STORM WATER PUMPING STATION DESIGN GUIDE
1. Introduction

1.1 Introduction to Grundfos

1.2 Introduction to flooding

1.3 Introduction to flood control

2. The sources of flooding - and the solutions

2.1 Can we prevent flooding?

2.1.1 Flood management

2.1.2 The flood risk cycle

2.2 The sources of flooding

2.3 Flood control solutions

2.3.1 Drain/rain water station

2.3.2 Network pumping station

2.3.3 Main pumping station

2.3.4 Storm water tank with installations

2.3.5 Pump gate pumping station

2.3.6 Flood control pumping station

2.3.7 Grundfos Remote Management System

2.4 Flooding, then what?

2.4.1 Water-borne illnesses and water contamination

2.4.2 Drainage pumps and service trucks

2.4.3 Filtering and disinfection

3 Designing a flood control pumping station

3.1 General considerations

3.1.1 Design sequence

3.2 Design conditions

3.2.1 Flow patterns and boundary geometry

3.2.2 Types of installation

3.2.3 Water flow (Q)

3.2.4 Head (H)

3.2.5 Net Positive Suction Head (NPSH)
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2.6 Water velocity</td>
<td>31</td>
</tr>
<tr>
<td>3.2.7 Power supply and backup</td>
<td>31</td>
</tr>
<tr>
<td>3.2.8 Trash racks and screens</td>
<td>32</td>
</tr>
<tr>
<td>3.2.9 Handling sludge</td>
<td>33</td>
</tr>
<tr>
<td>3.3 Pump selection</td>
<td>34</td>
</tr>
<tr>
<td>3.3.1 Axial flow propeller pump or mixed flow pump?</td>
<td>34</td>
</tr>
<tr>
<td>3.3.2 Number of pumps</td>
<td>36</td>
</tr>
<tr>
<td>3.3.3 Pump selection / determine column diameter</td>
<td>37</td>
</tr>
<tr>
<td>3.3.4 Minimum submergence (S)</td>
<td>38</td>
</tr>
<tr>
<td>3.3.5 Turbulence Optimiser™</td>
<td>42</td>
</tr>
<tr>
<td>3.3.6 Sensors in the pumps</td>
<td>43</td>
</tr>
<tr>
<td>3.4 Dimensioning the pumping station</td>
<td>45</td>
</tr>
<tr>
<td>3.4.1 Terminology and conventions</td>
<td>45</td>
</tr>
<tr>
<td>3.4.2 Different station layouts</td>
<td>46</td>
</tr>
<tr>
<td>3.4.3 Pump bay design</td>
<td>47</td>
</tr>
<tr>
<td>3.4.4 Pumping station dimensions</td>
<td>50</td>
</tr>
<tr>
<td>3.5 Duty strategy – reducing minimum water level</td>
<td>53</td>
</tr>
<tr>
<td>3.5.1 Grundfos dedicated controls</td>
<td>55</td>
</tr>
<tr>
<td>3.5.2 Communication modules SCADA implementation</td>
<td>55</td>
</tr>
<tr>
<td>3.5.3 Grundfos Remote Management (GRM)</td>
<td>56</td>
</tr>
<tr>
<td>3.5.4 Motor Protection (MP204)</td>
<td>57</td>
</tr>
<tr>
<td>3.5.5 Variable frequency drives (CUE)</td>
<td>58</td>
</tr>
<tr>
<td>3.5.6 Soft starters</td>
<td>58</td>
</tr>
<tr>
<td>3.6 Other considerations for the construction</td>
<td>59</td>
</tr>
<tr>
<td>3.6.1 Support beams and columns for the building</td>
<td>59</td>
</tr>
<tr>
<td>4 CFD and model testing</td>
<td>60</td>
</tr>
<tr>
<td>4.1 Computational Fluid Dynamics (CFD)</td>
<td>61</td>
</tr>
<tr>
<td>4.2 Model testing</td>
<td>63</td>
</tr>
<tr>
<td>5 Vortex – and how to prevent it</td>
<td>64</td>
</tr>
<tr>
<td>5.1 Types of vortices</td>
<td>65</td>
</tr>
<tr>
<td>5.2 How to prevent vortices</td>
<td>66</td>
</tr>
<tr>
<td>5.2.1 Sub surface vortices</td>
<td>66</td>
</tr>
<tr>
<td>5.2.2 Submerged vortices</td>
<td>67</td>
</tr>
<tr>
<td>5.2.3 Air-entraining vortices</td>
<td>68</td>
</tr>
<tr>
<td>5.3 Retrofitting FSI, Formed Suction intake</td>
<td>69</td>
</tr>
<tr>
<td>5.4 Retrofitting back-wall and floor splitters</td>
<td>69</td>
</tr>
<tr>
<td>5.5 Reducing surface vortex by retrofitted a baffle</td>
<td>69</td>
</tr>
<tr>
<td>6 Accessories</td>
<td>70</td>
</tr>
<tr>
<td>6.1 Column pipe</td>
<td>71</td>
</tr>
<tr>
<td>6.2 Anti-cavitation cone</td>
<td>71</td>
</tr>
<tr>
<td>6.3 Splitters</td>
<td>72</td>
</tr>
<tr>
<td>6.4 Cable entry</td>
<td>72</td>
</tr>
<tr>
<td>6.5 Cable support system</td>
<td>73</td>
</tr>
<tr>
<td>6.6 Monitoring unit</td>
<td>75</td>
</tr>
<tr>
<td>6.7 Formed suction intake (FSI)</td>
<td>75</td>
</tr>
<tr>
<td>7. Grundfos service and solutions</td>
<td>76</td>
</tr>
<tr>
<td>8. Glossary</td>
<td>80</td>
</tr>
<tr>
<td>9. Appendices</td>
<td>84</td>
</tr>
<tr>
<td>Appendix 1: Head loss calculations</td>
<td>85</td>
</tr>
<tr>
<td>Appendix 2: Grundfos products</td>
<td>102</td>
</tr>
<tr>
<td>Appendix 3: List of references</td>
<td>118</td>
</tr>
<tr>
<td>Appendix 4: Lloyd certificate</td>
<td>128</td>
</tr>
</tbody>
</table>

