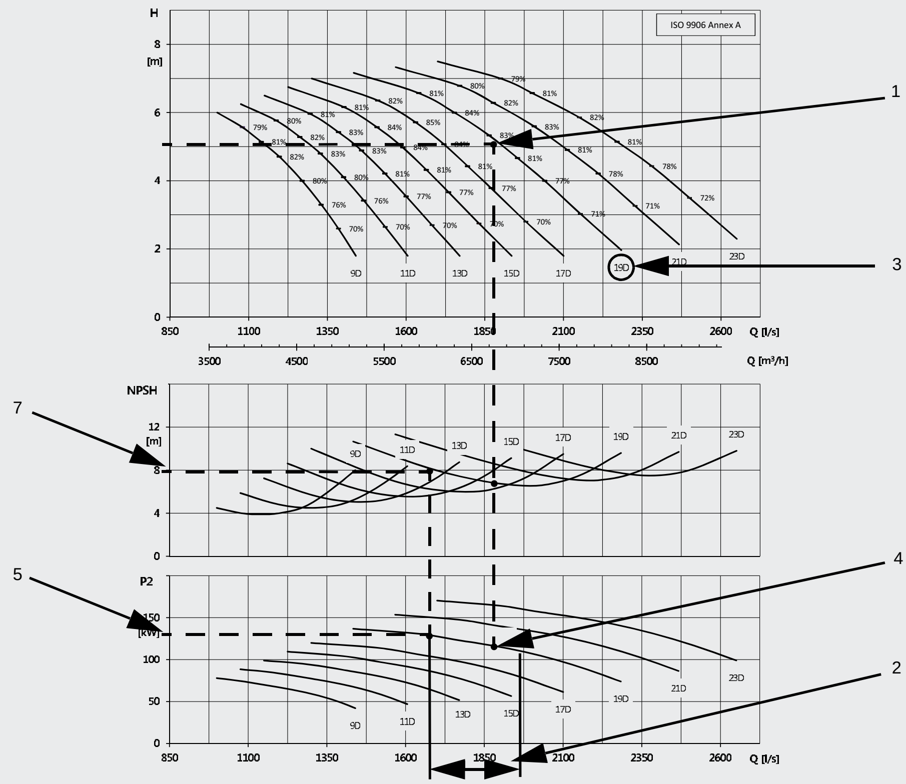
Example of how to choose motor size.

6. Calculate motor size and select model:
   Pmotor = P2max * 1.1 (10 % safety margin, specified by customer)
   Pmotor = 128 * 1.1 = 140.8 kW
   Pmotor ≤ rated motor
   Rated motor above Pmotor 160 kW

7. $NPSH_A$ (available) = 10 m, specified by customer.
   $NPSH_R$ (required) = 8 m (worst case for operating range).
   $NPSH_A > NPSH_R + 0.5$ m. (accepted)

Selected model: KPL.1000.160.10.T.50.19.A.

MODEL	MOTOR kW	FREQ. Hz	RATED SPEED rpm	POLES	TUBE	PRO. DIA. mm	NO. OF BLADES
KPL.1000.90.10.T.50.A	90	50	580	10	DN1000	700	4
KPL.1000.132.10.T.50.A	132						
6 → KPL.1000.160.10.T.50.A	160						
KPL.1000.200.10.T.50.A	200						



3.3.4 Minimum submergence (S)

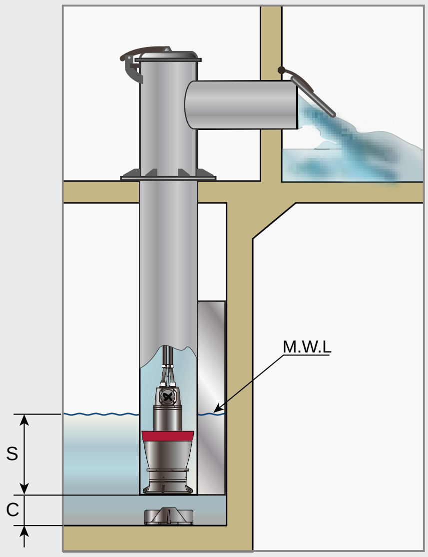
Finding the right minimum submergence of a pump is a vital design choice, as it defines the lowest point of the pumping station and therefore also a major part of the construction costs.

The Minimum Water Level (MWL) in a pumping station is usually defined by external conditions, including the level of the incoming pipe or culvert, or the NPSH requirements of the pump.

For NPSH requirements, see 3.2.4 or the KPL & KWM Pump data booklet.

The submergence of the intake

Typically, the submergence of an intake should be large enough to prevent air entraining vortices, swirling flow, and the influence of surface waves. This is possible in a conservative hydraulic design with a deeply submerged intake, although more costly than a design in which the minimum submergence is only just adequate.



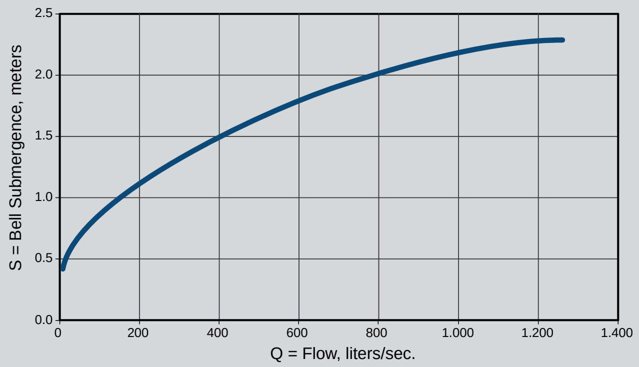
Minimum Water Level (MWL) = Clearance (C) + Submergence (S).

The clearance C = 0,5 x Column Diameter (D)

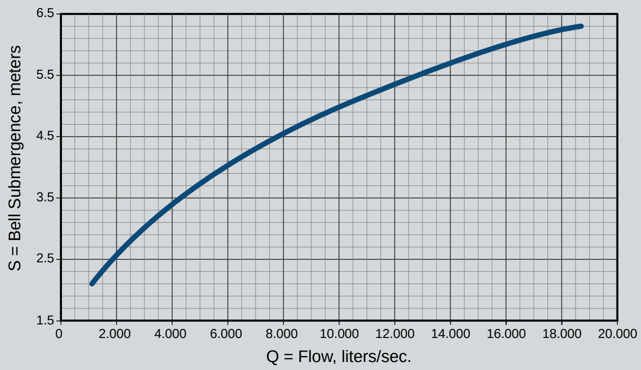
The minimum submergence is dictated by the level to avoid free surface vortices.

Determine the flow at minimum water level MWL. and look up the minimum submergence from the following curves from ANSI/HI:

Minimum submergence at flow up to 1.400 litres/sec:



Minimum submergence at flow above 1.400 litres/sec:



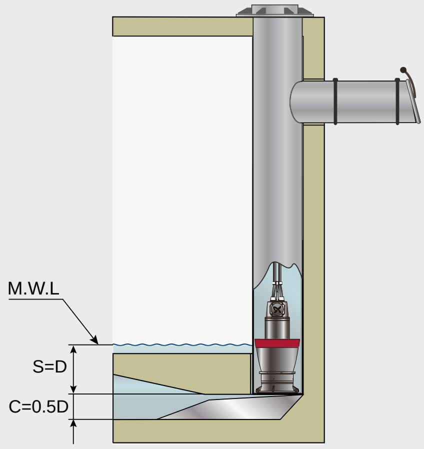
As a fast guide the following table can be used for reference:

Nominal Column Diameter	Min. Clearance	Min. submergence	Min. Water Level
D	C	S	M.W.L
500	250	1,000	1,250
600	300	1,100	1,400
700	350	1,600	1,950
800	400	1,800	2,200
900	450	2,000	2,450
1,000	500	2,200	2,700
1,200	600	2,300	2,900
1,400	700	2,500	3,200
1,500	750	2,900	3,650
1,600	800	3,100	3,900
1,800	900	3,300	4,200

All dimensions in mm.

Remember to check the NPSH, please refer to 3.2.5.

Formed Suction Intake (FSI)
The minimum water level can be optimised by using the Formed Suction Intake Type 10, designed by the US Army Corps of Engineers (USACE).



This, however, increases the demand for NPSH available vs. NPSH required:

$$NPSH_R + \text{safety margin} \leq NPSH_A$$
⇳
$$NPSH_R \leq 10 + Smin - \Delta H_{FSI} - \text{safety margin [m]}$$

ΔH_{FSI} is the friction loss through the FSI, which is dependent on design, material, surface structure etc.

Safety margin
A safety margin of 0.5 metres is often recommended. However, the real margin always relies on the individual conditions and has to be assessed in each case.

FSI calculation

In the following calculation we have used a safety margin of 0.5 metres including ΔHFSI:

$$NPSH_R \leq NPSH_A = 9.5 + Smin \ \ [m]$$

The USACE Formed Suction Intake Type 10 allows a minimum submergence of 0.94*D.

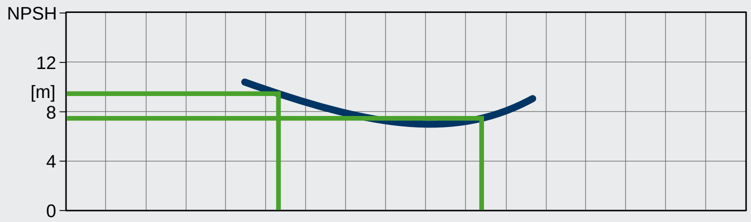
To get the full benefit of this optimised design, you need to select a pump that, in the full operating range, has a $NPSH_R$ equal to or lower than 9.5 + D. Alternatively, the minimum water level must be increased.

Example:

If you select a pump for a D = 1,000 mm column pipe, you can allow a minimum water level MWL = 1.5 metres if your pump has a NPSH required below 10.5 in the entire operating range.

If this is not the case, the minimum water level has to be increased.

This example is based on safety margin + ΔH_{FSI} = 0.5 m.



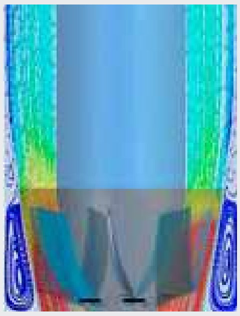
This table shows the maximum allowed $NPSH_R$ if the minimum submergence is D:

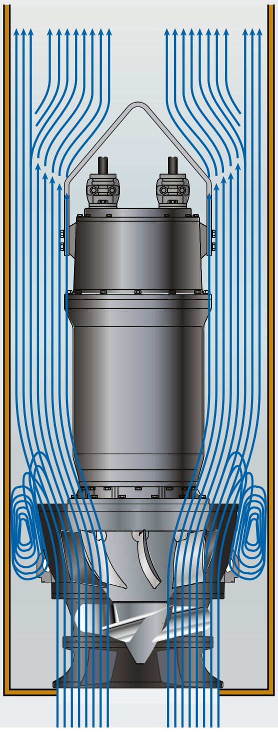
Nominal Column Diameter	Min. Clearance	Min. submergence	Min. Water Level	Max. NPSHrequired in the entire operating range
D	C	S	M.W.L	NPSHreq
[mm]	[mm]	[mm]	[mm]	[m]
500	250	500	750	10.0
600	300	600	900	10.1
700	350	700	1,050	10.2
800	400	800	1,200	10.3
900	450	900	1,350	10.4
1,000	500	1,000	1,500	10.5
1,200	600	1,200	1,800	10.7
1,400	700	1,400	2,100	10.9
1,500	750	1,500	2,250	11.0
1,600	800	1,600	2,400	11.1
1,800	900	1,800	2,700	11.3

3.3.5 Turbulence Optimiser™

With an instant change in diameter, turbulence will occur, resulting in loss of energy.

For column installed pumps this happens between the pump volute and the column itself.

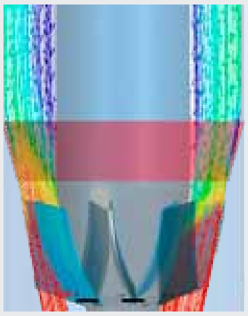




Without Turbulence Optimiser™: turbulence and loss of energy.

Reducing turbulence

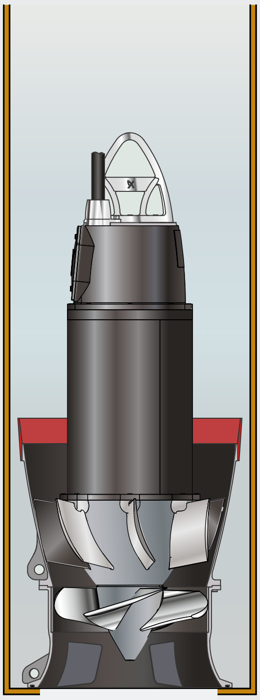
The Grundfos Turbulence Optimiser™ is a rubber diffuser mounted on the perimeter of the pump volute. The shape of the diffuser is optimised to reduce turbulence between the volute of the pump and the column pipe in which the pump is installed.



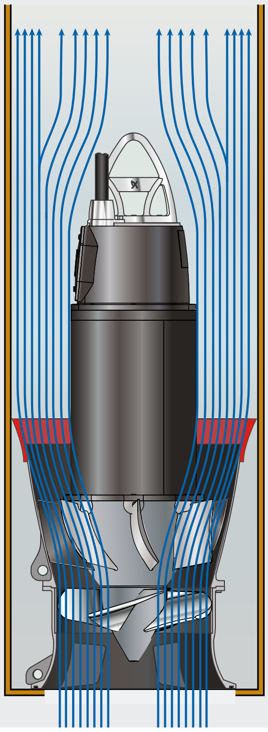
1-2% energy reduction

The idea is relatively simple; however the effect is outstanding.

When the pump is running, the Turbulence Optimiser™ expands and adapts perfectly to the pipe. This creates a turbulence-free flow and reduces energy losses. In fact, the Turbulence Optimiser™alone reduces energy consumption by 1-2%.



With Turbulence Optimiser™: even flow and efficient operation.



3.3.6 Sensors in the pumps

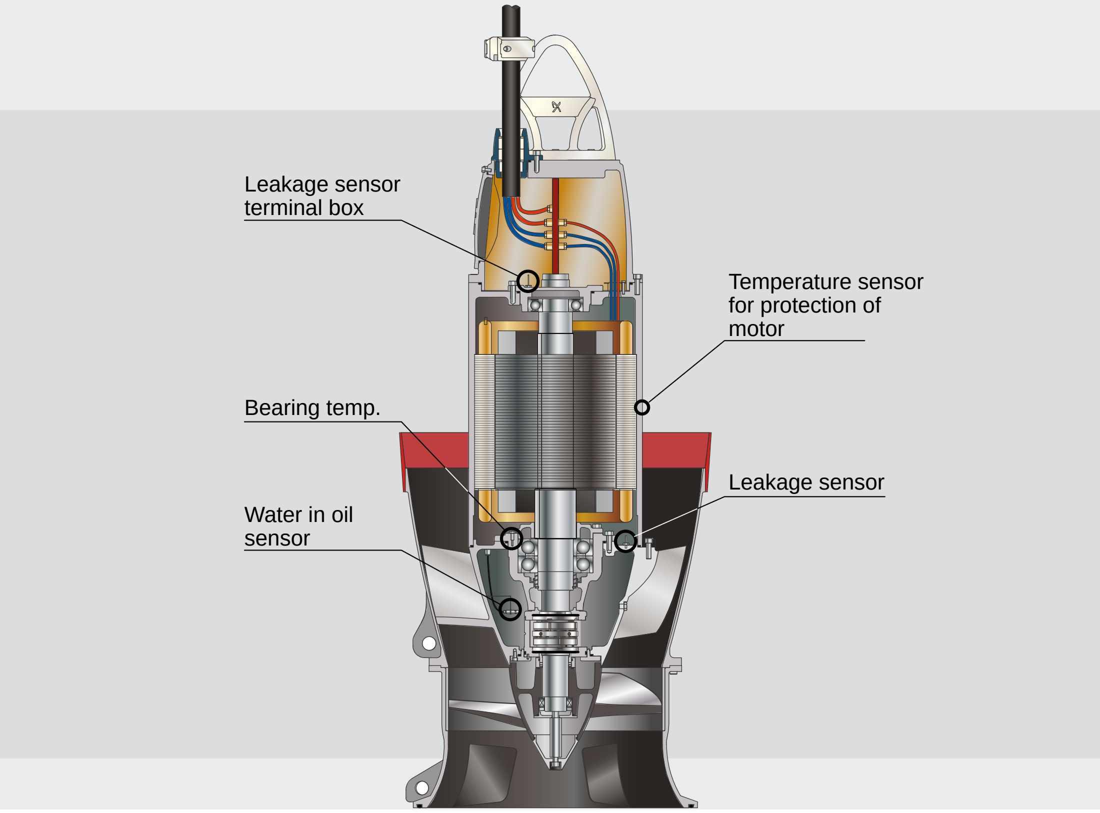
Sensors help alleviate main risks
When pumps are submerged, there is a greater risk of water entering the motor through the cable gland and shaft seal.

For that reason, most manufacturers incorporate an oil chamber with double sealing and also fit a range of sensors to protect the pumps – often far more than in smaller pumps.
Typical sensors in large pumps include:

- Bearing temperature sensors (lower and/or upper)
- Motor temperature sensors
- Water-in-oil sensors monitoring the conditions of the shaft seal
- Terminal box moisture sensors
- Vibration sensor
- Winding isolation resistance

Monitoring changes in values
In addition to the above pump sensor, most applications also have a sensor to keep an eye on power consumption, voltage, operating hours, etc. Often, keeping an eye on changes in values is more important than responding to absolute values.

During the commissioning stage, it will often be beneficial to experiment with different reference values to ascertain when action may be called for.



3.4 Dimensioning the pumping station

Grundfos has more than 30 years of experience with pumping station design. We know your business and what it takes to design a pumping station that will serve as a reliable guard against flooding – or minimise the consequences when it happens.

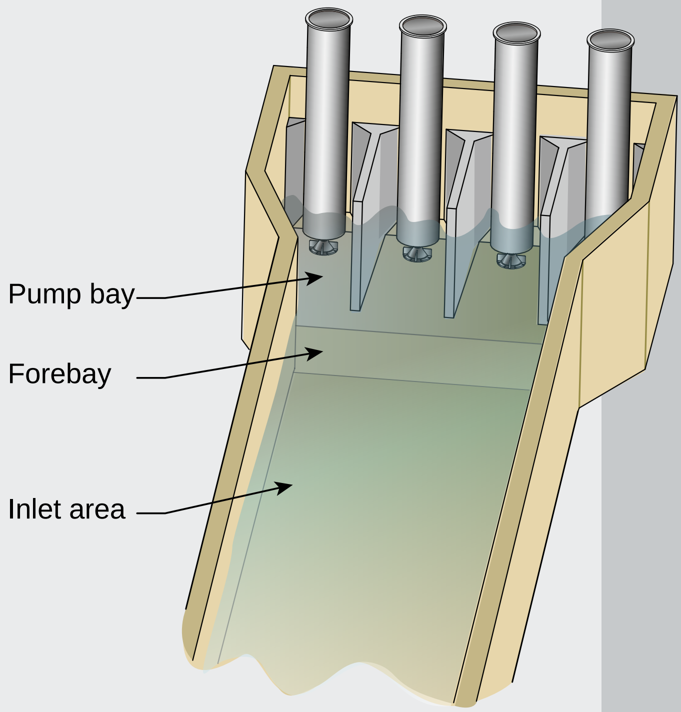
The design guidelines in the following are based on the recommendations of the American National Standards Institute (ANSI)and The Hydraulic Institute.

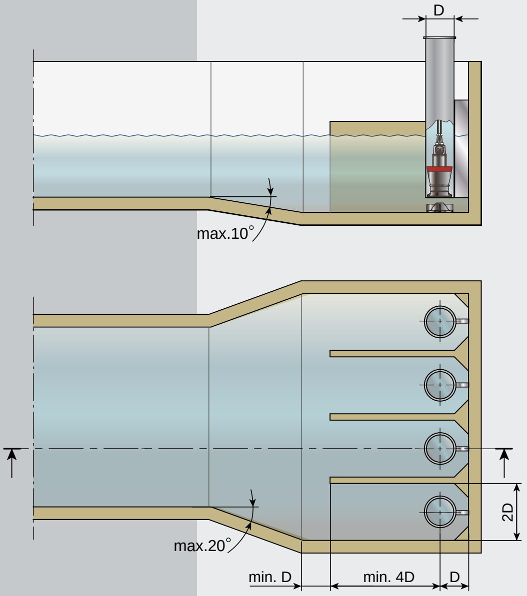
3.4.1 Terminology and conventions

Inlet
An inlet directs water to the pumping station from a supply source such as a culvert, canal or river. Usually, the inlet has a control structure such as a weir or a gate

Forebay
The forebay serves to create a uniform and steady flow to the pump bays. The design of the forebay depends on the water approach to the pumping station commonly encountered as parallel with the sump centreline, the preferred layout, or perpendicular to the sump centreline. To secure a steady inflow to each module, it is essential to follow the design guidelines presented here.

Pump bay
The pumps are located in the pump bay. Once the water flows through the pumps bay and reaches the pump inlet, it must be uniform and without swirls and entrained air.





3.4.2 Different station layouts

FRONT INFLOW
The inlet must be placed symmetrically to the pumps if water approaches the station parallel to the sump centreline. If the inlet width is smaller than the width of the pump bays, the forebay should diverge symmetrically.