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.us

Based on the ANSI standard

Grundfos Chicago 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 Centers, 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 located across the US, 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.
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 as flash floods, can develop in just a few minutes even without visible signs of rain. Some floods are local, impacting a neighborhood 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 urbanization 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.
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 minimize 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 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 minimize 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
- Spatial planning
- Flood defense
- Retention
- Preparedness
- Insurance

Flood event management
- Early warning
- Reservoir control
- Evacuation
- Rescue

Post-flood measures
- Relief
- Cleaning
- Reconstruction
- Organizational and financial aid

Preventive flood risk management
Our contribution to flood defense 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 storm water 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.

The sources of flooding – and the solutions
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 organize our society.
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: 80 - 160 gpm
Head: 33 ft

Benefits
• Safety: Surveillance and alarm
• Reliability

Products
Pumping stations: PUST
Pumps: AP/KP/CC/D/P/DWK/AUTO
Drives: CUE
Monitoring: GRM
Controls: LC/LCD/DC
Accessories: Pipes/Valves

www.grundfos.com/flood-control

2.3.2 Network pumping station

Application
Collects and distributes rainwater and storm water.

Flow: 160 - 1,600 gpm
Head: 230 ft

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

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

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

www.grundfos.com/flood-control

2.3.3 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.

2.3.3.1 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: 80 - 160 gpm
Head: 33 ft

Benefits
• Safety: Surveillance and alarm
• Reliability

Products
Pumping stations: PUST
Pumps: AP/KP/CC/D/P/DWK/AUTO
Drives: CUE
Monitoring: GRM
Controls: LC/LCD/DC
Accessories: Pipes/Valves

www.grundfos.com/flood-control

2.3.3.2 Network pumping station

Application
Collects and distributes rainwater and storm water.

Flow: 160 - 1,600 gpm
Head: 230 ft

Benefits
• Flexible extension -> less piping and gravitation -> reduced depth of main pump station
• Intelligent control between pump stations
• Combined with storm water tanks
• Surveillance and alarm

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

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

www.grundfos.com/flood-control
### 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:** 1,600 - 32,000 gpm
**Head:** 394 ft

**Benefits**
- Independent of gravity -> reduced construction costs
- Intelligent control in combination with network pumping stations, storm water tanks and other pumping stations
- Minimizing the environmental and human consequences of overflow

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

[www.grundfos.com/flood-control](http://www.grundfos.com/flood-control)

### 2.3.4 Storm water 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:** 1,600 - 8,000 gpm
**Head:** 6.5 ft

**Benefits**
- Reducing peak flow and equalizing flow rates
- Better utilization of the existing sewer system
- Allowing for intelligent management of storm water flows
- Savings on infrastructural investments

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

[www.grundfos.com/flood-control](http://www.grundfos.com/flood-control)

### 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. Gravity discharges the inside water. 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:** 2,400 - 1,600,000 gpm
**Head:** 33 ft

**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
- With or without water gate to the sea

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

[www.grundfos.com/flood-control](http://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:** 2,400 - 1,600,000 gpm
**Head:** 33 ft

**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

[www.grundfos.com/flood-control](http://www.grundfos.com/flood-control)
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 minimize 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.

Flow: 80 - 160 gpm
Head: 33 ft

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

www.grundfos.com/flood-control

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

www.grundfos.com/flood-control

www.grundfos.com/flood-control
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
# 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)
2. Pump size and quantity (see 3.3)
3. Pump selection (see 3.3)
4. Placing the pumps (see 3.3)
5. Minimum water level (See 3.3)
6. Determine slope (See 3.4)
7. Velocity (See 3.4)
8. Cross-flow velocity (See 3.2.6)
9. Dimensions (See 3.4)

- **Flow patterns and boundary geometry**: Identify the column pipe diameter.
- **Pump size and quantity**: Determine the number and size of pumps required to satisfy the range of operating conditions likely to be encountered.
- **Pump selection**: Identify the column pipe diameter.
- **Placing the pumps**: Determine the distance from pump bell mouth to floor.
- **Minimum water level**: Determine the minimum submergence of the pump and by that the minimum water level. Check NPSH at minimum water level.
- **Determine slope**: 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°.
- **Velocity**: Check the pump bay velocity for the maximum single-pump flow and minimum water depth with the bay width set to 2D. Max velocity 2 ft./sec.
- **Cross-flow velocity**: 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.
- **Dimensions**: Determine the dimensions of the pumping station.

# 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 customization 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.**
### 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 of 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 odors.

### 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)
There are many conditions to consider when you are calculating pump station dimensions — such as climate change, 10, 30 and 100 year’s rain, urban development and planning. General recommendations are therefore 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 \( H = H_{\text{geod}} + H_{\text{losses}} \)
(losses in pipes, valves, bends and flaps etc).

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 vapor bubbles in areas where the pressure locally drops to the fluid vapor 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 feet [ft] like the head.

Two different values
A distinction is made between two different NPSH values: NPSHA and NPSHR.

NPSHA stands for NPSH Available and expresses how close the fluid in the suction pipe is to vaporization.

NPSHR 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 NPSHR and not only the specific duty point.

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.

\[
H = H_{\text{geod}} + \frac{v^2}{2g} + H_w
\]
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 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 4 ft/s.
- The overall velocity of the water in the pumping station should be between 1 and 2 ft/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.

**In the column pipe**

If water velocity is too high, it causes excessive energy consumption.

If water velocity is too low, it leads to sedimentation or up-concentration of solids, making the water heavier and causing 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 other parts of the world, they do occur and can be 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.

**NPSH calculations**

NPSHₐ can be calculated as:

\[ \text{NPSH}_a = \left( \frac{P_{\text{bar}} - \text{atmospherical pressure}}{\rho \times g} \right) \]

P₀ = atmospheric pressure depends on your altitude.

**Example:**

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

\[ \text{NPSH}_a = \text{S}_{\text{min}} + 33 \times \text{safety margin} = \text{S}_{\text{min}} + 31 \text{ [ft]} \]

NPSHₐ = safety margin ≤ NPSHₐ (in all duty points)

NPSHₐ ≤ Sₐₜₘₙₐₓ + 33 - safety margin = Sₐₜₘₙₐₓ + 31 [ft]

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

**REMEMBER TO ALWAYS CONSIDER NPISHₐ FOR THE FULL OPERATING RANGE, AND NOT ONLY AT THE SPECIFIC DUTY POINT. A MINIMUM SAFETY MARGIN OF 2 FT IS RECOMMENDED, BUT DEPENDING ON THE APPLICATION, A HIGHER SAFETY LEVEL MAY BE REQUIRED**
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, minimizing 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 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.
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 optimize 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 20 - 1,300 hp, both Grundfos KPL and Grundfos KWM solutions are designed for high-volume water handling.