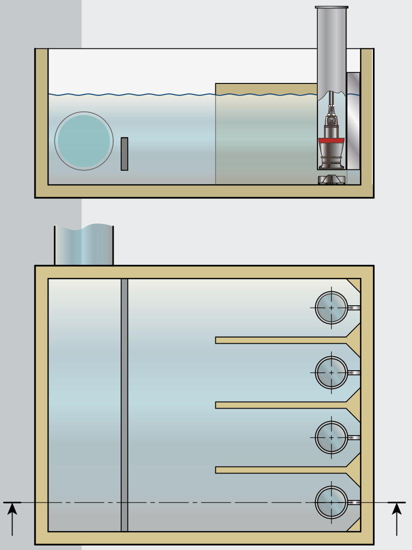
The total angle of divergence should not exceed 20° for open sump intake designs or 40° for formed intake designs. The bottom slope in the forebay should not be more than 10°.

If these limits cannot be met, devices to manage the flow direction can improve the flow distribution.

Using model tests of these or more complex layouts could suggest the optimal design.

Advantages
Balanced inflow to the individual pump bays.

Challenges
Size, and achieving enough water velocity to prevent sedimentation.



SIDE INFLOW
An overflow-underflow weir can help redistribute the flow if the inflow is perpendicular to the axis of the pump bays. However, a substantial head loss at the weir is required to remove much of the kinetic energy from the incoming flow.

Baffle systems may be used to redirect the flow, but their shape, position, and orientation must be determined in model tests.

The distance between the weir or baffles and the pump bays must be sufficient to prevent swirls and entrained air to reach the pump inlet.

Advantages
Compact design

Challenges
Unbalanced inflow to the individual pump bays.

3.4.3 Pump bay design

Column-installed pumps in a sump are high-volume pumps, making them sensitive to suction chamber conditions. Therefore, great care must be taken to ensure safe and long-lasting pump operation.

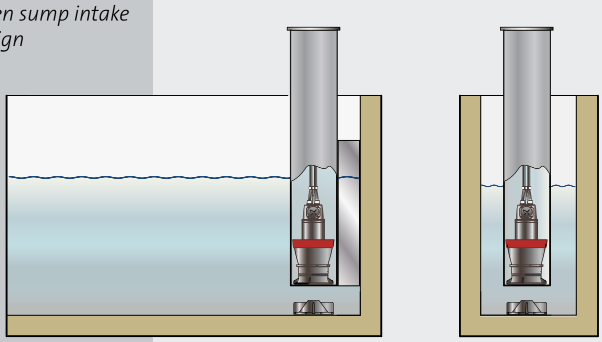
As we have touched upon earlier, the main design requirement for a sump design is to provide optimal inlet conditions for the pumps.

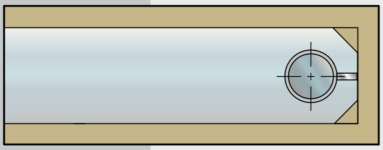
The basics

The flow being delivered to the pump units should be uniform, steady, and free of swirls or entrained air.

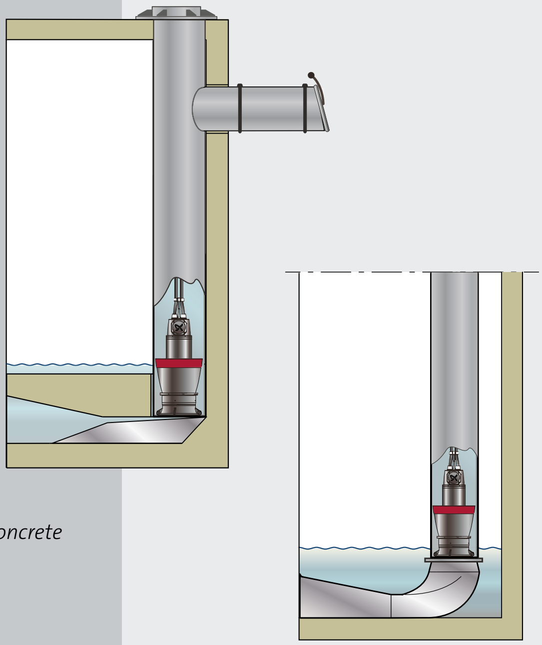
The dividing walls – and the positioning of the pumps – must be designed in a way that avoids surface vortices, air ingestion and entrainment, and turbulence.

Open sump intake design





FSI in concrete



FSI in steel

Pump bay design variations

1. Open sump intake

This design is sensitive to non-uniform flow, as it requires a longer forebay and longer dividing walls between the individual pump bays than the formed suction intake design installations. Furthermore, the design is sensitive to flow disturbances such as columns and beams of the civil structure of the pumping station.

Splitters and dividers

According to the ANSI standard 9.8-1998, the open sump intake design includes devices such as splitters and divider plates that alleviate the effects of minor asymmetries in the approaching flow.

GRUNDFOS RECOMMENDS USING OF OUR PATENTED ANTI-CAVITATION CONE, ACC, AS A FLOOR SPLITTER.

2. Formed suction intake

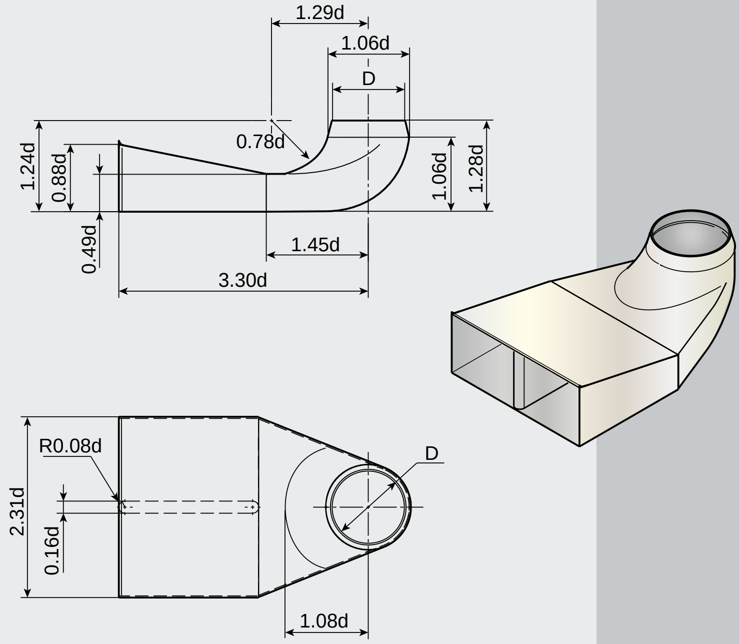
This design is least sensitive to disturbances of the approaching flow that can result from diverging or turning the flow in the forebay, or from single pump operation at partial load.

Formed suction intake design

According to the US Army corps of engineers (EM 1110-2-3105, Aug. 1994.), the FSI design can be constructed in either concrete or steel. The intake reduces disturbances and swirl in the approaching flow. The inclined front wall is designed to prevent stagnation of the surface flow.

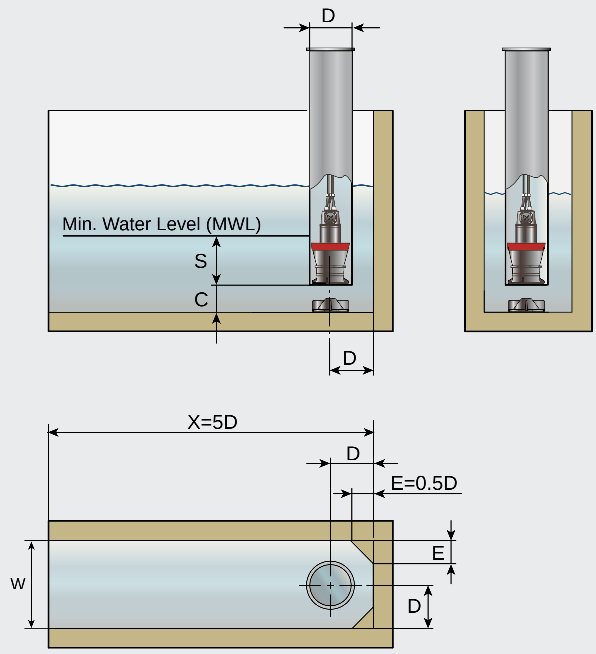
The geometrical features of this intake provide for smooth acceleration and turning as the flow enters the pump. The minimum submergence should not be less than the column diameter.

This design is recommended for stations with multiple pumps with various operating conditions



3.4.4 Pumping station dimensions

Open sump design:

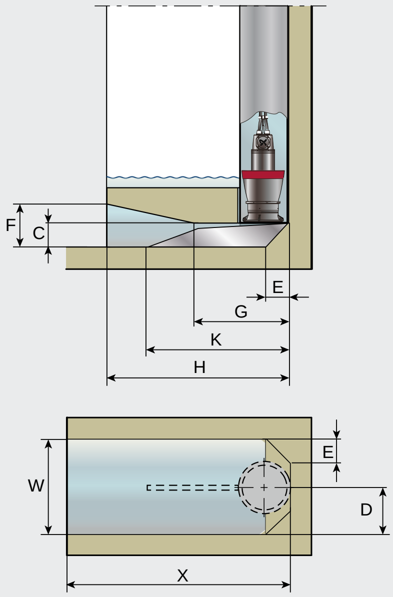


Nominal column diameter	Min. Clearance	Min. submergence*	Min. water level*	Pump bay width	Pump bay length	Fillet
D	C	S	M.W.L	W	X	E
500	250	1,000	1,250	1,000	2,500	250
600	300	1,100	1,400	1,200	3,000	300
700	350	1,600	1,950	1,400	3,500	350
800	400	1,800	2,200	1,600	4,000	400
900	450	2,000	2,450	1,800	4,500	450
1,000	500	2,200	2,700	2,000	5,000	500
1,200	600	2,300	2,900	2,400	6,000	600
1,400	700	2,500	3,200	2,800	7,000	700
1,500	750	2,900	3,650	3,000	7,500	750
1,600	800	3,100	3,900	3,200	8,000	800
1,800	900	3,300	4,200	3,600	9,000	900

All dimensions in mm.

* for the exact values of S and MWL, please refer to 3.3.4

Formed suction intake (FSI), concrete:

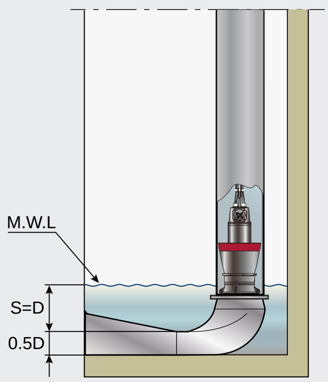


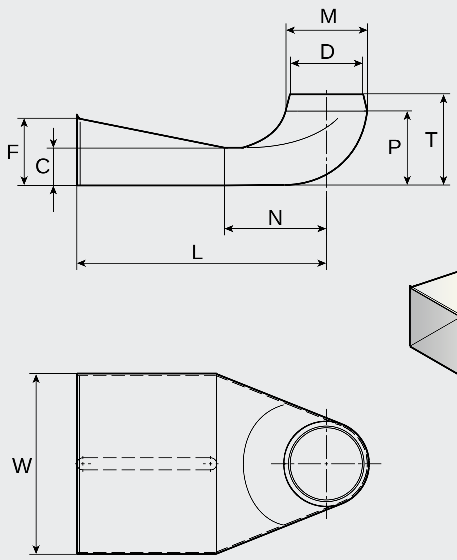
Nominal column diameter	Clearance	Formed Suction Intake FSI			Pump bay width	Pump bay length	Fillet	Floor splitter
D	C	H	G	F	W	X	E	K
500	250	1,900	1,000	450	1,000	2,500	250	1.500
600	300	2,280	1,200	540	1,200	3,000	300	1.800
700	350	2,660	1,400	630	1,400	3,500	350	2.100
800	400	3,040	1,600	720	1,600	4,000	400	2.400
900	450	3,420	1,800	810	1,800	4,500	450	2.700
1,000	500	3,800	2,000	900	2,000	5,000	500	3.000
1,200	600	4,560	2,400	1,080	2,400	6,000	600	3.600
1,400	700	5,320	2,800	1,260	2,800	7,000	700	4.200
1,500	750	5,700	3,000	1,350	3,000	7,500	750	4.500
1,600	800	6,080	3,200	1,440	3,200	8,000	800	4.800
1,800	900	6,840	3,600	1,620	3,600	9,000	900	5.400

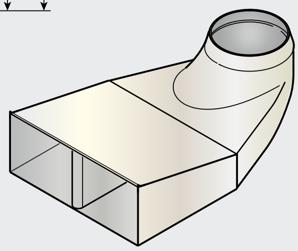
All dimensions in mm.

Remember to check NPSH

Formed suction intake FSI, steel:







USACE type 10.

Nominal column diameter	Formed Suction Intake (FSI) steel version							
D	C	F	L	M	N	P	T	W
500	250	440	1,650	530	725	530	640	1,155
600	300	540	1,980	636	870	636	768	1,386
700	350	630	2,310	742	1,015	742	896	1,617
800	400	720	2,640	848	1,160	848	1,024	1,848
900	450	810	2,970	954	1,305	954	1,152	2,079
1,000	500	900	3,300	1,060	1,450	1,060	1,280	2,310
1,200	600	1,080	3,960	1,272	1,740	1,272	1,536	2,772
1,400	700	1,260	4,620	1,484	2,030	1,484	1,792	3,234
1,500	750	1,350	4,950	1,590	2,175	1,590	1,920	3,465
1,600	800	1,440	5,280	1,696	2,320	1,696	2,048	3,696
1,800	900	1,620	5,940	1,908	2,610	1,908	2,304	4,158

All dimensions in mm.

Remember to check NPSH

3.5 Duty strategy - reducing the minimum water level

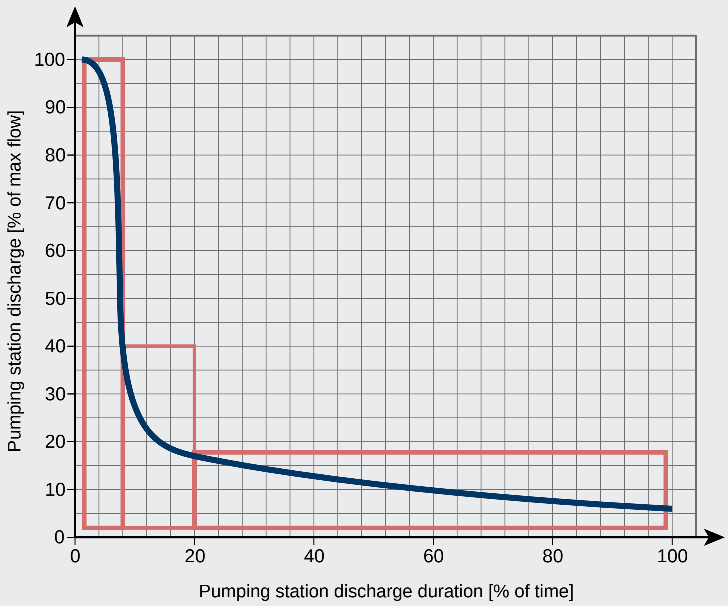
From an operational perspective, any water utility installation presents a balance. And sometimes this balance is a compromise between initial cost (CAPEX), and operation cost (OPEX).

Reducing CAPEX
CAPEX can be reduced by selecting pumps that are optimised as regards size and duty strategy. In that way you can construct a building that is smaller and not so deep in the ground, i.e. less excavation, less concrete, less cost.

Designing an oversized pumping station may be a reliable security against flood situations, but an expensive and energy inefficient solution.

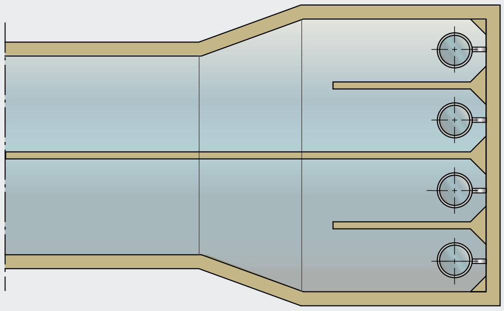
Reducing OPEX
OPEX can be reduced by considering the load duration profile of the pumping station and selecting pumps that in groups can cover the entire operation range as close to best efficiency point as possible.

Both objectives, reducing CAPEX and OPEX, can be met by grouping the pumps in such a way that the normal operation area is covered by the main pumps and then have smaller pumps to pump to the lowest level.



Two-chamber solution

Flood control pumping stations are often designed to operate under high peak flows in extreme flood situations. However, most of the year the flow is considerably lower.



Often, the final pumping station design ends up being quite unsuited for both scenarios.
The challenge is that if you optimise your pumping station to the water velocities at peak flow, you will most likely have stagnating zones at lower flow, which probably is most of the year.

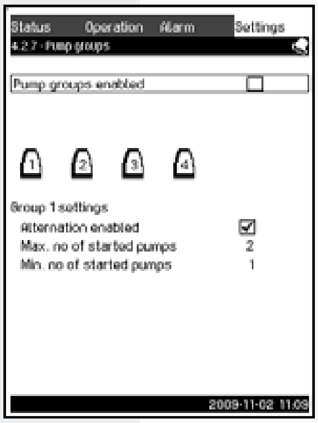
To overcome this challenge, the station can be divided into two chambers:

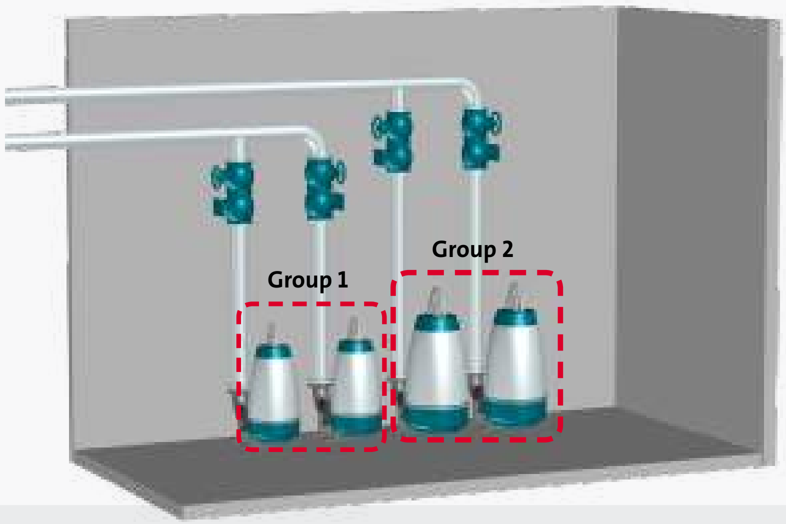
- Chamber 1: for low-season operation
- Chamber 1+2: for high-season and peak-flow situations.

The wall between the two chambers of the station must have a lower section or adjustable weir that allows the water to flow over into the second chamber in extreme flood situations.

Pump groups

Pump groups enables the user to group two sets of pumps.
An example could be to run with two small pumps 80 % of the time (typical load profile) and then in case of heavy rain group 2 will start.





3.5.1 Grundfos dedicated controls

Monitoring and control

Flood control pumps can be a big investment. In addition, service and repair can be relatively costly.

Despite optimal system design and high quality pumps, wear is inevitable – as is the risk of failure. However, monitoring the condition of pumps will lower the total life cycle cost of the flood control application.

Proper monitoring and control will:

- Protect expensive equipment
- Help ensure optimum station operation
- Reduce energy consumption
- Help avoid overflow – and report any incident
- Optimise service personnel schedules for preventive maintenance
- Meet demand for more accurate reporting, (e.g. to comply with stricter environmental legislation)

The changes in the pump conditions described above and the easy commissioning are the reasons for introducing performance on-demand control in Dedicated Controls from Grundfos.

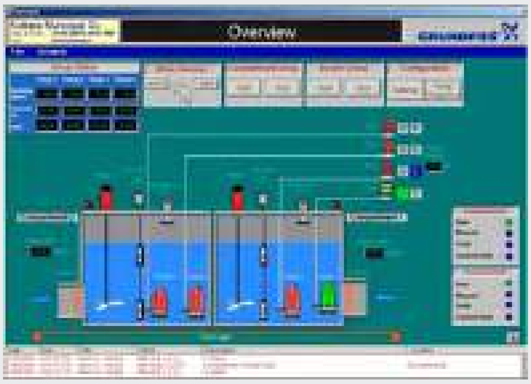
3.5.2 Communication modules and SCADA implementation

For complete control of pump systems, the Grundfos fieldbus concept is the right solution. The Communication Interface Module (CIM) and the Communication Interface Unit (CIU) enable data communication via open and interoperable networks and easy integration into SCADA systems.

Connecting Grundfos products to standard fieldbus networks offers substantial benefits:

- Complete process control
- One concept for Grundfos products
- Modular design – prepared for future needs
- Based on standard functional profiles
- 24-240 VAC/DC power supply in CIU modules
- Simple configuration and easy to install
- Open communication standards

Your Grundfos CIU/CIM communication interface solution can be connected to any SCADA, PLC or Building Management System for communication using the applicable open protocols for wired and wireless communication.



3.5.3 Grundfos Remote Management (GRM)

Grundfos Remote Management (GRM) is a cost-effective and straightforward way to monitor and manage pump installations in a water supply and wastewater infrastructure. It reduces the need for onsite inspections, and in the event of an alarm or warning, the relevant people are notified directly.

Connecting pumps and people
Grundfos Remote Management offers you a complete overview of your pumping systems and lets you be online with your pumps on a secure network hosted by Grundfos. You can monitor energy consumption, share documentation, manage service and maintenance, and maintain a flexible on-call schedule.

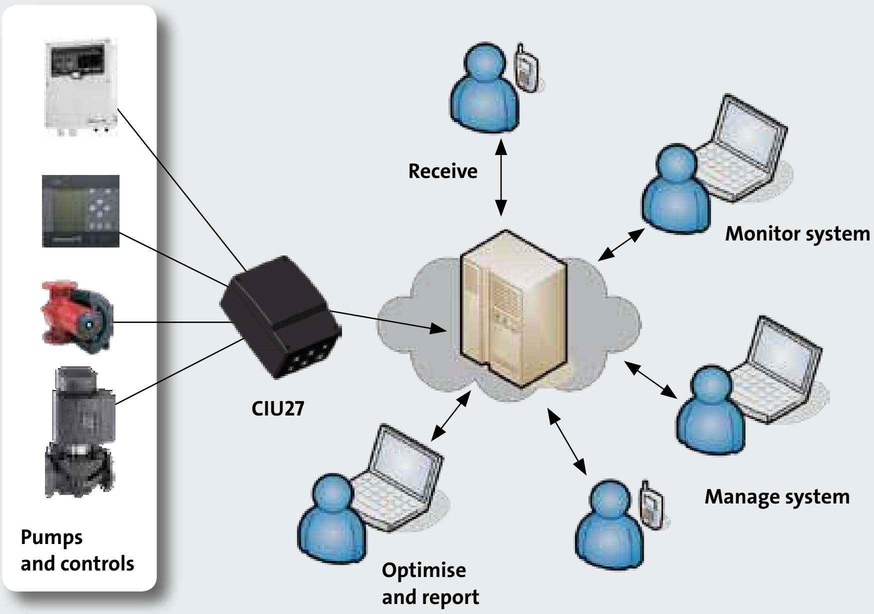
As opposed to traditional SCADA systems, GRM is ideal for everyone who does not require remote process automation. The initial investment is minimal, and a fixed low fee covers data traffic, hosting costs and system support, including back-up of all data.

Grundfos Remote Management offers many advantages for managing your critical installations:

Wastewater and flood pumping stations
Monitor standard wastewater pumps, sensors and controllers of any make and model, including automatic reports of operational data.

Water treatment plants
Monitor flow and pressure sensors, tank levels, pumps and security alarms, including automatic reports of power consumption and operational data.

Mines and construction sites
Receive alarms from dewatering pumps immediately in the critical event of breakdown or malfunction.



3.5.4 Motor Protection (MP204)

Protect your pumps against external threats
The MP 204 protects pump motors against under voltage, over voltage and other variations in power supply. So even if your external power supply is not entirely steady, your pump will continue its steady performance. Your pump motors will also be protected against the overheating that accompanies such variations and reduces pump lifetime.

Phase errors are a frequent cause of problems for pumps of this type. After you set the relevant phase (1 or 3) during set-up, the learning function of the MP 204 registers the correct phase and reacts if things are not right.

The MP 204 also monitors pump power consumption. As reduced power consumption is a strong indication that the pump is about to run dry, the MP 204 will immediately stop the pump if the power consumption drops below 60%.

Maximum uptime is ensured, preventing interruptions in boosting performance. All this in a unit that can be set up for operation in just 2 minutes.

3.5.5 Variable frequency drives (CUE)

Grundfos CUE is a series of variable frequency drives designed for speed control of a wide range of Grundfos pumps. The CUE contains the same control functionality as the Grundfos E-pumps.

Reasons for employing automatic frequency control can both be related to the functionality of the application and for saving energy.

For example, automatic frequency control is used in pump applications where the flow is matched either to volume or pressure. The pump adjusts its revolutions to a given set point via a regulating loop. Adjusting the flow or pressure to the actual demand reduces power consumption.

Energy vs. reliability
Reducing the power consumption is of course recommended, but never without considering the velocity.

Finding just the right balance is optimal, as high speed will remove sedimentation in the column, but increase energy cost. And low speed reduces energy costs, but increases the concentration of solids in the column. This makes the water heavier and causes the motor to trip on overload.

Flush cycle
The problem of sedimentation and a high concentration of solids in the water can be solved by an intelligent controller.

A Grundfos dedicated controller will automatically speed up the pumps to run a flush cycle, or a back flush function to prevent these common problems.

3.5.6 Soft starters

Soft-start eliminates the start-up power surge associated with conventional pumps, imposing minimal demand on inverters and generators.

IN THE COLUMN PIPE

IF VELOCITY IS TOO HIGH
↓
PRESSURE LOSS (ENERGY)

IF VELOCITY IS TOO LOW
↓
SEDIMENTATION OR HIGH CONCENTRATION OF SOLIDS

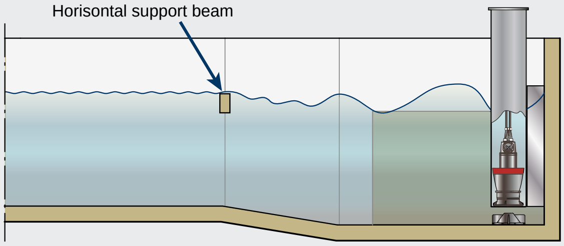
Use of soft starters and frequency drives is often recommended in order to reduce the load on the power supply or for adapting to a specific flow.
When using speed control it is important to consider the resonant frequency of the pump and the system in order to avoid vibrations that can transfer to other parts of the structure or system.
The ramp time must be adjusted to fit the system.

3.6 Other considerations for the construction

3.6.1 Support beams and columns for the building

If horizontal beams cannot be avoided, it is important to consider the normal water level and place the beams above this.

Prevent the bull whip effect
Even narrow submerged beams can cause considerable waves in the pump bay, also known as “the bull whip effect”.



CFD analysis is recommended
When placing columns to support the structure, consider the shadow areas they create and introduce fillets where appropriate.

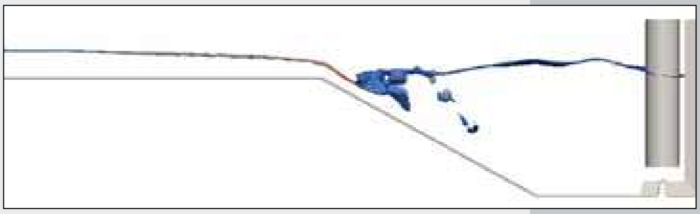
The fillets prevent stagnation regions and sedimentation. If possible, such stagnation regions should be filled with concrete before operation commences.

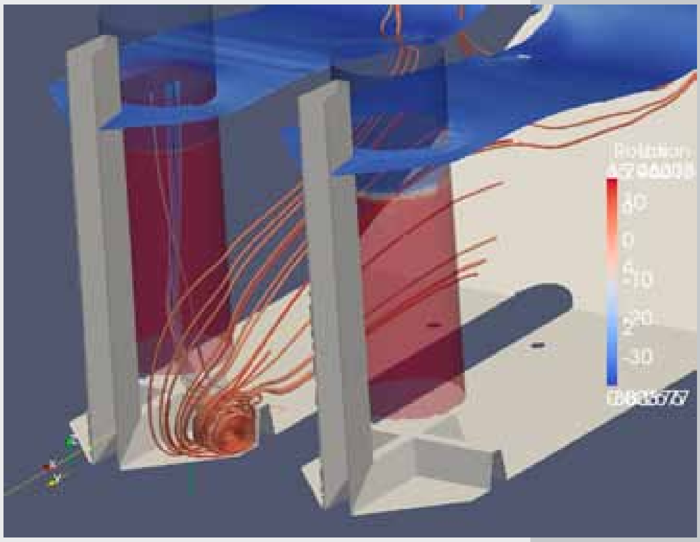
Need assistance?
For the best results, feel free to contact our experts at the Grundfos Water Utility Competence Centres during your planning stages.

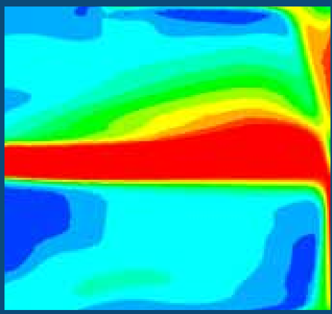
We can assist with everything you need within pumping station design, pump selection, future requirements, and the total Life Cycle Costs.

The Grundfos Water Utility Competence Centres are located in Copenhagen and Aurora in the USA.

For more information, please visit:
www.grundfos.com/flood-control







4 CFD AND MODEL TESTING

The previous sections of this design guide provide guidelines on how to design and dimension a flood pumping station. To verify and optimise the design, as well as identifying areas that need special attention, CFD or scale model testing is recommended.

Model testing and Computational Fluid Dynamics (CFD) offer important information to support vital design decisions. And both methods, regardless of preference, will resolve many complex issues and prevent flow problems before construction begins.

4.1 Computational Fluid Dynamics (CFD)

Computational Fluid Dynamics (CFD) simulation has proven to be a very useful tool in providing very detailed information within a wide range of areas at a very low cost.

When designing a pumping station, Grundfos specialists can apply CFD simulations to depict accurately fluid flows and pressure graphically at any location in the system. This means that we are able to simulate and discover flow problems in the simulation and correct them before construction begins.

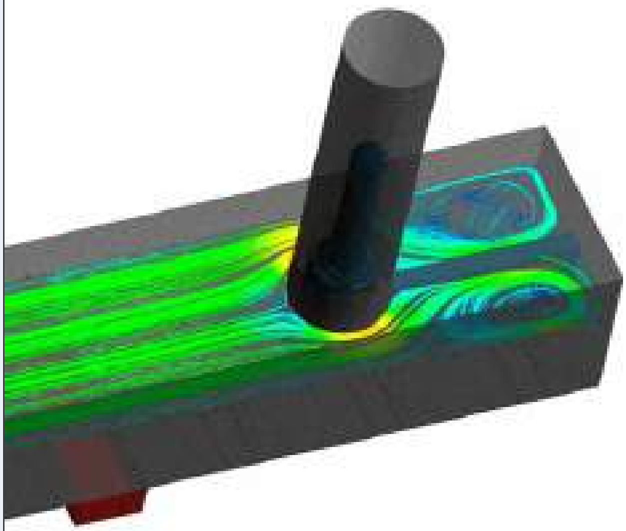
Provides design alternatives
CFD simulation enables the stakeholders to get a qualitative and quantitative understanding of pumping station hydraulics and offers good comparisons between various design alternatives.

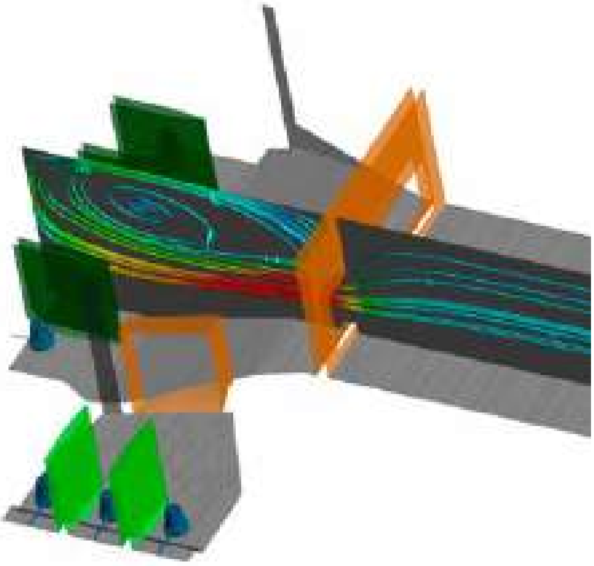
CFD simulation thus enables everyone involved in a project to make informed decisions before carrying out the actual infrastructure investments. This makes it possible to evaluate, adjust and eliminate potential risk.

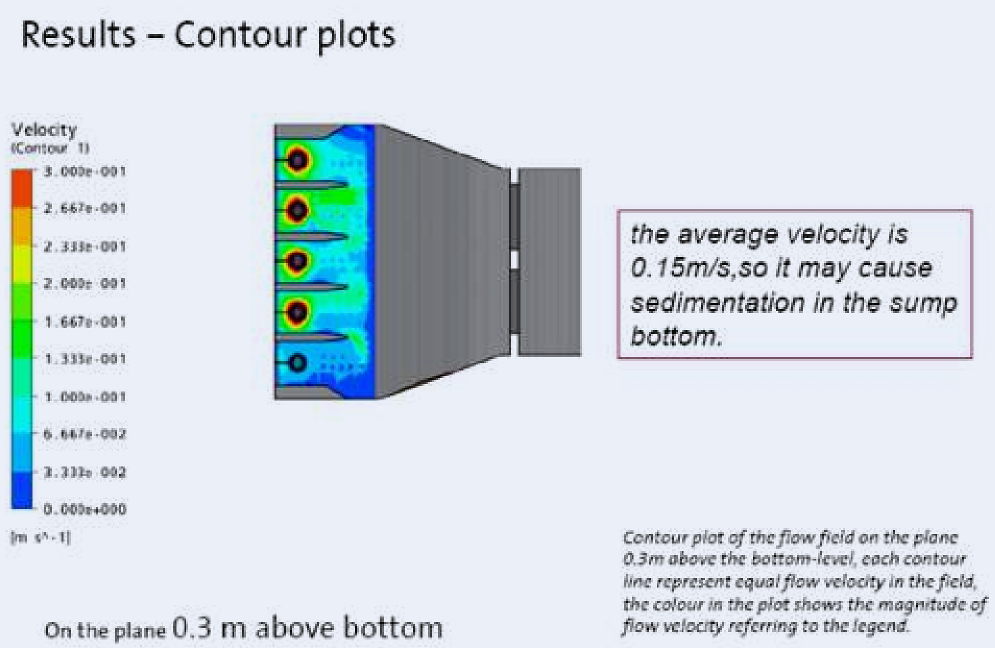
Advanced flooding simulations
Grundfos has been using advanced CFD simulation in many projects all over the world, including flood control projects.

Ensuring that flood events can be controlled often requires careful planning. Using advanced CFD simulations during the design phase, we can tailor pump solutions that can cope with the heavy demands of moving vast flows of surface or storm water – and guarantee that they work.

Regardless of your specific requirements, we will be more than happy to bring our expertise with CFD simulation to your project.



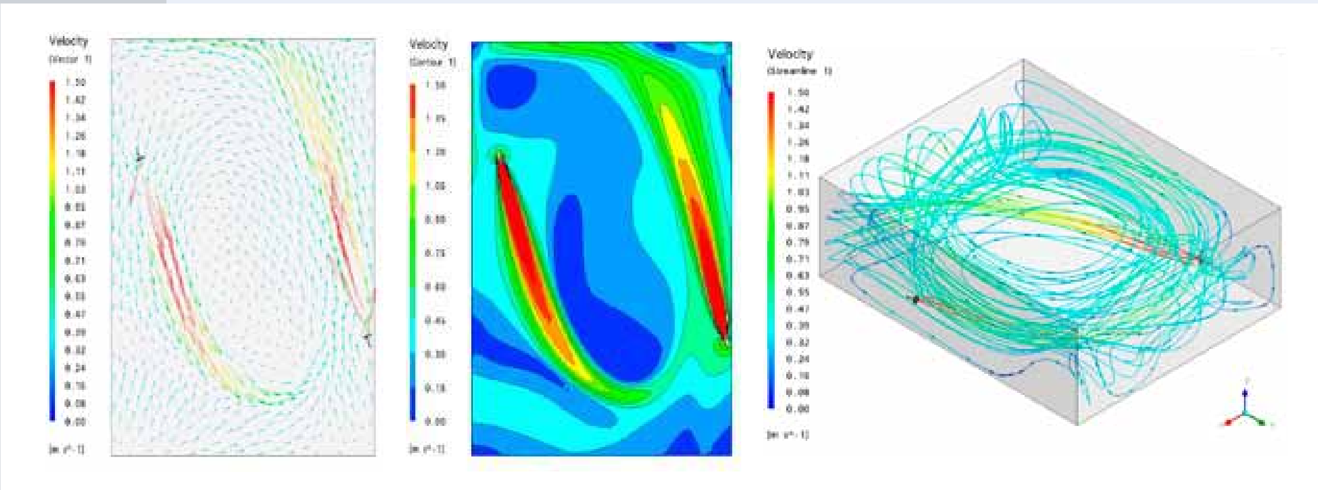




Vector and contour plot, and streamline of the flow field, show the flow direction and velocity.

Why use CFD?

1. Time: It's fast
2. Economy: Attractive cost
3. Flexibility: Parameters and geometry can easily be adjusted
4. Visual: Accurately fluid flows and pressure in the system



4.2 Model testing

Building an actual model of a pumping station can be the appropriate solution in some pumping station projects. This is especially the case when seeking solutions to problems in existing stations. If the cause of a problem is unknown, building a model of the pumping station can be a cost-effective and very efficient way to determine the source of the problem.

Model testing allows designers to test alternative solutions in a real life model rather than trial and error at full scale. Therefore, model testing can provide a tried and tested pumping station design or the perfect remedy to a complex problem.

The formation of a submerged side wall vortex.

Physical hydraulic model testing.

Wet well, complete with benching, baffle wall, 500 mm interconnecting level equalisation pipe and representations of two model pumps.

Representations of two model pump units.

5 VORTEX – AND HOW TO PREVENT IT

What is a vortex?
A vortex is a region within a fluid where the flow is mostly a spinning motion about an imaginary axis, straight or curved. That motion pattern is called a vortical flow or vortex.

How do they form?
Vortices form spontaneously in stirred fluids, and are a major component of turbulent flow. In the absence of external forces, viscous friction within the fluid tends to organise the flow into a collection of so-called irrotational vortices.

Vortex explained
Within such a vortex, the fluid's velocity is greatest next to the imaginary axis and decreases in inverse proportional distance from it. The vorticity (the curl of the fluid's velocity) is very high in a core region surrounding the axis and nearly zero in the rest of the vortex; while the pressure drops sharply as one approaches that region.

Vortices in pumping stations
Vortices in pumping station should be avoided or minimised as they can cause air entrancement in the pump and cavitation.

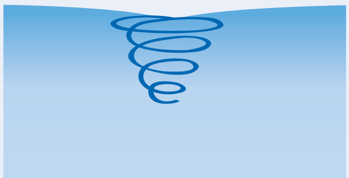
5.1 Types of vortices

Vortices are a result of flow, speed and pressure and can be formed from the surface when the water level is too low – but can also be formed submerged from the back or side wall or from the floor.

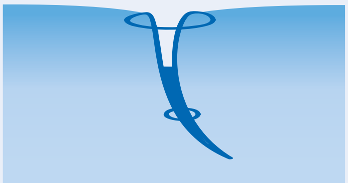
Here's a quick overview of the most common types of "free surface vortices":

1. Surface swirl

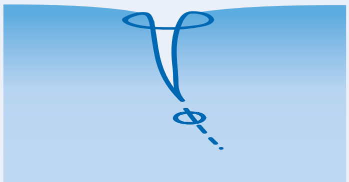
2. Surface dimple



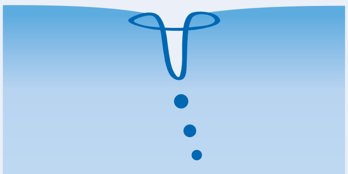
3. Dye core to intake: coherent swirl



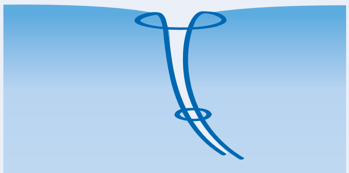
4. Vortex pulling floating trash but not air



5. Vortex pulling air bubbles



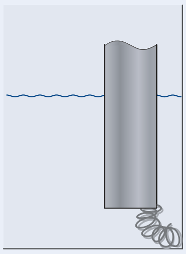
6. Full air core to intake



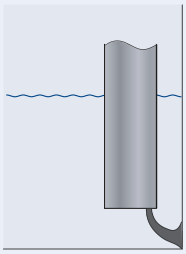
5.2 How to prevent vortices

In the following, we will introduce some of the most common types of vortices and corrective measures that can prevent them or reduce them to a minimum.

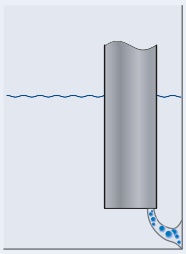
The designs we deal with in this book all have proven to work well in practise. However, replacing old pumps, difficult working conditions and other unforeseen restraints may in some cases be incompatible with the proper and straightforward design guidelines presen-ted here.



1. Swirl



2. Dye core



3. Air core or bubbles

5.2.1 Sub surface vortices: Excessive swirl around the pump tube

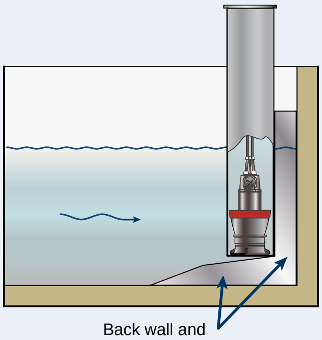
Problem:
In some cases, it can be impossible to provide adequate submergence and some vortexing or swirl may occur and cause undesirable features of the flow. This includes, excessive swirl around the pump tube with air-entraining surface vortices and with submerged vortices.

Solution
Swirl around the pump tube is usually caused by an asymmetrical velocity dis-tribution in the approach flow. Improving the symmetry subdivision of the inlet flow with dividing walls, and the introduction of training walls, baffles or varied flow resistance can in most cases reduce this problem.

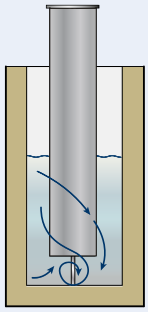
Alternatively, reducing the flow velocity by increasing the water depth in the sump will also minimise the problems of an asymmetrical approach.