KPL: Axial flow propeller pump
KWM: Mixed flow pump

**RULE OF THUMB:**
HEAD BELOW 30 ft => KPL AXIAL FLOW PROPELLER PUMP
HEAD ABOVE 30 ft => KWM MIXED FLOW PUMP
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 25,000 gpm => 3 pump installation
- Flow below 210,000 gpm => 4 pump installation
- Flow above 210,000 gpm => 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.

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 (if required in the application).
- 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 = 22 ft and 38,000 US gpm), specified by customer.
2. Operating range (33,000 - 39,000 US gpm), specified by customer.
3. Q-H curve is obtained at a propeller angle of 19°.
4. P2 at duty point 265 hp.
5. P2max in operating range 295 hp (at a flow of 33,000 US gpm).
6. Calculate motor size and select model: Pmotor = 295 * 1.15 = 340 hp
7. NPSHr (required) = 35 ft (worst case for operating range).
8. NPSHa (available) = 40 ft, specified by customer.
9. NPSHr > NPSHa + 2 ft. (accepted)

Selected model: KPL 40.355.10.T.60.19.A.
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.

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.

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

<table>
<thead>
<tr>
<th>Nominal Column Diameter</th>
<th>Min. Clearance</th>
<th>Min. Submergence</th>
<th>Min. Water Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>C</td>
<td>S</td>
<td>M.W.L</td>
</tr>
<tr>
<td>20</td>
<td>10</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>24</td>
<td>12</td>
<td>44</td>
<td>56</td>
</tr>
<tr>
<td>28</td>
<td>14</td>
<td>64</td>
<td>78</td>
</tr>
<tr>
<td>32</td>
<td>16</td>
<td>72</td>
<td>88</td>
</tr>
<tr>
<td>36</td>
<td>18</td>
<td>80</td>
<td>98</td>
</tr>
<tr>
<td>40</td>
<td>20</td>
<td>88</td>
<td>108</td>
</tr>
<tr>
<td>48</td>
<td>24</td>
<td>92</td>
<td>116</td>
</tr>
<tr>
<td>56</td>
<td>28</td>
<td>100</td>
<td>128</td>
</tr>
<tr>
<td>60</td>
<td>30</td>
<td>116</td>
<td>146</td>
</tr>
<tr>
<td>64</td>
<td>32</td>
<td>124</td>
<td>156</td>
</tr>
<tr>
<td>72</td>
<td>36</td>
<td>132</td>
<td>168</td>
</tr>
</tbody>
</table>

All dimensions in inches.
Remember to check the NPSH, please refer to 3.2.5.

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

The clearance C = 0.5 x Column Diameter (D)
**Formed Suction Intake (FSI)**

The minimum water level can be optimized 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:

\[
\text{NPSH}_{2} + \text{safety margin} \leq \text{NPSH}_{3} \\
\Delta H_{FSI} \leq \text{safety margin} - \text{NPSH}_{4} \leq \text{safety margin} - \Delta H_{FSI}
\]

\(\Delta H_{FSI}\) is the friction loss through the FSI, which is dependent on design, material, surface structure etc.

**Safety margin**

A safety margin of 2 ft 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 2 ft including \(\Delta H_{FSI}\):

\[
\text{NPSH}_{2} \leq \text{NPSH}_{4} = 31 + \text{Smin} \ [\text{ft}]
\]

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

To get the full benefit of this optimized design, you need to select a pump that, in the full operating range, has a NPSHR equal to or lower than 31 ft + D. Alternatively, the minimum water level must be increased.

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

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>32.7</td>
</tr>
<tr>
<td>24</td>
<td>12</td>
<td>24</td>
<td>36</td>
<td>33.0</td>
</tr>
<tr>
<td>28</td>
<td>14</td>
<td>28</td>
<td>42</td>
<td>33.3</td>
</tr>
<tr>
<td>32</td>
<td>16</td>
<td>32</td>
<td>48</td>
<td>33.7</td>
</tr>
<tr>
<td>36</td>
<td>18</td>
<td>36</td>
<td>54</td>
<td>34.0</td>
</tr>
<tr>
<td>40</td>
<td>20</td>
<td>40</td>
<td>60</td>
<td>34.3</td>
</tr>
<tr>
<td>48</td>
<td>24</td>
<td>48</td>
<td>72</td>
<td>35.0</td>
</tr>
<tr>
<td>56</td>
<td>28</td>
<td>56</td>
<td>84</td>
<td>35.7</td>
</tr>
<tr>
<td>60</td>
<td>30</td>
<td>60</td>
<td>90</td>
<td>36.0</td>
</tr>
<tr>
<td>64</td>
<td>32</td>
<td>64</td>
<td>96</td>
<td>36.3</td>
</tr>
<tr>
<td>72</td>
<td>36</td>
<td>72</td>
<td>108</td>
<td>37.0</td>
</tr>
</tbody>
</table>

**Example:**

If you select a pump for a D = 40 in column pipe, you can allow a minimum water level MWL = 5 ft if your pump has a NPSH required below 34.3 ft 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 + \(\Delta H_{FSI} = 2 \text{ ft}\).
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.

Reducing turbulence

The Grundfos Turbulence Optimiser™ is a rubber diffuser mounted on the perimeter of the pump volute. The shape of the diffuser is optimized 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%.

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 minimize 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 centerline, the preferred layout, or perpendicular to the sump centerline. 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 pump 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 centerline. 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 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.
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.

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.

GRUNDFOS RECOMMENDS USING OF OUR PATENTED ANTI-CAVITATION CONE, ACC, AS A FLOOR SPLINTER.
3.4.4 Pumping station dimensions

Open sump design:

<table>
<thead>
<tr>
<th>Nominal column diameter</th>
<th>Min. Clearance</th>
<th>Min. submergence*</th>
<th>Min. water level*</th>
<th>Pump bay width</th>
<th>Pump bay length</th>
<th>Fillet</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>C</td>
<td>S</td>
<td>M.W.L</td>
<td>W</td>
<td>X</td>
<td>E</td>
</tr>
<tr>
<td>20</td>
<td>10</td>
<td>40</td>
<td>50</td>
<td>40</td>
<td>100</td>
<td>10</td>
</tr>
<tr>
<td>24</td>
<td>12</td>
<td>44</td>
<td>56</td>
<td>48</td>
<td>120</td>
<td>12</td>
</tr>
<tr>
<td>28</td>
<td>14</td>
<td>64</td>
<td>78</td>
<td>56</td>
<td>140</td>
<td>14</td>
</tr>
<tr>
<td>32</td>
<td>16</td>
<td>72</td>
<td>88</td>
<td>64</td>
<td>160</td>
<td>16</td>
</tr>
<tr>
<td>36</td>
<td>18</td>
<td>80</td>
<td>98</td>
<td>72</td>
<td>180</td>
<td>18</td>
</tr>
<tr>
<td>40</td>
<td>20</td>
<td>88</td>
<td>108</td>
<td>80</td>
<td>200</td>
<td>20</td>
</tr>
<tr>
<td>48</td>
<td>24</td>
<td>92</td>
<td>116</td>
<td>96</td>
<td>240</td>
<td>24</td>
</tr>
<tr>
<td>56</td>
<td>28</td>
<td>100</td>
<td>128</td>
<td>112</td>
<td>280</td>
<td>28</td>
</tr>
<tr>
<td>60</td>
<td>30</td>
<td>116</td>
<td>146</td>
<td>120</td>
<td>300</td>
<td>30</td>
</tr>
<tr>
<td>64</td>
<td>32</td>
<td>124</td>
<td>156</td>
<td>128</td>
<td>320</td>
<td>32</td>
</tr>
<tr>
<td>72</td>
<td>36</td>
<td>132</td>
<td>168</td>
<td>144</td>
<td>360</td>
<td>36</td>
</tr>
</tbody>
</table>

All dimensions in inches. * For the exact values of S and M.W.L, please refer to 3.3.4