Problem:
Small asymmetries of flow

Solution:
Inserting splitter plates between the pump tube and the back wall of the sump and underneath the pump on the floor can remove relatively small asymmetries of flow. The plates block the swirl around the tube and prevent formation of wall vortices.



Back wall and floor splitter plates



Back wall vortex caused by floor splitter only

5.2.2 Submerged vortices

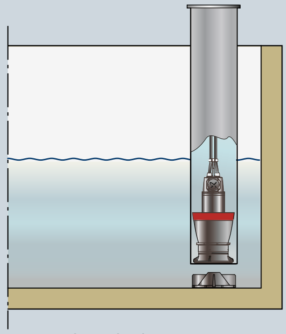
Problem:

Submerged vortices are often difficult to detect from above the free surface, as they form almost anywhere on the solid boundary of the sump.

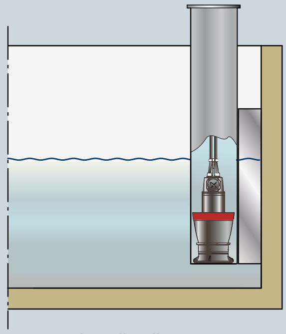
In fact, only erosion of the propeller blades or rough running of the pumps may reveal them.

Solution:

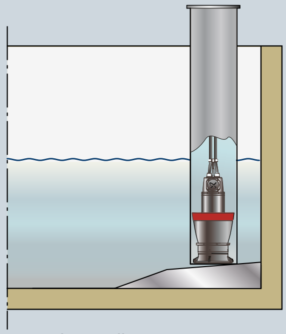
Submerged vortices can be eliminated by disturbing the formation of stagnation points in the flow. Addition of a centre cone or a splitter under the pump, or insertion of fillets and benching between adjoining wall may correct the flow pattern.



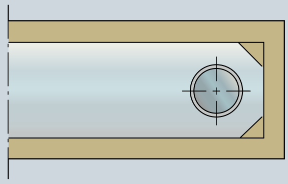
A: Anti Cavitation Cone ACC



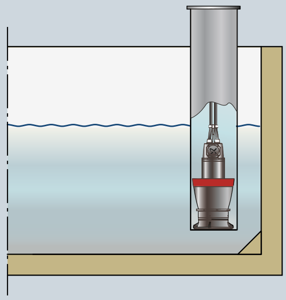
B: Back wall splitter



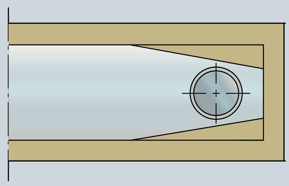
C: Floor splitter



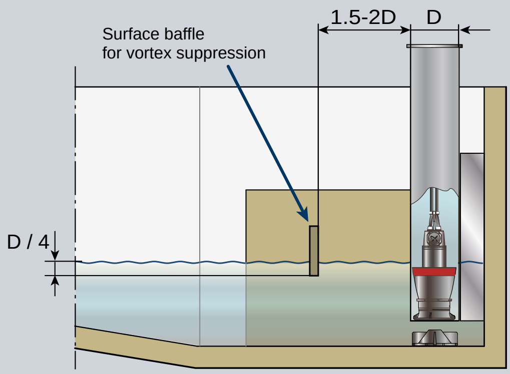
D: Corner fillets

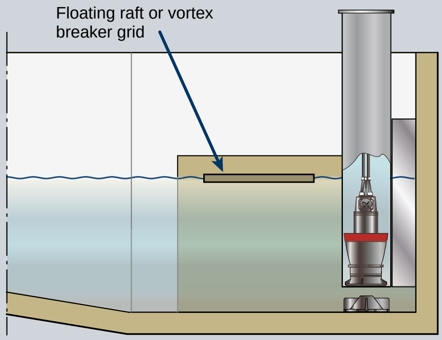


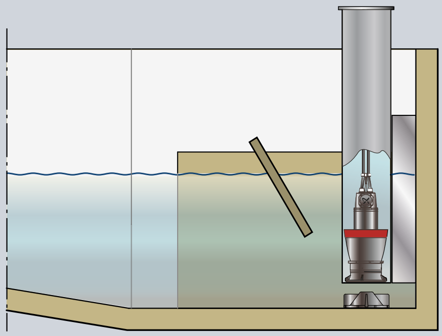
E: Back wall fillets



F: Side wall fillets







5.2.3 Air-entraining vortices

Problem

Air-entraining vortices develop either in the wake of the pump tube if the inlet velocity is too high or the depth of flow is too small. And if the velocity is too low, they develop upstream from the pump.

Solution

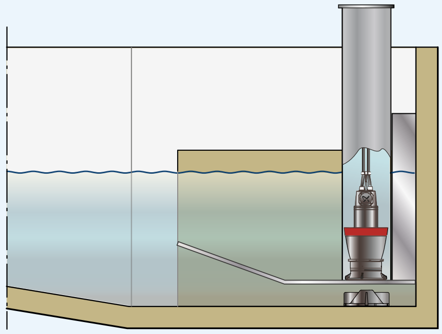
Air-entraining vortices can be eliminated by adding extra turbulence to the surface flow. Placing a transverse beam or baffle at a depth equal to about one quarter of the tube diameter and at a point about 1.5–2.0 diameters upstream of the tube may solve the problem.

If the water levels vary significantly, a floating beam and a floating raft (plate or grid) upstream of the tube may be a better choice to eliminate air-entraining vortices.

A possible alternative is the use of an inclined plate.

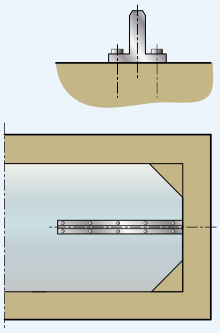
5.3 Retrofitting FSI, Formed Suction Intake

If you run into cavitation and vortex problems, it is possible to establish a formed suction intake e.g. by means of steel plates:



5.4 Retrofitting back-wall and floor splitters

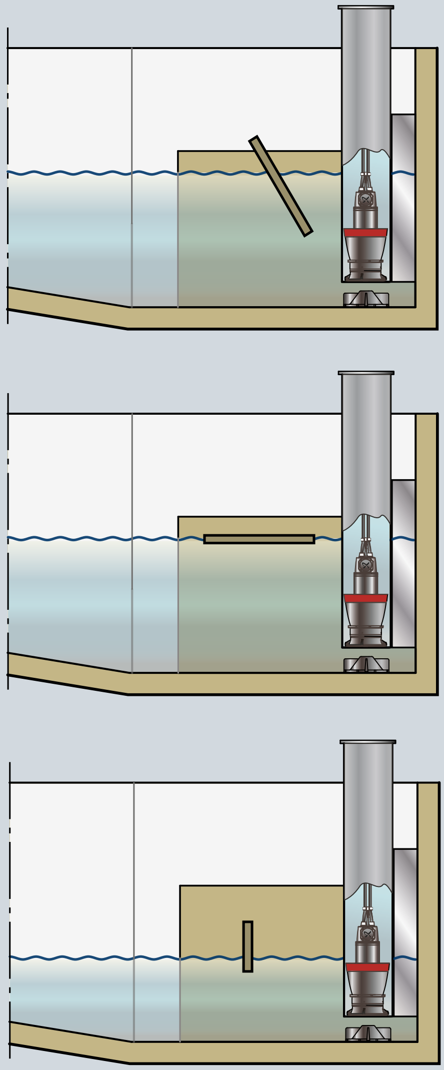
The first and most cost effective step to take when running into problems is to install a floor splitter, e.g. as a steel plate, shaped and bolted to the pump bay floor.



PLEASE NOTE THAT THE FLOOR SPLITTER MUST BE A SINGLE VANE, PARALLEL TO THE PUMP BAY WALL IN THE CENTRELINE OF THE PUMP, NOT A CROSS.

5.5 Reducing surface vortex by retrofitting a baffle

If you run into cavitation and vortex problems, it is possible to establish a formed suction intake e.g. by means of steel plates:



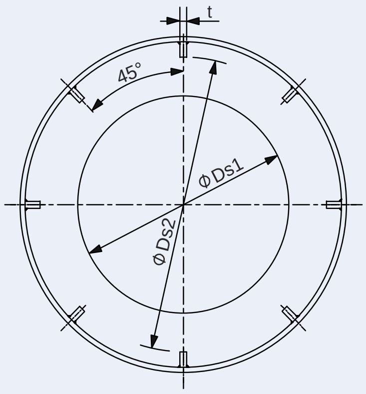
6 ACCESSORIES

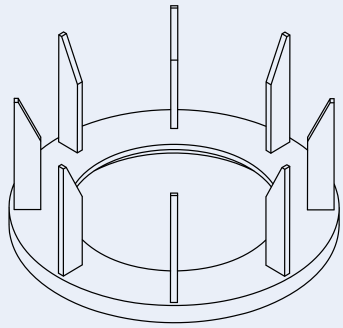
6.1 Column pipe

Column pipes are typically manufactured locally according to the design recommendations of Grundfos, but can of course also be ordered from your local Grundfos company.

In addition, the seat ring in the bottom of the column pipe can be ordered from Grundfos; please refer to KPL and KWM data booklet.

The seat ring is welded to the column pipe.





6.2 Anti Cavitation Cone (ACC)

The patented Anti Cavitation Cone provides an optimal inlet flow to the pump.

Cavitation – and the noise and vibrations associated with this harmful process – can be prevented by fitting an anti-cavitation cone below the pump just beneath the suction bowl.

The ACC will prevent:

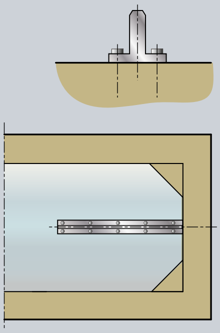
- Cavitation
- Pre Swirl
- Fluid separation phenomenon
- Reduce vortices

Advantages:
Reduces noise and vibrations and extends the lifetime of the pump.

6.3 Splitters

Back wall and floor splitters can be formed in concrete or manufactured in steel.

The stainless steel version is typically bent or made from a welded stainless steel sheet or a hot dip galvanised T-bar.



A back wall splitter should end above the maximum water level.

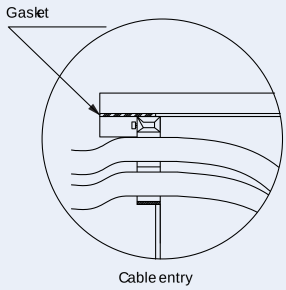
A floor splitter should pass the column pipe. The total length of the floor splitter should be 1.5 - 2.0 diameters from the back wall.

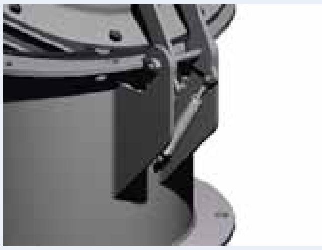
If you need further information or additional advice, please contact your local Grundfos company.

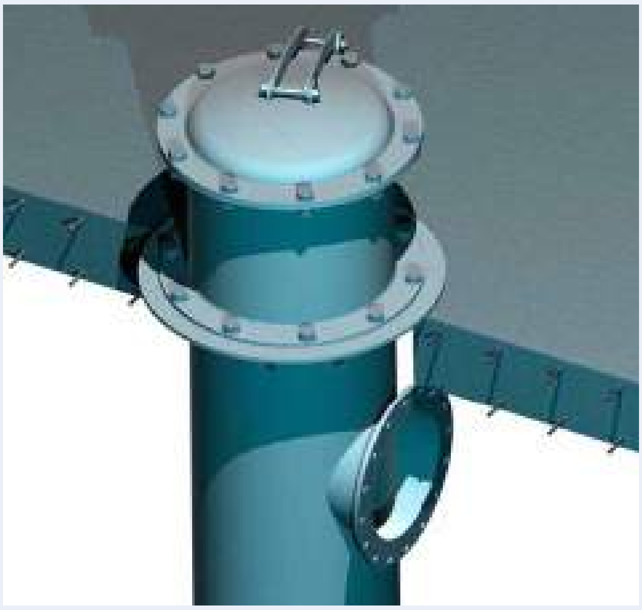
6.4 Cable entry

When designing the column pipe including the lid top, we recommend side-entry of the cables. In comparison with a top entry through the lid, side entry improves handling during service.

There are several cable entries available on the market, and cable entries can also be ordered from Grundfos.







6.5 Cable support system

Cable protection

Keeping all chains and cables tight in a tube installation is essential. Loose cables and chains that move with the flow will be subject to wear and damage and eventually result in premature failure. Therefore, a reliable cable suspension system is crucial.

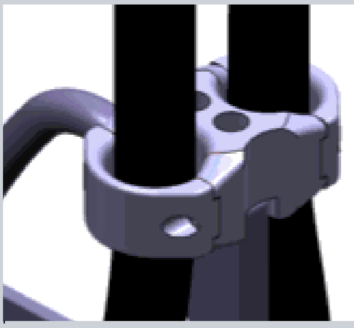
Cable clamps or fixation to the wire or chain should be placed with a distance suitable for the flow conditions in the column pipe.

For more information, please refer to the KPL and KWM data booklet.

Cable and chain protection in sea water applications

Recommendations for column tube installations in sea water applications:

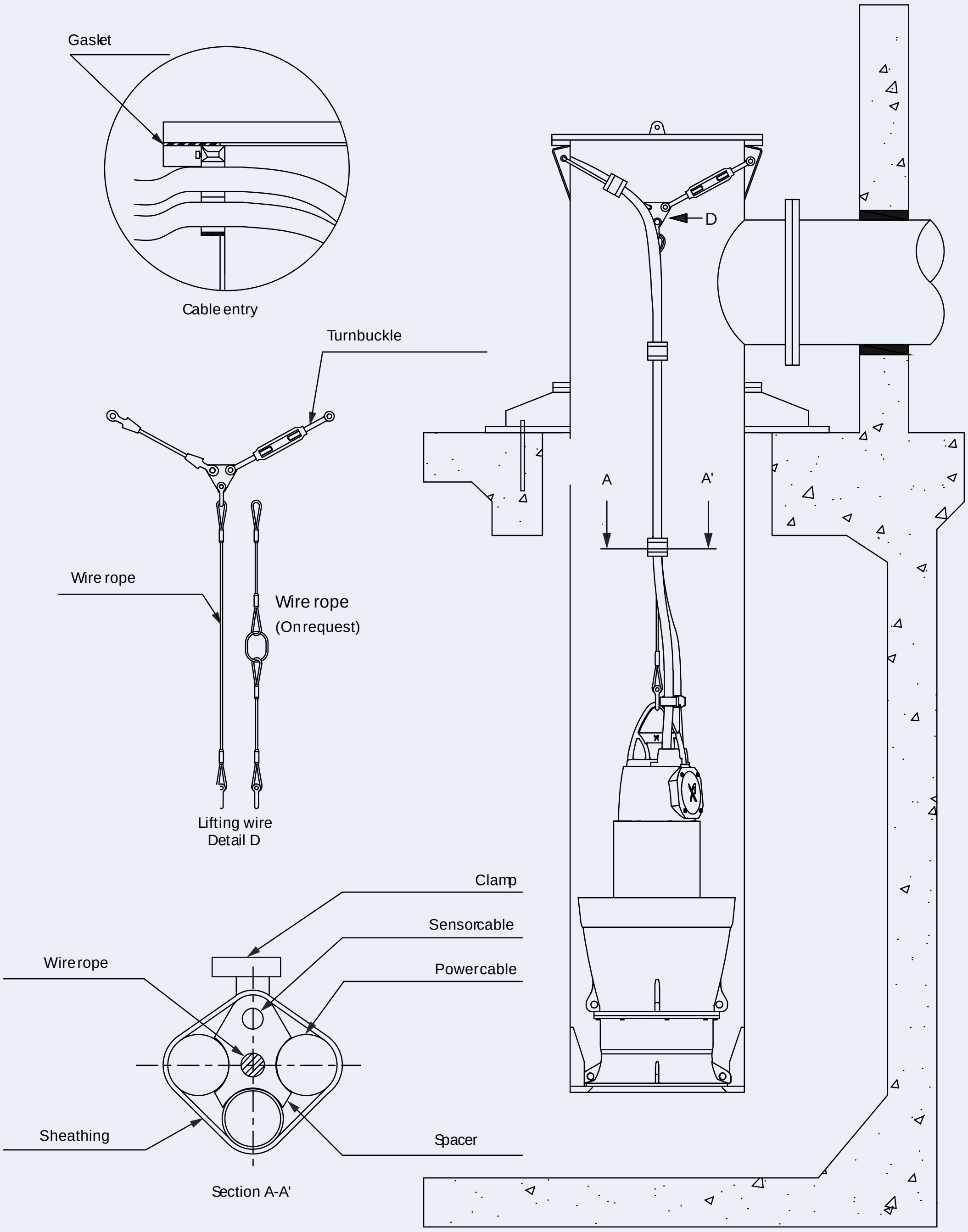
- Stainless steel lifting chain, cable protection, and lifting handle
- Zinc anodes on pump
- Stainless steel column tube
- Epoxy painted steel column tube and pipe to prevent corrosion - min. 300 µm.



Grundfos axial flow pumps have cable support integrated in the lifting handle.

Cable suspension system.

Securing the cable to the lifting chain.



6.6 Monitoring unit

A complete pre-engineered system designed to meet future demands and backed by reliable support.

Depending on motor size, each pump incorporates sensors for maximum protection at a reasonable cost. Your choice includes sensors to monitor winding temperature, seal condition, moisture, water-in-oil, vibration sensor and bearing temperature.

In addition, our controllers also monitor insulation resistance and power consumption and offer protection of motors from overload to phase sequencing etc.

They are designed to offer complete monitoring and protection of your pumps for peace of mind.

The monitoring unit shows:

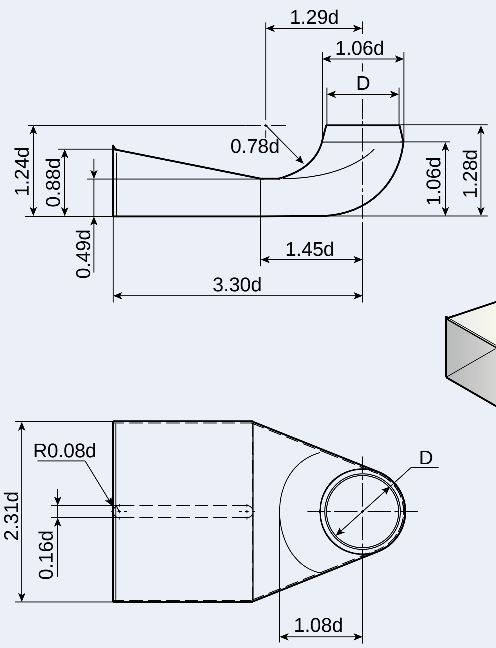
- Bearing temperature – upper and lower
- Stator temperature – 3 phases
- Moisture in cable compartment
- Moisture in motor compartment
- Customised alarm setting

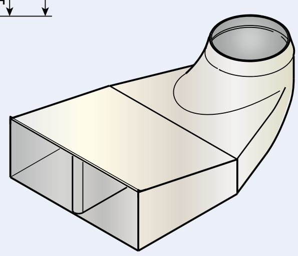
6.7 Formed Suction Intake (FSI)

A USACE type 10 formed suction intake can be constructed in concrete or in steel. For a concrete solution, please see section 3.4.3.

Grundfos can provide the FSI, or the intake can be manufactured locally according to our drawings.

Please contact Grundfos for further advice.





7 GRUNDFOS SERVICE & SOLUTIONS

At Grundfos, we are dedicated to delivering top of the line service. This includes commissioning, repair, and maintenance solutions that prevent breakdowns or rectify problems quickly and professionally.

We have a service solution for every link in our customers' value chain. We add a little extra to your businesses and contribute to protecting people and infrastructure when disaster strikes.

Operational when you need it
Many pumping stations for flood control are not operational all year round.

Depending on demand and the capacity of the pumping station, some pumps run only a few times a year during the flood season.

To ensure that your pumping station is operational and ready to meet immediate demands, we recommend yearly inspections of your pumps and necessary service checks and maintenance immediately prior to the flood season.

For further information about yearly inspections, please refer to the relevant service instruction from Grundfos.

Holistic approach to service
As with all other systems and applications, not only the moving parts require inspections and service. Control systems, alarms and a wide range of general applications also depend on regular service checks to operate reliably.

Example: If a pit is full of construction material, checking only the alarm function is not sufficient. If the pit itself is not checked, it will probably not operate when a flood comes.

To prevent unplanned stops, it is important to check the application continuously according to a well defined, specified scheme.

What to check
Every installation works according to its own specific conditions. Therefore, it is important that operation and maintenance are tailored to the individual application and your specific demands.

However, there are a couple of general recommendations that apply to a wide range of applications. They include:

- Checking of resistance between phases.
- Listening for bearings/noise
- Checking alarms e.g. high level
- Checking rotation direction

A regular check of even insignificant components is essential and can prove very costly if neglected. An example is the moisture switch alarm. If it does not go off when required, the motor will fill with water and break down. The result is a complete repair of the pump and undesirable downtime.

The natural choice of service provider
Our decades of hands-on experience designing and manufacturing pumps have given us vital knowledge of pump applications, processes, problems, and businesses. We continuously use this knowledge during the development of new pump solutions that fit changing customer needs.

Our business knowledge is of course also applied through service product offerings. At Grundfos, we have always cultivated close customer relationships and taken an interest in our customers' problems, needs, and ideas. This has made it possible for us to analyse and define the exact needs of our customers.

Combining this with our product expertise, we are able to develop a range of service product offerings that assist and empower our customers in just the right place and at just the right time. We can help ensure that our customers' operations run as smoothly as possible and that our customers achieve the service life, return on investment, and efficiency they expect from their pumps, from pump selection and installation through pump operation and replacement.