3.4.4.1 Formed suction intake (FSI), concrete:

<table>
<thead>
<tr>
<th>Nominal column diameter</th>
<th>Clearance</th>
<th>Formed Suction Intake FSI</th>
<th>Pump bay width</th>
<th>Pump bay length</th>
<th>Fillet</th>
<th>Floor splitter</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>C</td>
<td>H</td>
<td>G</td>
<td>F</td>
<td>W</td>
<td>X</td>
</tr>
<tr>
<td>20</td>
<td>10</td>
<td>76</td>
<td>40</td>
<td>18</td>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>24</td>
<td>12</td>
<td>91</td>
<td>48</td>
<td>22</td>
<td>48</td>
<td>120</td>
</tr>
<tr>
<td>28</td>
<td>14</td>
<td>106</td>
<td>56</td>
<td>25</td>
<td>56</td>
<td>140</td>
</tr>
<tr>
<td>32</td>
<td>16</td>
<td>122</td>
<td>64</td>
<td>29</td>
<td>64</td>
<td>160</td>
</tr>
<tr>
<td>36</td>
<td>18</td>
<td>137</td>
<td>72</td>
<td>32</td>
<td>72</td>
<td>180</td>
</tr>
<tr>
<td>40</td>
<td>20</td>
<td>152</td>
<td>80</td>
<td>36</td>
<td>80</td>
<td>200</td>
</tr>
<tr>
<td>48</td>
<td>24</td>
<td>182</td>
<td>96</td>
<td>43</td>
<td>96</td>
<td>240</td>
</tr>
<tr>
<td>56</td>
<td>28</td>
<td>213</td>
<td>112</td>
<td>50</td>
<td>112</td>
<td>280</td>
</tr>
<tr>
<td>60</td>
<td>30</td>
<td>228</td>
<td>120</td>
<td>54</td>
<td>120</td>
<td>300</td>
</tr>
<tr>
<td>64</td>
<td>32</td>
<td>243</td>
<td>128</td>
<td>58</td>
<td>128</td>
<td>320</td>
</tr>
<tr>
<td>72</td>
<td>36</td>
<td>274</td>
<td>144</td>
<td>65</td>
<td>144</td>
<td>360</td>
</tr>
</tbody>
</table>

All dimensions in inches. Remember to check NPSH
Designing an FL ood controL pumping station

Formed suction intake FSI, steel:

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 optimized 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.

All dimensions in inches. 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 optimized 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.

3 Nominal column diameter
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>10</td>
<td>18</td>
<td>66</td>
<td>21</td>
<td>29</td>
<td>21</td>
<td>26</td>
<td>46</td>
</tr>
<tr>
<td>24</td>
<td>12</td>
<td>22</td>
<td>79</td>
<td>25</td>
<td>35</td>
<td>25</td>
<td>31</td>
<td>55</td>
</tr>
<tr>
<td>28</td>
<td>14</td>
<td>25</td>
<td>92</td>
<td>30</td>
<td>41</td>
<td>30</td>
<td>36</td>
<td>65</td>
</tr>
<tr>
<td>32</td>
<td>16</td>
<td>29</td>
<td>106</td>
<td>34</td>
<td>46</td>
<td>34</td>
<td>41</td>
<td>74</td>
</tr>
<tr>
<td>36</td>
<td>18</td>
<td>32</td>
<td>119</td>
<td>38</td>
<td>52</td>
<td>38</td>
<td>46</td>
<td>83</td>
</tr>
<tr>
<td>40</td>
<td>20</td>
<td>36</td>
<td>132</td>
<td>42</td>
<td>58</td>
<td>42</td>
<td>51</td>
<td>92</td>
</tr>
<tr>
<td>48</td>
<td>24</td>
<td>43</td>
<td>158</td>
<td>51</td>
<td>70</td>
<td>51</td>
<td>61</td>
<td>111</td>
</tr>
<tr>
<td>56</td>
<td>28</td>
<td>50</td>
<td>185</td>
<td>59</td>
<td>81</td>
<td>59</td>
<td>72</td>
<td>129</td>
</tr>
<tr>
<td>60</td>
<td>30</td>
<td>54</td>
<td>198</td>
<td>64</td>
<td>87</td>
<td>64</td>
<td>77</td>
<td>139</td>
</tr>
<tr>
<td>64</td>
<td>32</td>
<td>58</td>
<td>211</td>
<td>68</td>
<td>93</td>
<td>68</td>
<td>82</td>
<td>148</td>
</tr>
<tr>
<td>72</td>
<td>36</td>
<td>65</td>
<td>238</td>
<td>76</td>
<td>104</td>
<td>76</td>
<td>92</td>
<td>166</td>
</tr>
</tbody>
</table>

All dimensions in inches. Remember to check NPSH

Pumping station discharge [% of max flow]

Pumping station discharge duration [% of time]
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
• Optimize 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.

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.

3.5.2 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 pump 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.
3.6 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 Centers during your planning stages.

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

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 Centers are located in Copenhagen and Aurora, IL.

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.

3.5.5 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.

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.