Service partner network

All of this, of course, would be of no use to our customers, if our service product offerings were hard to obtain.

But with Grundfos, assistance is never far away. Our service centre and partner network means that service products are just a phone call away. And so are our pumping station experts in our Water Utility Competence Centres.

8 GLOSSARY

Air Core Vortex
A vortex strong enough to form an elongated core of air.

Anti-Flotation Baffle
Device used to inhibit the rotation of fluid at or near the suction.

Approach Channel
A structure that directs the flow to the pump.

Axial Flow (propeller) Pump
High flow rate/low head, high specific speed pump.

Backwall
A vertical surface behind the inlet to a suction fitting.

Backwall Clearance
The distance between the backwall and the point of closest approach of the suction fitting.

Backwall Splitter
A device formed or fabricated and attached to the backwall that guides the movement of flow at or near a suction.

Baffles
Obstructions that are arranged to provide a more uniform flow at the approach to a pump or suction inlet.

Bay
A portion of an intake structure configured for the installation of one pump.

Bell
The entrance to an axial flow pump or the flared opening leading to pump inlet piping.

Benching
A type of fillet used to minimise stagnant zones by creating a sloping transition between vertical and horizontal surfaces. Benching is applied between sump walls and the sump bottom, or between the back wall and the sump bottom. It is also referred to as fillets, such as "side wall fillets" and "back wall fillets".

Cavitation
Formation and implosion of liquid vapor bubbles caused by low local pressures.

Curtain Wall
A near vertical plate or wall located in an intake that extends below the normal low liquid level to suppress vortices

Fillet
A triangular element at the vertex of two surfaces to guide the flow.

Floor Clearance
The distance between the floor and the suction bet or opening.

Floor Cone
A conical fixture placed below the suction between the floor and the suction bell.

Floor Vane
A vertical plate aligned with the approach flow and centered under the suction bell.

Flow Straighter
Any device installed to provide a more uniform flow.

Forebay
The region of an intake before individual partitioning of the flow into individual suctions or intake bays.

Formed Suction Intake
A shaped suction inlet that directs the flow in a particular pattern into the pump suction.

Guide Vanes
Devices used in the suction approach that direct the flow in an optimal manner.

Intake
The structure or piping system used to conduct fluid to the pump suction.

Intake Velocity
The average or bulk velocity of the flow in an intake.

NPSH
The amount of suction head, over vapour pressure, required to prevent more than a 3% loss in total head from the first stage impeller at a specific flow rate.

Physical Hydraulic Model
A reduced-scale replica of the geometry that controls approach flow patterns operated according to certain similitude laws for flow, velocity and time.

Pre-swirl
Rotation of the flow at the pump suction due to the approach flow patterns.

Scale
The ratio between geometric characteristics of the model and prototype.

Scale Effect
The impact of reduced scale on the applicability of test results to a full-scale prototype.

Sediment
Settleable materials suspended in the flow.

Snoring
The condition that occurs when a pump is allowed to draw down the liquid level very close to the pump inlet. Snoring refers to the gurgling sound associated with continuous air entrainment.

Solids
Material suspended in the liquid.

Submergence
The height of liquid level over the suction bell or pipe inlet.

Submersible Pump
A close coupled pump and drive unit designed for operation while immersed in the pumped liquid.

Suction Bell Diameter
Overall OD of the suction connection at the entrance to a suction.

Sump
A pump intake basin or wet well. See Forebay.

Swirl
Rotation of fluid around its mean, axial flow direction.

Swirl Angle
The angle formed by the axial and tangential (circumferential) components of a velocity vector

Volute
The pump casing for a centrifugal type of pump, generally spiral or circular in shape.

Vortex
A well-defined swirling flow core from either the free surface or from a solid boundary to the pump inlet.

Vortex, Free Surface
A vortex that terminates at the free surface of a flow field.

Vortex, Subsurface
A vortex that terminates on the floor or side walls of an intake.

Wall Clearance
Dimensional distance between the suction and the nearest vertical surface.

References

American National Standard for Pump Intake Design, ANSI/HI 9.8-1998

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Prevention of Vortices at Intakes
Water Power, Oct. 1968

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Pump Intake Design Investigations
Cranfield April 1968, Paper 1

9 APPENDICES

Appendix 1: Head loss calculations

Although the calculations in appendix 1 are from Grundfos' Sewage Pumping Handbook, the principles and calculations are also apply to flood pumping stations.

Pipe losses and rising main characteristic curves
In the following the theory for calculation of flow losses in pipelines is presented. Practical calculations can be made with the help of the detailed instructions with calculation diagrams and nomograms presented in Appendix A, or with a computer program.

Flow velocities used in sewage pumping are high enough to ensure uniform turbulent flow in the piping. Flow losses therefore increase with the square of the flow velocity. The flow loss of a rising main is the sum of the friction loss of the pipeline constituent parts and the local losses from the various components and fittings.

Friction losses
Pipe friction losses depend on the following factors:

- pipe length
- pipe internal diameter
- flow velocity
- pipe wall relative roughness
- fluid kinematic viscosity.

A dimensionless relation, Reynold's number is introduced:

$$Re = \frac{vD}{\nu}$$

where
Re = Reynold's number
v = flow velocity (m/s)
D = pipe internal diameter (m)
ν = kinematic viscosity (m²/s)

The kinematic viscosity for water is dependent on temperature:

t °C	0	20	40	60	100
$\nu\,10^{-6}$ m²/s	1,78	1,00	0,66	0,48	0,30

The equation for pipeline losses can be written:

$$H_{Jp} = \lambda \frac{lv^2}{D2g}$$

where
HJp= pipeline loss (m)
λ = friction factor
l = pipeline length (m)
v = flow velocity (m/s)
g = acceleration of gravity (9,81 m/s²)
D = pipeline internal diameter (m)

Obtaining the friction factor λ from the diagram in Figure 54, equation 24 can be solved. Surface roughness values (mm) presented in the following table can be used:

Pipe material	k new	k old
Plastic	0,01	0,25
Drawn steel	0,05	1,0
Welded steel	0,10	1,0
Drawn stainless steel	0,05	0,25
Welded stainless steel	0,1	0,25
Cast iron	0,25	1,0
Bituminized cast iron	0,12	
Asbestos cement	0,025	0,25
Concrete	0,3...2,0	

The surface of an old pipe material becomes rougher from erosion. Corrosion and sediment layers forming on the pipe surface may decrease the pipe diameter, also leading to higher flow losses.

The effect of pipe diameter change can be calculated with the following relation:

$$H'_{Jp} = H_{Jp}\left(\frac{D'}{D}\right)^5$$

Thus an increase of pipe diameter from, for instance, 100 mm to 108 mm decreases the flow loss by 30%.

Equation 25 is sufficiently accurate for practical purposes when comparing flow losses in rising mains of different diameter, particularly since accurate surface roughness values are seldom available.

Rising main flow losses are frequently calculated with the help of proprietary computer programs, also available from some pump manufacturers. These programs may also suggest some pump selections from the manufacturer's range to best suit the purpose. It is advisable to take a cautious view on the pump selection suggested by a program only, and always contact the pump manufacturer in dubious cases.

The rising main is sometimes divided into two separate parallel pipelines. They have the same length but may have different diameters or be made of different materials. The distribution of flow between the two lines and the ensuing losses in these lines can be difficult to determine. Grundfos has developed a method for this, where the two lines are substituted with a single virtual rising main. An equivalent diameter is determined for this so that the resulting flow losses are equal to the resultant losses of the two true rising mains.

The equivalent diameter is calculated with the following equations:

A. Both rising mains have the same diameter

where D = diameter of the two parallel rising mains

B. The rising mains have different diameters

$$D_e = 1,3 \cdot D$$

where D_1 and D_2 are the different diameters of the parallel rising mains.

$$D = (D_1^{2,65} + D_2^{2,65})^{0,3774}$$

The volume rates of flow for the two rising mains are calculated wit then following equations:

A. Both rising mains have the same diameter

$$Q_1 = \frac{Q}{2}$$

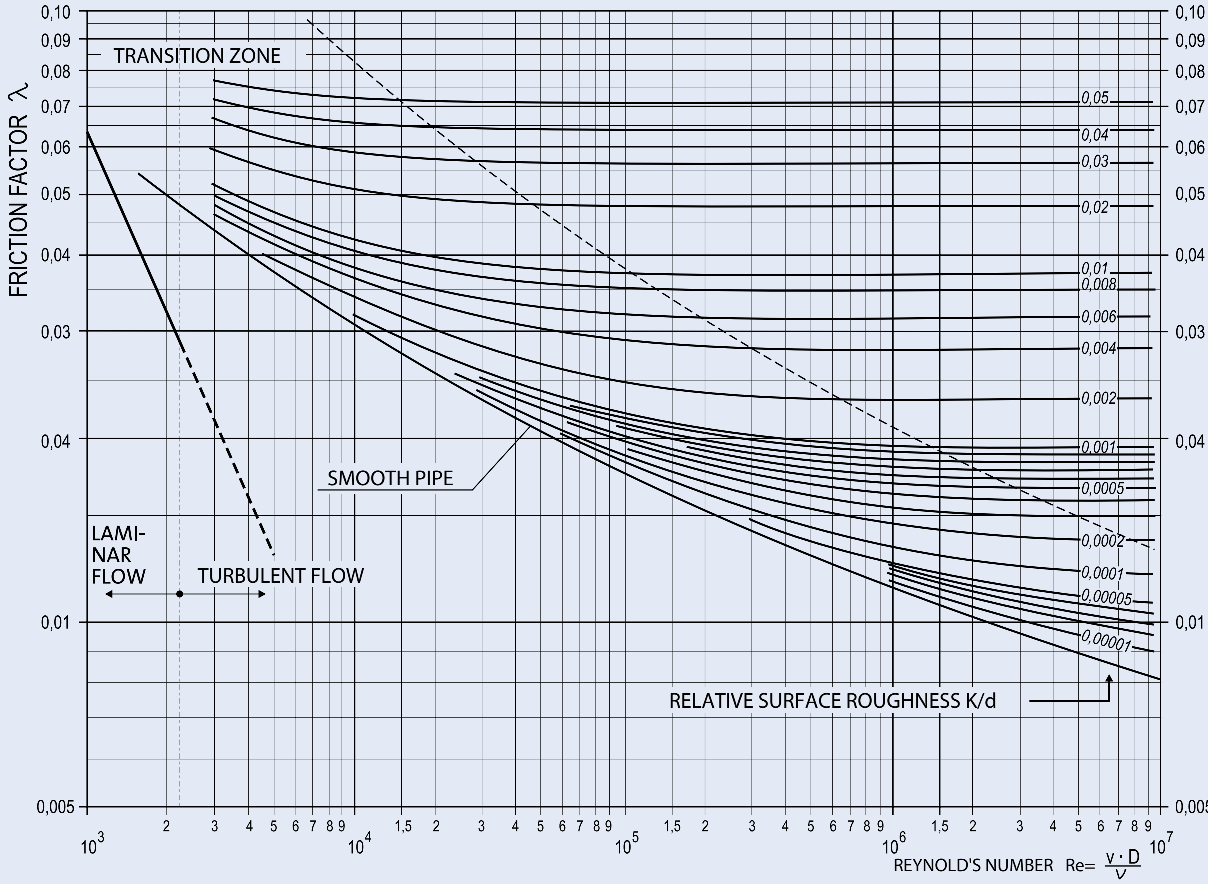
B. The rising mains have different diameters

$$Q_1 = \left(\frac{D_1}{D_e}\right)^{2,65} \cdot Q$$

$$Q_2 = Q - Q_1$$

The equations above are valid for turbulent flow, which is normal for water pumping. The equations require that both pipelines have the same surface roughness.

Fig. 54



Moody diagram for establishing the friction factor λ. The value of λ is obtained using Reynold's number and the relative roughness number k/D as parameters, where D is pipe internal diameter in mm and k equivalent surface roughness in mm. Completely turbulent flow can be assumed in wastewater applications.

Local losses

Changes in pipeline internal diameter and shape, bends, valves, joints, etc. as included in the rising main cause additional losses that comprise both a friction and turbulence component. The following equation is used to calculate the losses:

$$H_{Jn} = \zeta \frac{v^2}{2g}$$

where
HJn= local loss (m)
ζ = local resistance factor
v = flow velocity (m/s)
g = acceleration of gravity (9,81 m/s²)

Local resistance factors for different pipeline elements and fittings are presented in Appendix A. The friction loss of these are not included in the local resistance factor, but is calculated as part of the rising main friction loss by including their length and internal diameter when calculating pipeline length.

Pipe expansion discontinuity loss can be calculated using the Borda equation:

$$H_{Jn} = \frac{(v_1 - v_2)^2}{2g}$$

where
HJn= local loss (m)
v1 = flow velocity 1 (m/s)
v2 = flow velocity 2 (m/s)
g = acceleration of gravity (9,81 m/s²)

If the pipe expansion is designed with a conical section with an expansion angle of 10°, the loss is reduced to 40% of the value calculated with equation 32. This fact is important when expanding the pipe section right after the pump pressure flange, where the flow velocity can be quite high. By designing the transition with a 10° gradual expansion joint, energy can be saved. In a contracting pipe section the losses are much smaller, and the conical section can be built much shorter.

Losses in a section with velocity reduction are generally much greater than in section with increasing velocity.

The final component of pipeline loss is the outlet loss at the end of the rising main. If no expansion is provided, the loss equals the velocity head or $v^2/2g$. Loss coefficients for different valves are provided by the manufacturers. Guide values for the most common valves used in sewage installations are presented in Appendix A.

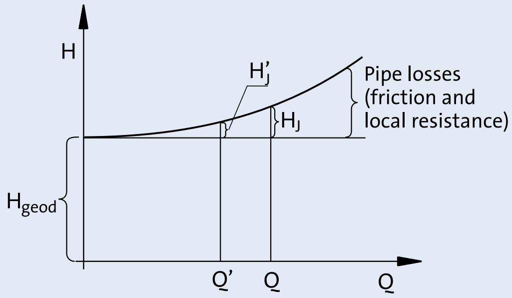
Rising main characteristic curve

In sewage installations the pump sump and the delivery well are open to the atmosphere, and the rising main characteristic curve will contain the geodetic head and the flow losses only. Figure 55 shows the general shape of the characteristic resistance curve for a pipeline.

Since the flow is turbulent at the flow velocities in consideration, it can be assumed that the flow loss varies in proportion to the square of the flow rate. Thus, if the flow loss at one flow rate is calculated with the method described above, the other points of the curve are obtained sufficiently exactly with the following equation:

$$H'_J = H_J \left(\frac{Q'}{Q}\right)^2$$

Fig. 55

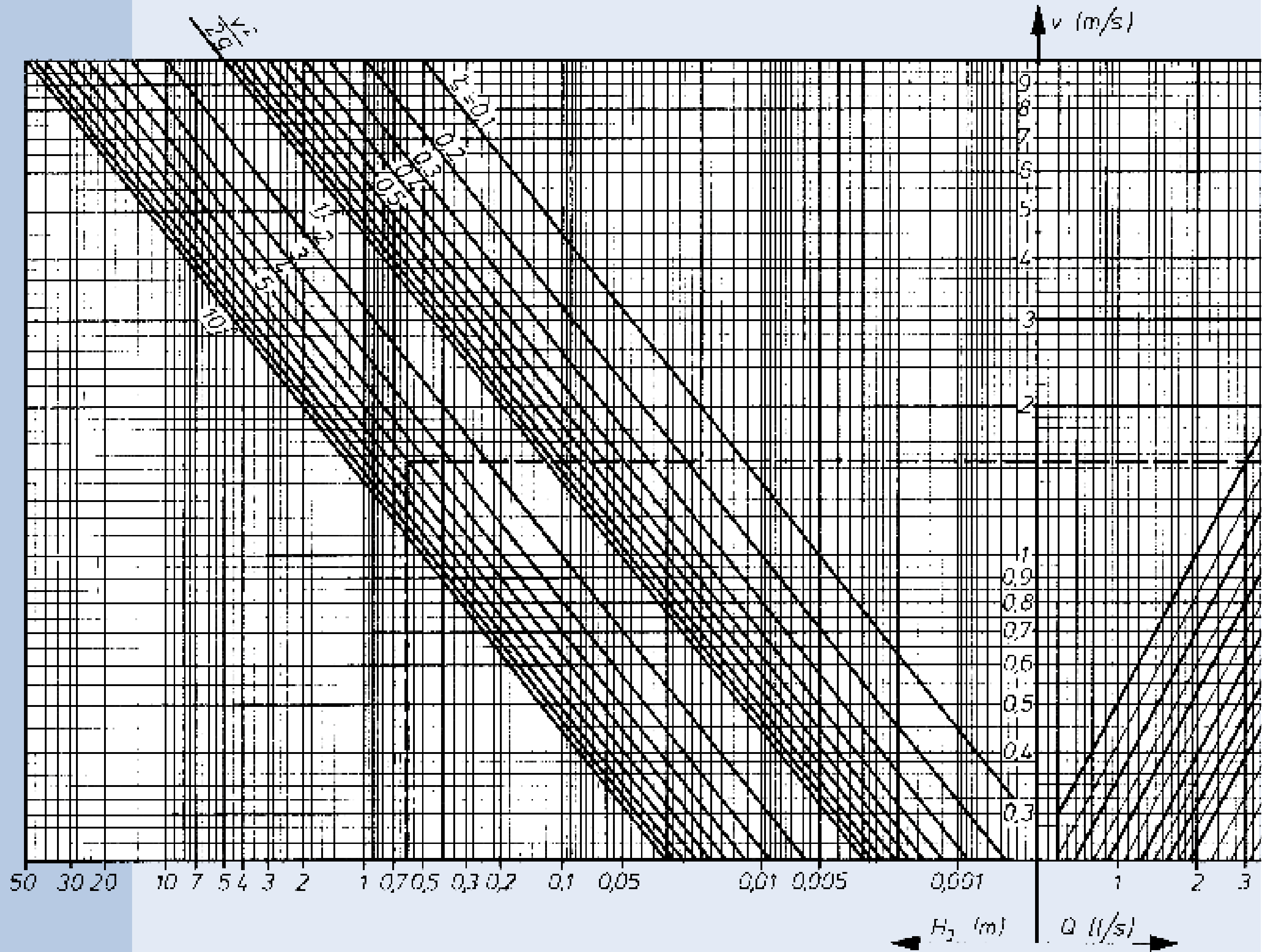


Characteristic resistance curve for a pipeline. Pipe losses (H_J) are plotted against flow rate (Q) and added to the geodetic head, which is constant.

Nomogram for head losses in bends, valves etc.

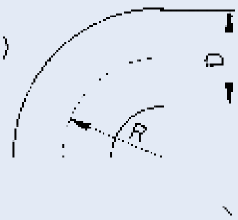
Q = Flow, l/s
D = Pipe inner diameter, mm
v = Flow velocity, m/s
ζ = Loss coefficient
H_J = Head losses, m

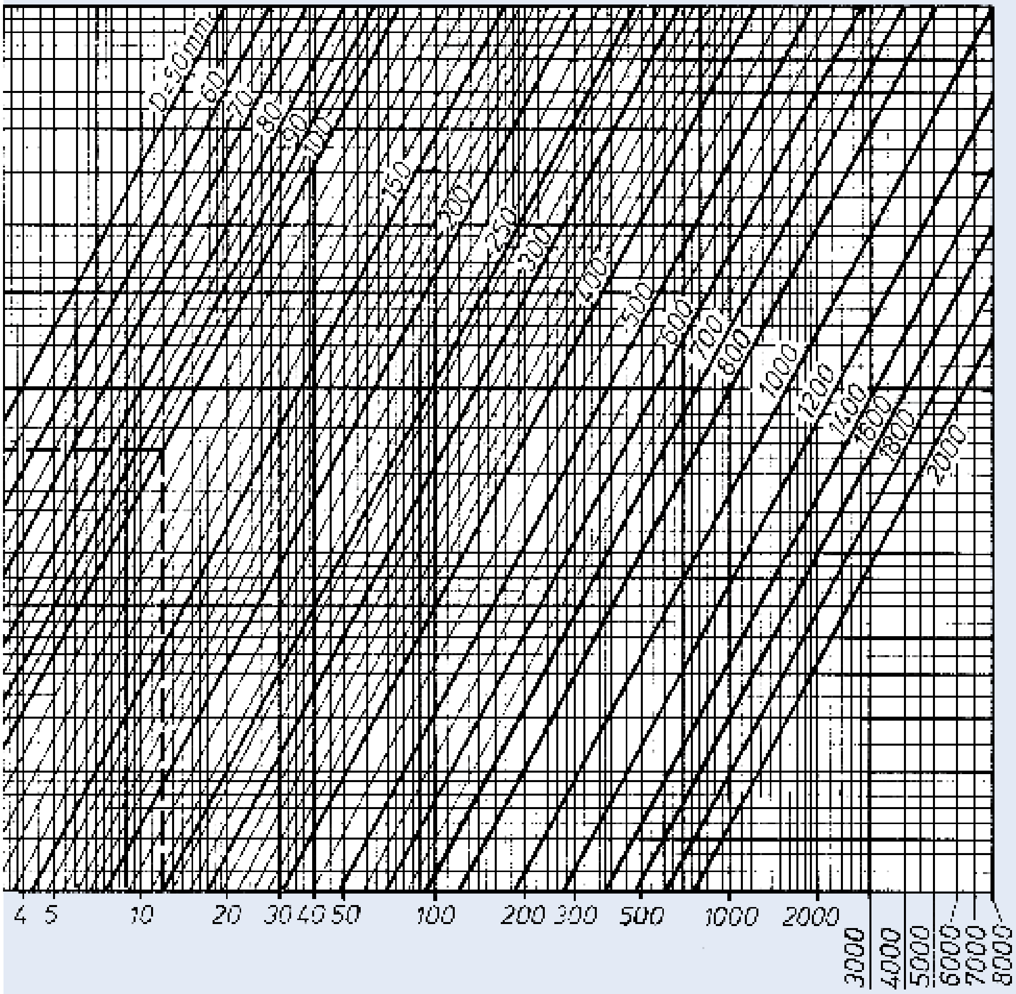
Example
Q = 12 l/s
D = 100 mm
v = 1, 55 m/s
Σζ = 5
H_J = 0,6 m



Guide values for head losses in bends, valves, etc.

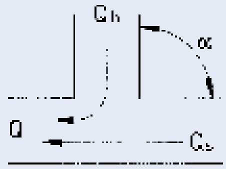
	ζ
▪ Pipe bend 90 °, R/D = 1,5	0,3
▪ Discharge loss	1,0 (pipe without expansion)
▪ Swing check valve	1...2
▪ Ball check valve	0,7...1,2
▪ Gate valve	0,2





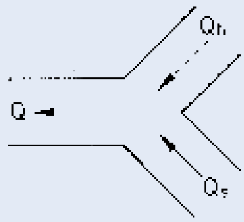
▪ T-piece

Q_H/Q	α = 90 °		α = 45 °	
	ζ_h	ζ_s	ζ_h	ζ_s
0,0	-1,00	0,04	-0,90	0,04
0,2	-0,40	0,17	-0,38	0,17
0,4	0,08	0,30	0,00	0,19
0,6	0,47	0,41	0,22	0,09
0,8	0,72	0,51	0,37	-0,17
1,0	0,91	0,60	0,37	-0,54

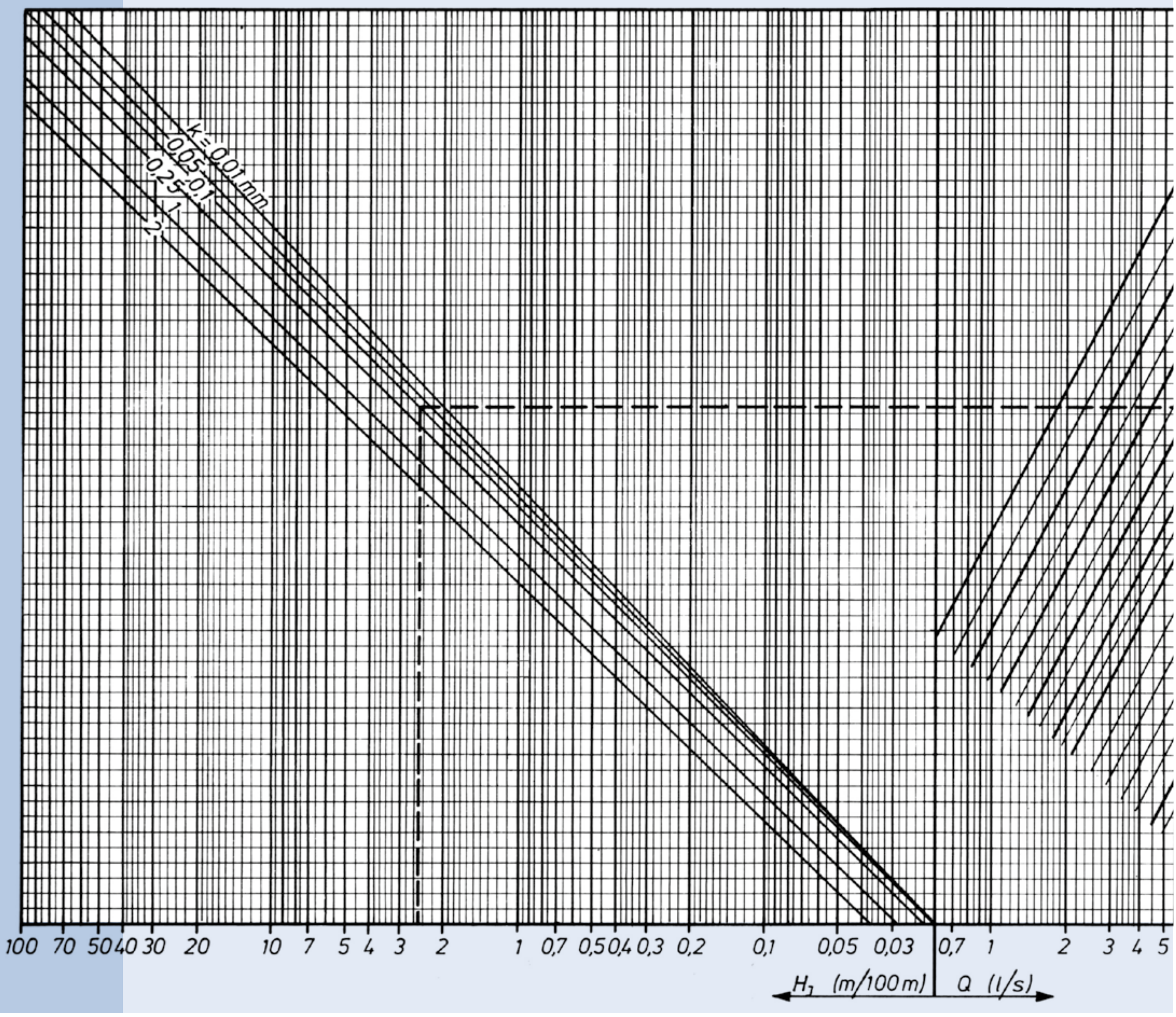


▪ Y-piece

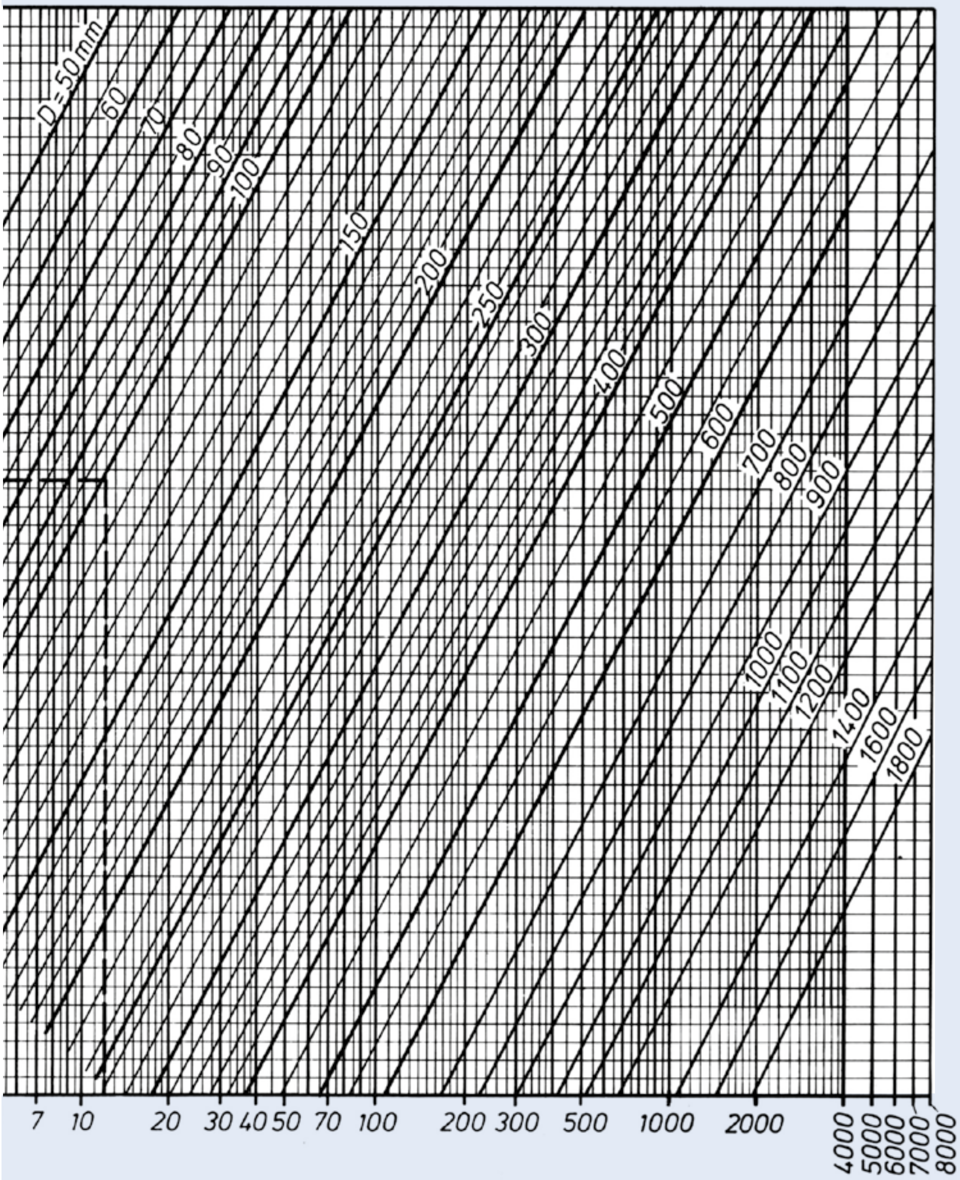
Q_H/Q	ζ_h	ζ_s
0,0	-	0,6
0,5	0,3	0,3
1,0	0,6	-



Pipe loss nomogram for clean water 20°C



Guide values for surface roughness (k) for pipes



Q = Flow, l/s
D = Pipe inner diameter, mm
k = Surface roughness, mm
H_J = Pipe losses, m/100 m

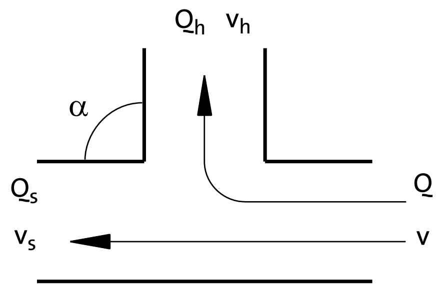
Example
Q = 12 l/s
D = 100 mm
k = 0,1 mm
H_J = 2,5 m/ 100 m

pipe material	new pipe k (mm)	old pipe k (mm)
plastic	0,01	0,25
drawn steel	0,05	1,0
welded steel	0,1	1,0
drawn stainless steel	0,05	0,25
welded stainless steel	0,1	0,25
cast iron	0,25	1,0
galvanized steel	0,15	
bituminized cast iron	0,12	
concrete	0,3...2,0	
asbestos cement	0,025	

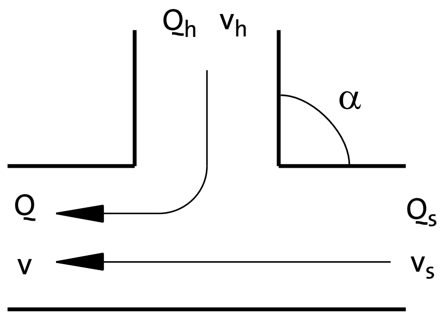
Local resistance factors

The pressure loss in a pipe system is caused by friction, changes of direction and transfer loss. Determining the variables involving total pressure loss in a pipe system requires knowledge of the resistance factors for fittings, pipe connections and valves.

Branches

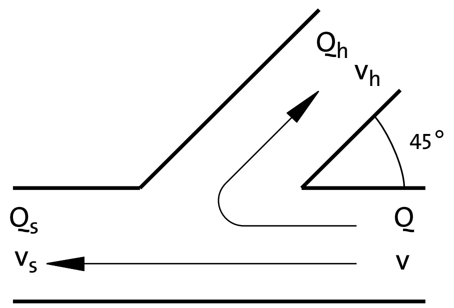


Q_h/Q	Diverging flows			
	α = 90°		α = 45°	
	ζ_h	ζ_s	ζ_h	ζ_s
0,0	0,95	0,04	0,90	0,04
0,2	0,88	-0,08	0,68	-0,06
0,4	0,89	-0,05	0,50	-0,04
0,6	0,95	0,07	0,38	0,07
0,8	1,10	0,21	0,35	0,20
1,0	1,28	0,35	0,48	0,33

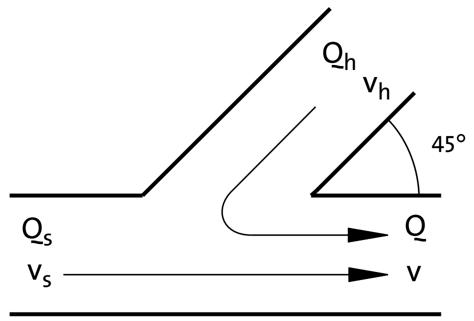


Q_h/Q	Merging flows			
	α = 90°		α = 45°	
	ζ_h	ζ_s	ζ_h	ζ_s
0,0	-1,00	0,04	-0,90	0,04
0,2	-0,40	0,17	-0,38	0,17
0,4	0,08	0,30	0,00	0,19
0,6	0,47	0,41	0,22	0,09
0,8	0,72	0,51	0,37	-0,17
1,0	0,91	0,60	0,37	-0,54

Local resistance factors for different pipeline elements and fittings are presented in the following. The friction loss of these are not included in the local resistance factor, but is calculated as part of the rising main friction loss by including their length and internal diameter when calculating pipeline length.



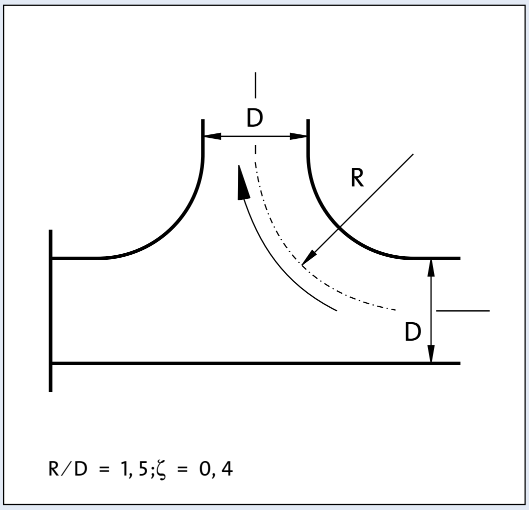
Q_h/Q	Merging flows	
	ζ_h	ζ_s
0,0	-0,82	0,06
0,2	-0,30	0,24
0,4	0,17	0,41
0,6	0,60	0,56
0,8	1,04	0,80
1,0	1,38	1,13

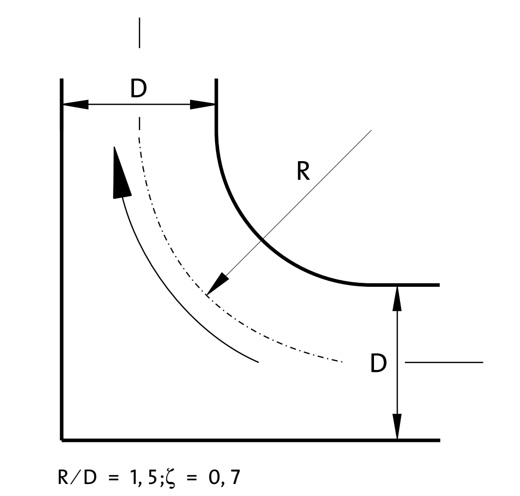


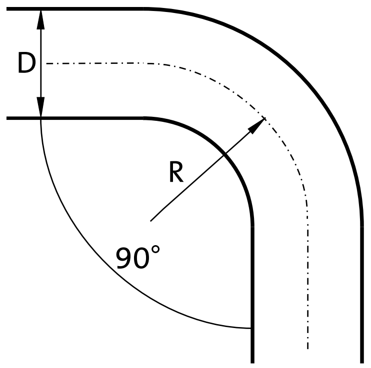
Q_h/Q	Diverging flows	
	ζ_h	ζ_s
0,0	0,92	0,06
0,2	0,97	-0,06
0,4	1,12	0,00
0,6	1,31	0,09
0,8	1,50	0,20
1,0		0,30

Local resistance factors

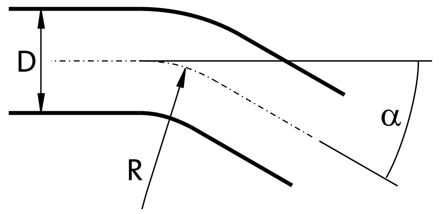
Bends



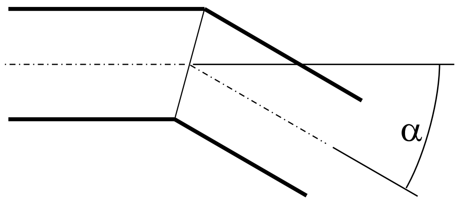




R/D	1	2	3	4	6
ζ	0,36	0,19	0,16	0,15	0,21
R/D	8	10	12	16	20
ζ	0,27	0,32	0,35	0,39	0,41

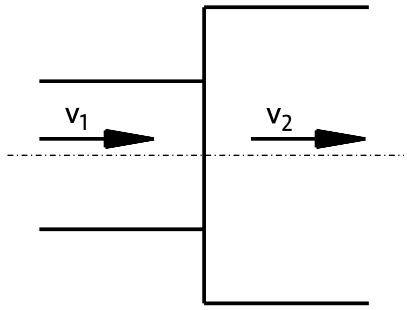


α	ζ		
	R/D		
	1	2	4
20°	0,07	0,03	0,03
40°	0,13	0,06	0,06
60°	0,20	0,10	0,09
80°	0,27	0,13	0,12
90°	0,32	0,15	0,13
120°	0,39	0,19	0,17
140°	0,46	0,23	0,20
160°	0,52	0,26	0,23
180°	0,60	0,30	0,26

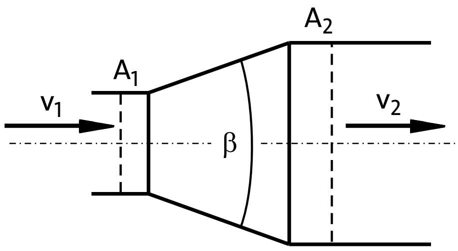


α	20°	40°	50°	70°	80°
ζ	0,03	0,12	0,24	0,54	0,74
α	90°	120°	140°	180°	
ζ	1,00	1,86	2,43	3,00	

Expansions and contractions

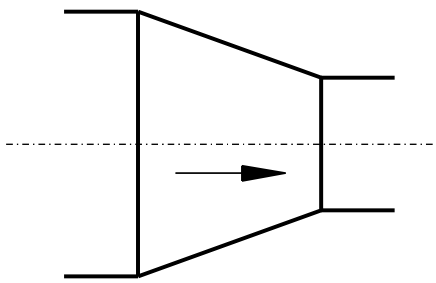


$$H_{Jn} = \frac{(v_1 - v_2)^2}{2g}$$



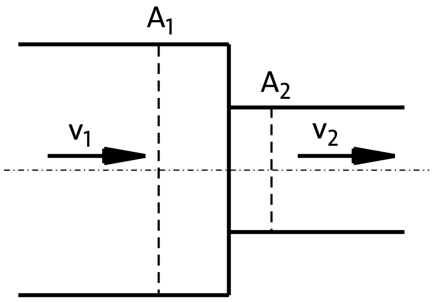
$$H_{Jn} = \zeta \frac{v_1^2}{2g} \qquad \zeta = k\left(1 - \frac{A_1}{A_2}\right)^2$$

β°	k	β°	k	β°	k
5	0,13	45	0,93	100	1,06
10	0,17	50	1,05	120	1,05
15	0,26	60	1,12	140	1,04
20	0,41	70	1,13	160	1,02
30	0,71	80	1,10		
40	0,90	90	1,07		



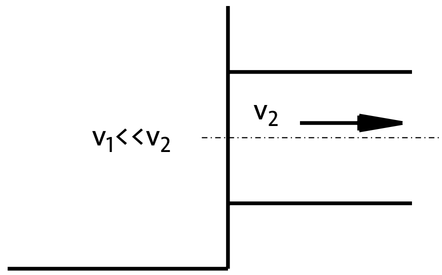
$H_{Jn} \approx 0$

Friction drag not included

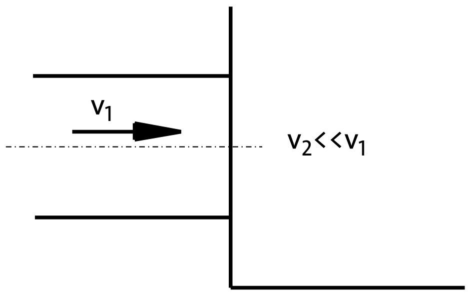


$$H_{Jn} = \zeta \frac{v_2^2}{2g}$$

A_2/A_1	0	0,1	0,2	0,3	0,4
ζ_2	0,50	0,46	0,41	0,36	0,30
A_2/A_1	0,5	0,6	0,7	0,8	0,9
ζ_2	0,24	0,18	0,12	0,06	0,02

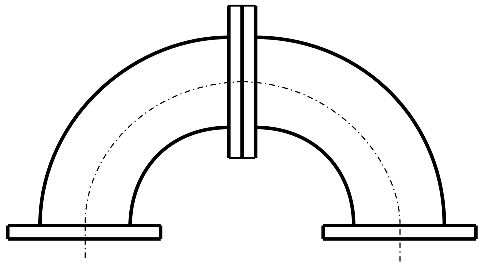


$$H_{Jn} = 0,5 \frac{v_2^2}{2g}$$

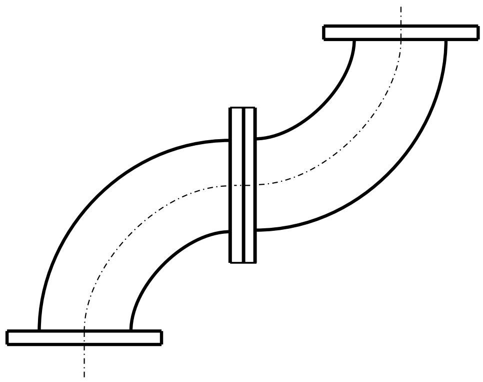


$$H_{Jn} = \frac{v_1^2}{2g}$$

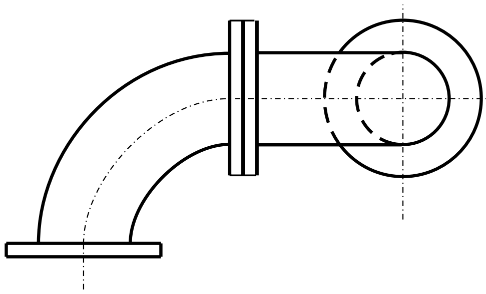
Bend combinations



$\zeta = 2 \times \zeta_{90°}$

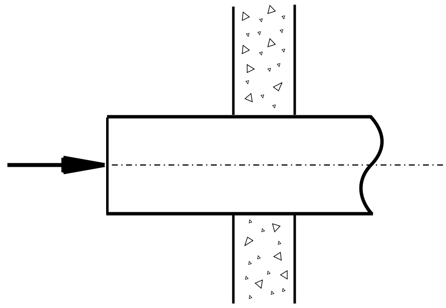


$\zeta = 3 \times \zeta_{90°}$

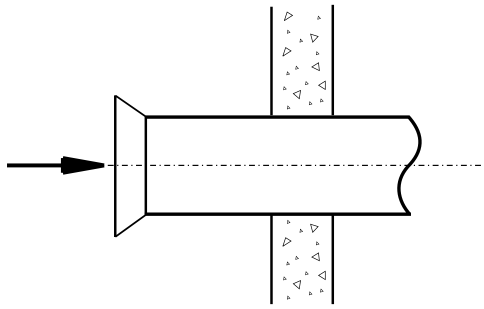


$\zeta = 4 \times \zeta_{90°}$

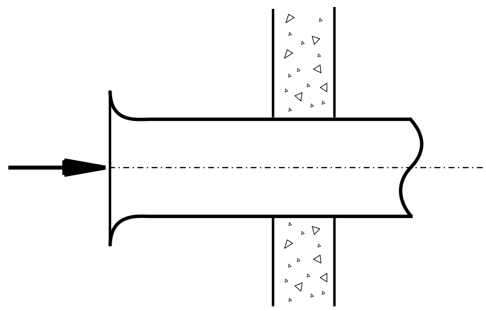
Suction inlets



$\zeta = 3,0$



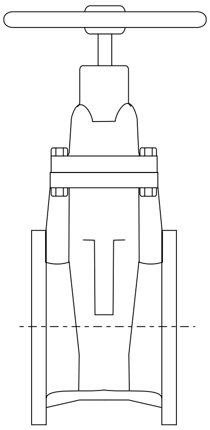
$\zeta = 0,2$



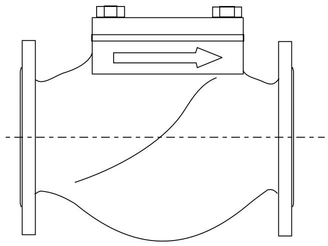
$\zeta = 0,05$

Valves

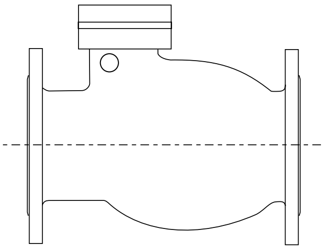
ξ-values depend strongly on shape.
Factory values should be used when available.



Gate valves without narrowing: ξ = 0,1...0,3
Gate valves with narrowing: ξ = 0,3...1,2



Ball non-return valves ξ ≈ 1,0 (fully open)



Flap non-return valves ξ = 0,5...1,0 (fully open)

ξ-values above are valid for fully open valves. In partly open position, ξ may be 1,5-2 times as high. Depending on shape and position, a certain minimum flow velocity through the valve is required for it to be regarded as fully open.

Exact information on each valve is available from the manufacturer or supplier.

Appendix 2 - Grundfos products

KPL

Axial-flow propeller pump designed for high flow at low head

Technical data:

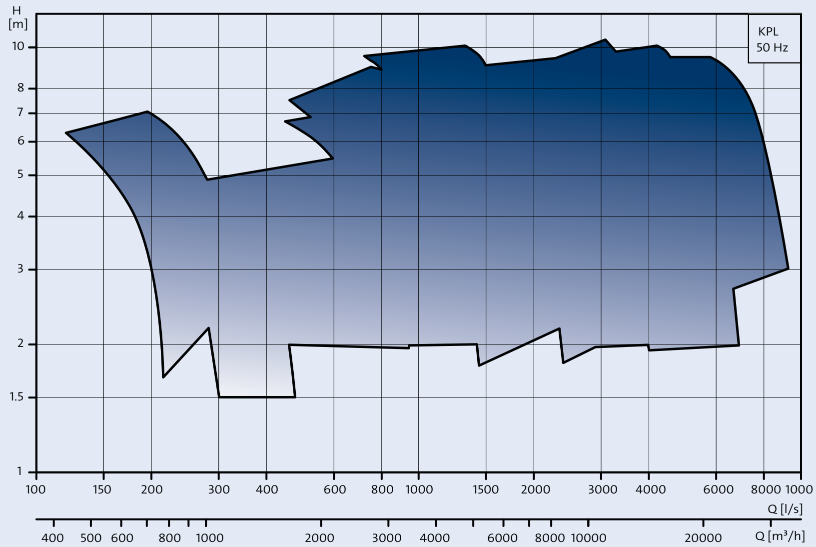
- Column diameter: 500-2,200 mm
- Full 50 and 60 Hz
- Voltage: 220-6,600 V
- Flow: 5-700 m³/min
- Head: Up to 9 m
- Power: 11-1,000 kW

Applications

- Flood and storm water control
- Large-volume drainage and irrigation
- Raw water intake
- Circulation of large quantities of water, e.g. in water parks
- Water-level control in coastal and low-lying areas
- Filling and emptying of dry docks and harbour installations
- Filling or emptying of reservoirs

Features and benefits

- Optimal Hydraulic for highest hydraulic efficiency
- Single-unit cartridge seal for easy replacement
- A unique “Turbulence optimiser”
- Easy maintenance with wearing, cable compartment, inspection hole and shaft seal



KWM

Mixed flow pump designed for high flow at medium head

Technical data:

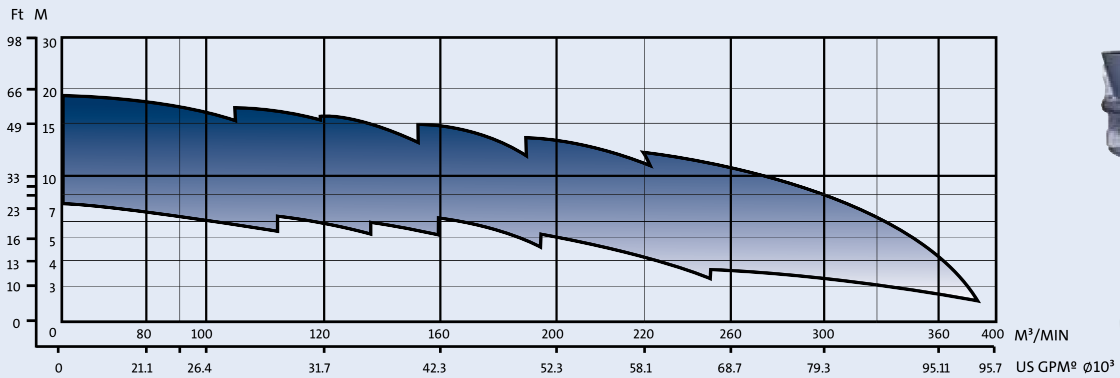
- Column diameter: 500-2,200 mm
- Full 50 and 60 Hz
- Voltage: 220-6,600 V
- Flow: 5-400 m³/min
- Head: Up to 50 m
- Power: 11-1,000 kW

Applications

- Flood and storm water control
- Large-volume drainage and irrigation
- Raw water intake
- Circulation of large quantities of water, e.g. in water parks
- Water-level control in coastal and low-lying areas
- Filling and emptying of dry docks and harbour installations
- Filling or emptying of reservoirs

Features and benefits

- Robust, reliable and cost-effective
- Minimal, easy service
- All models available in cast iron or stainless steel
- Special materials (e.g. aluminium, bronze or stainless steel propeller)
- Pump and motor size up to 1MW by special request



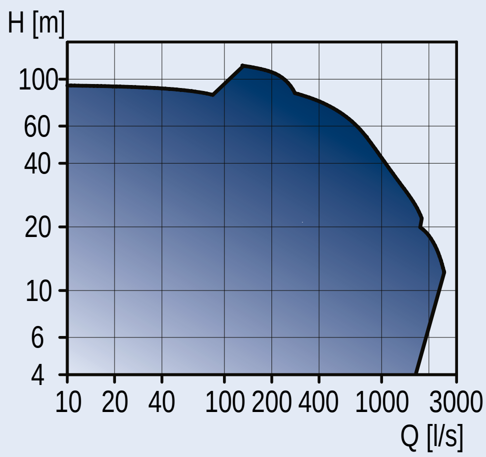
S PUMPS
Supervortex pumps, single- or multichannel impeller pumps

Technical data:
Flow rate: max. 2500 l/s
Head: max. 116 m
Liquid temp.: 0 °C to +40 °C
Discharge dia.: DN 80 to DN 800
Particle size: max. ∅ 145.

Applications
- Transfer of wastewater
- Transfer of raw water
- Pumping of sludge-containing water
- Pumping of industrial effluent.

Features and benefits
- SmartTrim
- With/without cooling jacket
- Submerged or dry installation
- Different types of impellers
- Built-in motor protection.

Options
- Control and protection systems
- External cooling water
- External seal flush system
- Sensors for monitoring of pump conditions
- Various cast stainless-steel versions available.



SL1/SLV and SE1/SEV

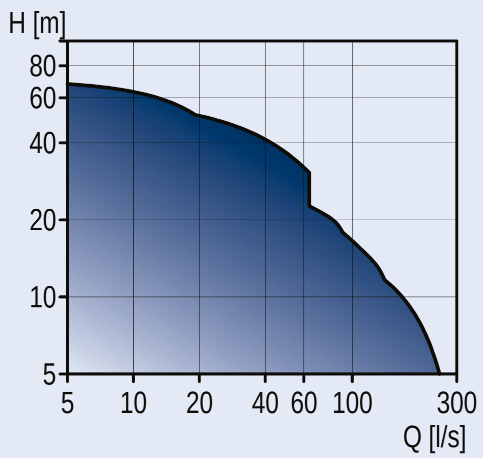
Heavy-duty submersible pumps

Technical data:
Flow rate: max. 270 l/s (1080 m^3/h)
Head: max. 70 m
Free passage: 50 mm to 160 mm
pH range: pH 0 to 14
Discharge dia.: DN 65 to DN 300.

Applications
- Drainage water and surface water
- Domestic and municipal wastewater
- Industrial wastewater.

Features and benefits
- Service friendly (smartdesign)
- Reliable and energy efficient (Grundfos Blueflux®)
- Intelligent solution (AUTOADAPT)
- S-**tube** or SuperVortex impellers.

Options
- Control and protection systems
- Motor control
- Built-in sensors for pump monitoring
- Various cast stainless-steel versions available
- Ideal for pumping stations.



Pomona

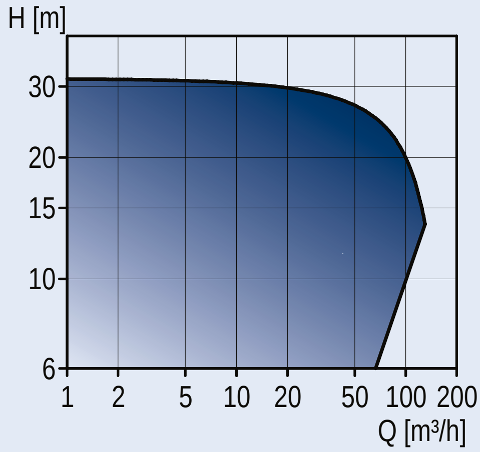
Portable, self-priming pumps for temporary or permanent installation

Technical data:
Flow rate: max. 130 m^3/h
Head: max. 31 m
Liquid temp.: 0 °C to +80 °C
Operat. pressure: max. 6 bar.

Applications
- Dewatering of construction sites
- Groundwater water level control
- Irrigation in gardens and parks
- Water supply in horticulture and agriculture
- Industrial applications.

Features and benefits
- Robust and compact design
- Motor variation (electrical or internal combustion engines)
- Insensitive to impurities
- Wear-resistant
- Handling solid sizes up to 30 mm.

Options
- Pomona can be supplied as bare-shaft pump as well as with the motor on a trolley, carrying frame or base plate.



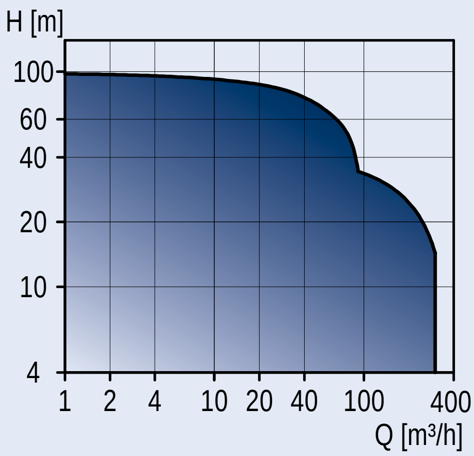
DW
Contractor pumps

Technical data:
Flow rate: max. 300 m^3/h
Head: max. 100 m
Liquid temp.: 0 °C to +40 °C.

Applications
- Tunnels
- Mines
- Quarries
- Gravel pits
- Fish ponds
- Building sites.

Features and benefits
- Service friendly (smartdesign)
- Reliable and energy efficient (Grundfos Blueflux®)
- Intelligent solution (AUTOADAPT)
- S-**tube** or SuperVortex impellers.

Options
- Corrosion resistant due to use of aluminum and stainless steel parts
- Extremely hard-wearing due to specially selected materials
- Simple installation
- Service-friendly
- Protection against abrasive particles
- Plug and pump (no special equipment required)
- Motor protection for longer life.



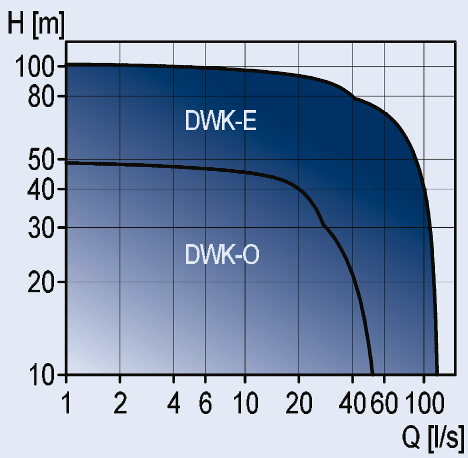
DWK

Heavy-duty dewatering pumps

Technical data:
Flow rate: max. 432 m^3/h
Head: max. 102 m
Liquid temp.: 0 °C to +40 °C
Installation depth: max. 25 m.

Applications
- Dewatering
- Construction sites
- Excavation sites
- Tunnels
- Mines
- Draining
- Underground building pits
- Industrial pits
- Stormwater pits.

Features and benefits
- Durability
- Ductile/high-chrome impeller
- Easy to operate
- High efficiency
- Compact design
- High-pressure capabilities.



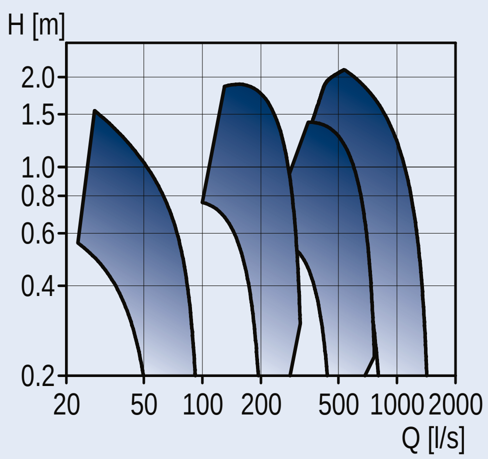
SRP
Submersible recirculation pumps

Technical data:
Flow rate: max. 1430 l/s (5130 m^3/h)
Head: max. 2.1 m
Liquid temp.: 5 °C to +40 °C

Applications
- Recirculation of sludge in sewage treatment plants
- Pumping of stormwater.

Features and benefits
- High-efficiency stainless-steel impeller
- Totally submerged installations
- Built-in motor protection.

Options
- Control and protection systems.



Peerless VTP
Vertical turbine pump (VTP)

A turbine pump installed inside a well casing below the pumping water level in the well. The motor is not installed in the water.

Technical data:
Flow, Q: max 600 l/s (2,200 m^3/h)
Head, H: max 30 m
Liquid temp.: max 60 °C

Applications
Water and other nonabrasive fluids in a wide range of applications:
From small, single pump commercial applications to large, multi-pump municipal water supply systems

- Flood control
- Raw water transfer
- Mining
- Agriculture

Features and benefits
- Standard cast iron discharge head
- Handles pressures up to 35 bar
- Bronze impellers are standard construction
- Dual bowl bearings
- Bronze and rubber seal protect against wear
- Patented “double-seal” in bowls for high efficiency
- Lateral rings protect bowl surfaces
- Carbon steelsupport for larger-diameter columns

Dedicated controls
Pump controllers

Technical data:
Supply voltage: 1 x 230, 3 x 230, 3 x 400 V, 50/60 Hz.

Applications
- Dedicated controls are suitable in wastewater applications for emptying wastewater pits (up to six pumps).
- Pressurised pumping stations
- Network pumping stations
- Commercial buildings.

Features and benefits
- Automatic energy optimization
- Easy installation and configuration
- Configuration wizard
- Electrical overview
- Advanced data communication
- Advanced alarm and warning priority
- Supports several languages
- Daily emptying
- Mixer control or flush valve
- User-defined functions
- Anti-blocking
- Start level variation
- Advanced pump alternation with pump groups
- SMS scheduling
- Communication to SCADA, BMS, GRM or cell phone.

Optional
- Available as ready-made control panels or as modules for local assembly.

CUE
Frequency converters for three-phase pumps

Technical data:
- Mains voltage:
  1 x 200-240 V
  2 x 200-240 V
  3 x 380-500 V
  3 x 525-600 V
  3 x 575-690 V
- Power: 0,55-250 kW

Applications
Adjustment of the pump performance to the demand. Together with sensors, the CUE offers these control modes:

- Proportional differential pressure
- Constant differential pressure
- Constant pressure
- Constant pressure with stop function
- Constant level
- Constant level with stop function
- Constant flow rate
- Constant temperature.

The CUE can also be controlled by an external signal or via GENIbus.

Features and benefits
- Adjustment of the pump performance to the demand, thus saving energy.
- Easy installation, as the CUE is designed for GRUNDFOS pumps.
- Short-circuit-protected output; no motor-protective circuit breaker required.
- Fault indication via display and a relay, if fitted.
- External setpoint influence via three programmable inputs.

MP 204, CU 300, CU 301

Control and monitoring units

Applications

Monitoring and protection of pump installations.

Features and benefits

- Protection against dry running and too high motor temperature
- Constant monitoring of pump energy consumption.

Options

- Connection to large control systems via bus communication
- Connection of sensors enabling control based on sensor signals
- Wireless remote control via Grundfos R100, MI 201, MI 202 and MI 301.

IO 111
Input/Output Module

The IO 111 forms interface between a Grundfos wastewater pump with analogue and digital sensors and the pump controller. The most important sensor status is indicated on the front panel. One pump can be connected to an IO 111 module. Together with the sensors, the IO 111 forms a galvanic separation between the motor voltage in the pump and the controller connected.

Technical data:
- Supply voltage: 24 VAC ±10%, 50 & 60 Hz 24 VDC ±10%
- Supply current: Min. 2.4 A; max. 8 A
- Power consumption: Max. 5 W
- Ambient temperature: –25°C to +65°C
- Enclosure class: IP 20

By means of the IO 111 it is possible to:
- Protect the pump against over-temperature
- Monitor sensors for analog measurement of:
  - motor temperature
  - water content [%] in oil
  - stator insulation resistance
  - bearing temperature
  - digital measurement of moisture in motor
- Stop the pump in case of alarm
- Remote monitor the pump via RS485 communication (Modbus or GENIbus)
- Operate the pump via frequency converter

If the cable is more than 10 metres long, it is advisable to equip the frequency converter with an output filter to prevent incorrect analog measurements.

GRM
Grundfos Remote Management

Grundfos Remote Management is a secure, internet-based system for monitoring and managing pump installations in commercial buildings, water supply networks, wastewater plants, etc.

Pumps, sensors, meters and Grundfos pump controllers are connected to a CIU271 (GPRS Datalogger). Data can be accessed from an Internet PC, providing a unique overview of your system. If sensor thresholds are crossed or a pump or controller reports an alarm, an SMS will instantly be dispatched to the person on duty.

Changes in pump performance and energy consumption can be tracked and documented using automatically generated reports and trend graphs. This can give an indication of wear or damage, and service and maintenance can be planned accordingly.

Applications
Grundfos Remote Management is a secure, internet-based system for monitoring and managing pump installations in commercial buildings, water supply networks, wastewater plants, etc.

Features and benefits
- Complete status overview of the entire system you manage
- Live monitoring, analysis and adjustments from the comfort of your office
- Follow trends and reports to reveal opportunities for energy-reducing performance optimisation
- Plan who receives SMS alarms with easy-to-use weekly schedules
- Plan service and maintenance based on actual operating data
- Share system documentation online with all relevant personnel.

FlushJet WA / FlushJet WW

Frequency converters for three-phase pumps

The FlushJet is a hydroejector designed to automatically clean tanks used for the temporary storage of stormwater or wastewater so that odour problems are avoided and storage capacity is maintained.

The FlushJet continues flushing until the tank is completely empty and all the contents have been pumped into the sewer system. It uses the water already in the tank and hence does not need an external source of fresh water.

The FlushJet is made entirely of stainless steel of AISI 304/DIN1.4301 or AISI 316/DIN 1.4401, and is coupled to a wastewater pump of the SE or S type.

Applications
No matter what the size and layout, a customised solution of one or more FlushJets can easily be designed to clean detention, equalisation or stormwater tanks used for the storage of excess water in order to minimise the risks of:

- Flooding or pollution of receiving waters if capacity of the sewer system is exceeded
- Damage of biological processes at the WWTP if untreated industrial process water arrives
- Disruption of purification processes at the WWTP due to hydraulic overload.

Features and benefits
- Available as water/water or water/air ejectors
- FlushJet WA available with a 2nd stage for extra thrust
- Made completely in stainless steel for strength
- Available with standard pumps in many motor sizes
- Fitted with sturdy submersible wastewater pump of the SE or S type
- Suits tanks of different sizes, depths and shapes
- Mixing and cleaning handled by same the unit
- Large free passage – no clogging
- Fixed or auto-coupling connections suiting every type of installation
- Pumps on auto-coupling to make maintenance easier and more flexible.

Appendix 3: Reference list

Please visit Grundfos.com/flood-control for reference list and case stories as well as films from our many projects around the world.

Completion YEAR	Quantity	Motor output (kW)	Model	Job Site	Country
2012	2	600	KPL	BMA	Thailand
2012	2	420	KPL	KSA	Dubai
2012	1	300	KPL	Myung Ryun P/S	Korea
2012	4	300	KPL	Chenqiao	China
2012	4	260	KPL	Mun San P/S	Korea
2012	1	210	KWM	Gaecheok	Korea
2012	1	140	KPL	PTIAM	Malaysia
2012	20	130	KPL	RID	Thailand
2012	20	130	KPL	RID	Thailand
2012	2	130	KWM	RID	Philippines
2012	1	120	KPL	PTIAM	Malaysia
2012	1	110	KPL		New Zealand
2012	2	110	KPL	Bitec	Thailand
2012	1	90	KWM	No Gok P/S	Korea
2012	1	90	KWM	No Gok P/S	Korea
2012	2	90	KPL	San Juan	Philippines
2012	1	75	KPL	Yeon Pung P/S	Korea
2012	4	75	KPL	Yeon Pung P/S	Korea
2012	2	75	KPL	Yeon Pung P/S	Korea
2012	5	75	KPL	Bitec	Thailand
2011	2	550	KWM	Han An P/S	Korea
2011	2	550	KPL		India
2011	5	465	KPL	Bossuit	Belgium
2011	1	450	KWM	Ham An P/S	Korea
2011	9	400	KWM	IDOT #27	USA
2011	1	370	KWM	Gu Ri	Korea
2011	2	350	KPL	Gu Ri	Korea

Completion YEAR	Quantity	Motor output (kW)	Model	Job Site	Country
2011	2	300	KPL	Myung Ryun P/S	Korea
2011	5	210	KPL	Moen	Belgium
2011	4	200	KPL	Omnoi	Thailand
2011	1	190	KWM		Malaysia
2011	2	185	KWM	Buyeo	Korea
2011	2	180	KPL		USA
2011	6	175	KPL	TJ	China
2011	2	150	KPL	Pa Ju P/S	Korea
2011	2	150	KPL	Pa Ju P/S	Korea
2011	1	130	KWM	Yang San City	Korea
2011	2	110	KWM	Gyung Ju	Korea
2011	2	110	KWM	Sok Cho	Korea
2011	2	110	KWM	Young Ju	Korea
2011	2	110	KPL		Thailand
2011	1	90	KPLX		USA
2011	3	90	KWM		Malaysia
2011	1	90	KPL		Australia
2011	1	90	KPL	Hemaraj	Thailand
2011	3	90	KPL		Indonesia
2011	2	90	KPL	Pasadena	USA
2011	4	75	KWM	Busan	Korea
2011	8	75	KPL	Omnoi	Thailand
2011	8	75	KPL	IKEA	Thailand
2011	4	65	KWM		Slovakia
2011	2	65	KPL		Hungary
2011	6	65	KPL	KMITL	Thailand
2011	2	63	KPL	Merwin	USA
2011	3	55	KWM	Mu Lim P/S	Korea
2011	2	55	KWM		Russia
2011	2	55	KPL		Italy
2011	4	55	KPL		Australia
2011	2	55	KPL	Ratchapeuk	Thailand

Completion YEAR	Quantity	Motor output (kW)	Model	Job Site	Country
2011	4	55	KPL	Novara	Italy
2010	4	730	KPLX		Korea
2010	1	730	KPLX		Korea
2010	2	730	KPLX		Korea
2010	3	550	KPL		Korea
2010	1	550	KPL		Korea
2010	2	550	KPL		India
2010	5	420	KPL		Belgium
2010	1	400	KPL		Korea
2010	10	365	KPL		Hungary
2010	1	305	KPL		Korea
2010	2	300	KPL		Hungary
2010	1	270	KPL		Korea
2010	1	270	KPL		Korea
2010	2	260	KPL		Korea
2010	1	220	KPL		Korea
2010	1	190	KPL		Korea
2010	2	185	KWM		Korea
2010	3	170	KPL		Hungary
2010	2	160	KPL		Korea
2010	2	160	KWM		USA
2010	2	150	KWM		Korea
2010	2	150	KPL		Korea
2010	12	130	KPL		Bulgaria
2010	5	130	KPL		Indonesia
2010	2	110	KPL		Indonesia
2010	3	100	KWM		USA
2010	2	90	KPL		Korea
2010	2	90	KPL		Hungary
2010	3	90	KPL		Indonesia
2010	3	65	KPL		Bulgaria
2010	1	55	KPL		Indonesia

Completion YEAR	Quantity	Motor output (kW)	Model	Job Site	Country
2009	3	550	KPL	Mumbai	India
2009	9	300	KPL		Malaysia
2009	3	130	KPL	Surabaya	Indonesia
2009	3	90	KPL	Surabaya	Indonesia
2009	3	55	KWM	Surayaba	Indonesia
2009	2	55	KPL	Kelantan	Italy
2009	2	55	KPL		Malaysia
2008	3	680	KPL	Gumiri P/S	Korea
2008	8	500	KPL	Irla P/S	India
2007	3	730	KPL	Pa-Ju P/S	Korea
2007	4	620	KPL	Yeonchun P/S	Korea
2007	1	220	KWM	Kudu P/S	Indonesia
2007	2	110	KPL	Jakarta	Indonesia
2007	2	75	KPL	Parit Lima & Sanglang	Malaysia
2007	3	55	KPL	Jakarta	Indonesia
2007	2	55	KPL	Parit Lima & Sanglang	Malaysia
2007	2	55	KPL	ROME	Italy
2007	2	45	KPL	Parit Lima & Sanglang	Malaysia
2006	1	530	KWM	Tala P/S	India
2006	6	400	KPL	Songnan P/S	China
2006	4	350	KPL	Johobaru	Malaysia
2006	6	310	KPL	Shouyang P/S	China
2006	4	300	KWM	Drydocks	Dubai
2006	6	300	KPL	S.Jiangyang P/S	China
2006	6	260	KPL	Minzhu P/S	China
2006	3	250	KWM	Chung Yang	Korea
2006	4	190	KPL	Zhangmiao P/S	China
2006	1	190	KWM	Jakarta	Indonesia
2006	1	160	KWM	Chung Yang	Korea
2006	2	150	KPL	Hannam P/S	Korea
2006	1	140	KPL	E.N.S.P.M.	Korea
2006	3	110	KPL	Gu Wal P/S	Korea

Completion YEAR	Quantity	Motor output (kW)	Model	Job Site	Country
2006	1	110	KWM	Yong In P/S	Korea
2006	1	110	KWM	Pa Ju LCD	Korea
2006	6	110	KPL	Hwan Lien	Taiwan
2006	6	110	KWM	Feng Shan	Taiwan
2006	2	110	KPL	Jakarta	Indonesia
2006	1	75	KPL	Jakarta	Indonesia
2006	2	75	KPL	Jakarta	Indonesia
2006	3	55	KPL	Chung Yang	Korea
2006	1	55	KWM	Yong In P/S	Korea
2006	2	55	KPL	ROME	Italy
2006	1	55	KPL	Jakarta	Indonesia
2006	3	55	KPL	Jakarta	Indonesia
2006	6	55	KPL	Bangkok	Thailand
2005	3	250	KWM	Dea hong	Korea
2005	1	250	KPL	Dea hong	Korea
2005	1	190	KWM	Napier	New Zealand
2005	1	190	KWM	Surabaya	Indonesia
2005	1	160	KWM	Dea hong	Korea
2005	2	150	KPL	Dea hong	Korea
2005	4	150	KPL	Bangkok	Thailand
2005	1	140	KPL	E.N.S.P.M.	Korea
2005	3	130	KWM	Sam Sin	Korea
2005	5	130	KPL	Jakarta	Indonesia
2005	1	110	KWM	Jang Am	Korea
2005	2	110	KPL	Dea hong	Korea
2005	1	110	KWM	Yong In Environment	Korea
2005	2	90	KWM	Jang Am	Korea
2005	2	75	KPL	Jakarta	Indonesia
2005	3	75	KPL	Jakarta	Indonesia
2004	6	700	KWM	Korea Land Corp.	Korea
2004	6	400	KWM	Pusan City	Korea
2004	4	350	KWM	Kolkata	India

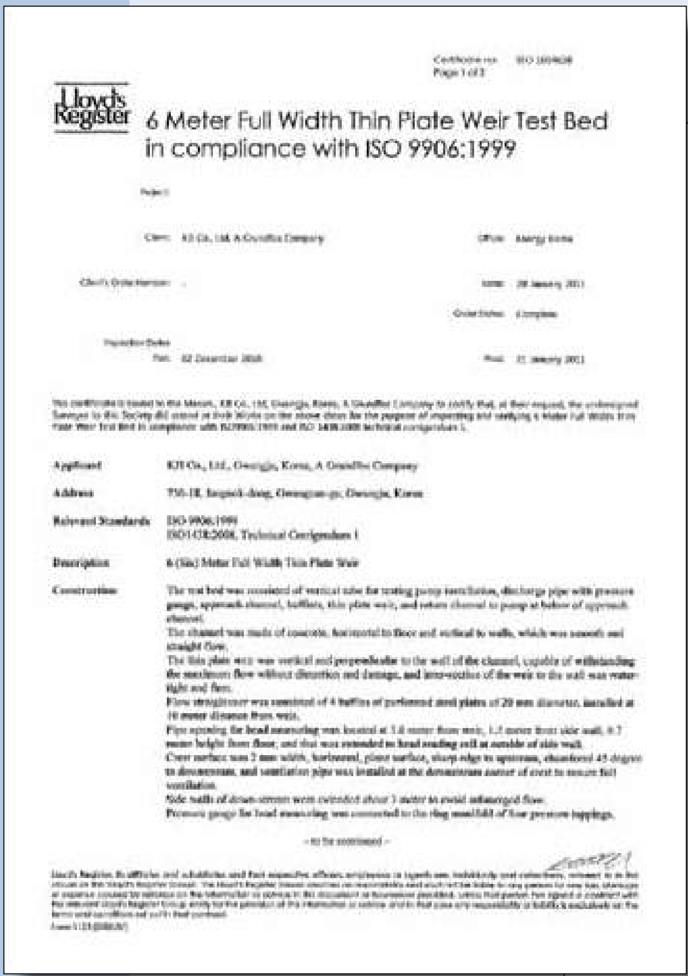
Completion YEAR	Quantity	Motor output (kW)	Model	Job Site	Country
2004	2	300	KPL	Jinju City	Korea
2004	2	300	KPL	Keelung	Taiwan
2004	4	280	KPL	Nan Ging	China
2004	1	230	KPL	Inchon City	Korea
2004	4	220	KPL	Tainan	Taiwan
2004	1	190	KWM	Surabaya	Indonesia
2004	2	150	KPL	Surabaya	Indonesia
2004	2	130	KPL	Pohang Industry	Korea
2004	3	130	KPL	Surabaya	Indonesia
2004	3	110	KPL	Hamaxin	Taiwan
2004	1	100	KPL	Yungduk City	Korea
2004	2	90	KWM	TianJin Power plant	China
2004	3	90	KPL	Xinbin	Taiwan
2004	3	75	KWM	Dongdaemun, Seoul City	Korea
2004	1	75	KWM	Guro, Seoul City	Korea
2004	6	75	KWM	Illinois, D.O.T.	USA
2003	5	315	KPL	Misung Machine	Korea
2003	4	300	KWM	SADPS/Kolkata	India
2003	1	230	KPL	Inchon City	Korea
2003	1	230	KPL	Inchon City	Korea
2003	2	220	KPL	Da-Shir P/S	Taiwan
2003	3	190	KPL	Bangkok Metropolitan	Thailand
2003	1	175	KWM	Osaka	Japan
2003	1	150	KPL	Texas, D.O.T.	USA
2003	18	130	KPL	Surabaya	Indonesia
2003	2	110	KPL	Surabaya	Indonesia
2003	1	100	KPL	Yungduk City	Korea
2003	2	90	KPL	Yungduk City	Korea
2003	1	75	KPL	Surabaya	Indonesia
2002	1	355	KPL	ChunCheoun City	Korea
2002	1	350	KPL	Deasung Pump	Korea
2002	2	350	KPL	Daesung Pump	Korea

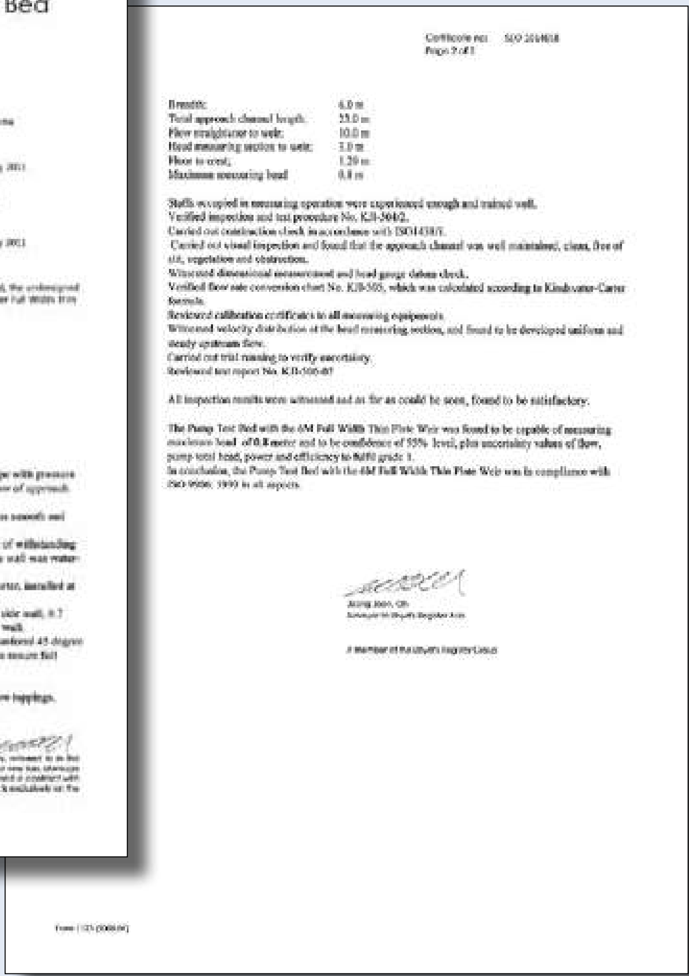
Completion YEAR	Quantity	Motor output (kW)	Model	Job Site	Country
2002	6	335	KPL	Pohang City	Korea
2002	2	210	KPL	Yesan County	Korea
2002	6	190	KPL	Bangkok Metropolitan	Thailand
2002	1	130	KPL	Daesung Pump	Korea
2002	3	125	KPL	Surabaya	Indonesia
2002	3	110	KPL	Hanyoung	Korea
2002	2	90	KPL	Surabaya	Indonesia
2002	1	75	KPL	Hanyoung	Korea
2002	1	75	KWM	Environmental Corp.	Korea
2002	3	75	KWM	Iksan City	Korea
2001	3	400	KPL	Kaohsiung County	Taiwan
2001	1	230	KPL	Inchon City	Korea
2001	6	200	KPL	Daean Construction	Korea
2001	5	190	KPL	Keumjun	Korea
2001	1	160	KWM	Kumduk Pump	Korea
2001	5	150	KPL	Keumjun	Korea
2001	1	150	KPL	Texas, D.O.T.	USA
2001	2	130	KWM	SungHeung	Korea
2000	5	550	KPL	Keumchon P.S	Korea
2000	5	450	KPL	Bongilchun P.S	Korea
2000	4	300	KWM	Bangkok Metropolitan	Thailand
2000	3	200	KWM	Chulwon County	Korea
2000	6	190	KPL	Bongilchun P.S	Korea
2000	4	190	KWM	Sunyu P.S	Korea
2000	4	190	KWM	Paju City	Korea
2000	5	167	KPL	Munmak WWTP	Korea
2000	3	160	KPL	Penang P/S	Malaysia
2000	1	150	KWM	Orim Construction	Korea
2000	3	135	KPL	Keumjun	Korea
2000	5	130	KPL	Bangkok Metropolitan	Thailand
2000	2	110	KPL	Surabaya	Indonesia
2000	2	90	KPL	Bangkok Metropolitan	Thailand

Completion YEAR	Quantity	Motor output (kW)	Model	Job Site	Country
2000	3	75	KPL	Surabaya	Indonesia
2000	2	75	KPL	Surabaya	Indonesia
2000	1	75	KPL	Penang P/S	Malaysia
2000	7	55	KPL	Surabaya	Indonesia
1999	3	260	KPL	Yeoncheon County	Korea
1999	3	260	KWM	Guri City	Korea
1999	6	240	KPL	SongJongchun P.S	Korea
1999	2	185	KWM	Guri City	Korea
1999	10	175	KPL	Bangkok Metropolitan	Thailand
1999	2	130	KPL	Yeoncheon County	Korea
1999	20	130	KPL	Bangkok Metropolitan	Thailand
1999	5	130	KPL	Bangkok Metropolitan	Thailand
1999	6	110	KPL	Bangkok Metropolitan	Thailand
1999	1	90	KPL	Yeoncheon County	Korea
1998	4	560	KPL	Hyosung Ebara	Korea
1998	6	520	KWM	Bangkok Metropolitan	Thailand
1998	4	400	KPL	Wonhong Ind.	Korea
1998	4	375	KPL	Bangkok Metropolitan	Thailand
1998	1	250	KPL	Daekyung Ind.	Korea
1998	4	200	KPL	Bangkok Metropolitan	Thailand
1998	2	175	KPL	Bangkok Metropolitan	Thailand
1998	3	160	KWM	Daewoo	Korea
1998	2	150	KPL	Pohang City	Korea
1998	4	150	KPL	Ulsan City	Korea
1998	2	110	KPL	Bangkok Metropolitan	Thailand
1997	5	220	KPL	Nonsan City	Korea
1997	3	120	KWM	Keumjung P.M	Korea
1997	2	110	KWM	Gapyeong Gun	Korea
1997	2	90	KPL	Yeongdeok Gun	Korea
1997	2	75	KWM	Gapyeong Gun	Korea
1997	2	63	KPL	Keumjung P.M	Korea
1996	2	600	KPL	Chungwon	Korea

Completion YEAR	Quantity	Motor output (kW)	Model	Job Site	Country
1996	6	210	KPL	Chungwon	Korea
1996	1	200	KWM	Dongdaemun	Korea
1996	1	150	KPL	Dongjin	Korea
1996	3	110	KPL	Youngpoong	Korea
1995	3	500	KPL	Busan City	Korea
1995	1	190	KPL	Busan City	Korea
1994	1	300	KWM	Dongdaemun	Korea
1993	2	375	KPL	Pohang City	Korea
1993	2	190	KWM	KAMES	Korea
1993	1	190	KPL	Yeongdeungpo ward office	Korea
1993	3	175	KWM	Mokpo City	Korea
1993	2	132	KPL	Sangwoo	Korea
1992	5	355	KPL	Chuncheon City	Korea
1992	2	300	KWM	Busan City	Korea
1992	2	236	KPL	Chuncheon City	Korea
1992	3	190	KPL	Yeongdeungpo ward office	Korea

Appendix 4: Lloyd certificate





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GRUNDFOS Holding A/S
Poul Due Jensens Vej 7
DK-8850 Bjerringbro
Tel: +45 87 50 14 00
www.grundfos.com

GRUNDFOS