IN THE COLUMN PIPE

IF VELOCITY IS TOO HIGH
↓
PRESSURE LOSS (ENERGY)
IF VELOCITY IS TOO LOW
↓
SEDIMENTATION OR HIGH CONCENTRATION OF SOLIDS

Horizontal support beam

3.5.6 Soft starters

Soft-start eliminates the start-up power surge associated with conventional pumps, imposing minimal demand on inverters and generators.
The previous sections of this design guide provide guidelines on how to design and dimension a flood pumping station. To verify and optimize 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.
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.

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

The average velocity is 0.5 ft/s, so it may cause sedimentation in the sump bottom.

On the plane 1 ft above bottom

The formation of a submerged side wall vortex.

Physical hydraulic model testing.

Wet well, complete with benching, baffle wall, 500 mm interconnecting level equalization pipe and representations of two model pumps.
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 minimized as they can cause air entrainment 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 practice. However, replacing old pumps, difficult working conditions and other unforeseen restraints may in some cases be incompatible with the proper and straightforward design guidelines presented here.

5.2.1 Sub-surface vortices:

- **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 distribution 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 minimize the problems of an asymmetrical approach.

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 center cone or a splitter under the pump, or insertion of fillets and benching between adjoining wall may correct the flow pattern.

---

**Storm Water Pumping Station Design Guide**

1. Swirl
2. Dye core
3. Air core or bubbles

**Vortex – and how to prevent it**

- 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.
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 galvanized 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.
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
- Customized 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.
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 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 analyze 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 center 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 Centers.
Air Core Vortex
A vortex strong enough to form an elongated core of air.

Anti-Flotation Baffle
A 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/flow head, high specific speed pump.

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

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

Backwall Splitter
A device formed or fabricated and attached to the back wall 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 Straightener
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 vapor 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
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

US Army corps of Engineers ETL 110-2-327

Hydraulic institute Standards for centrifugal, rotary, and reciprocating pumps, Hydraulic Institute [Cleveland Ohio, 1983]


Anwar, H.O.
Prevention of Vortices at Intakes
Water Power, Oct. 1968

Patterson, I.S. and Campbell, G.
Pump Intake Design Investigations
Cranfield April 1968, Paper 1
Appendix 1: Head loss calculations

Although the calculations in appendix 1 are from Grundfos’ Sewage Pumping Handbook, the principles and calculations are also applicable 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)
- \(\nu\) = kinematic viscosity (m²/s)

The kinematic viscosity for water is dependent on temperature.

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Viscosity (m²/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0072</td>
</tr>
<tr>
<td>20</td>
<td>0.0056</td>
</tr>
<tr>
<td>40</td>
<td>0.0050</td>
</tr>
<tr>
<td>60</td>
<td>0.0046</td>
</tr>
<tr>
<td>100</td>
<td>0.0042</td>
</tr>
</tbody>
</table>

The equation for pipeline losses can be written:

\[
H_{fp} = \frac{v^2}{2g} \left( \frac{l}{D} \right) \lambda
\]

where

- \(H_{fp}\) = pipeline loss (m)
- \(\lambda\) = 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 \(\lambda\) from the diagram in Figure 54, equation 24 can be solved. Surface roughness values (mm) presented in the following table can be used:

<table>
<thead>
<tr>
<th>Pipe material</th>
<th>(k_{new})</th>
<th>(k_{old})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic</td>
<td>0.01</td>
<td>0.03</td>
</tr>
<tr>
<td>Galvanized steel</td>
<td>0.05</td>
<td>0.10</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>0.05</td>
<td>0.10</td>
</tr>
<tr>
<td>Cast iron</td>
<td>0.10</td>
<td>0.20</td>
</tr>
<tr>
<td>Bituminized cast iron</td>
<td>0.05</td>
<td>0.10</td>
</tr>
<tr>
<td>Aseobon cement</td>
<td>0.0025</td>
<td>0.025</td>
</tr>
<tr>
<td>Concrete</td>
<td>0.3-2.0</td>
<td>0.05</td>
</tr>
</tbody>
</table>
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:

\[ H_{IP} = H_{IP1} \left( \frac{D}{D_1} \right)^{1.3} \]

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

\[ D_e = 1.3 \cdot D \]

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

B. The rising mains have different diameters

\[ D = \left( \frac{D_1^{1.65} + D_2^{1.65}}{2} \right)^{0.5774} \]

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

A. Both rising mains have the same diameter

\[ Q_1 = \frac{Q}{2} \]

B. The rising mains have different diameters

\[ Q_1 = Q - Q_2 \]

\[ Q_2 = Q - Q_1 \]

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.

Moody diagram for establishing the friction factor \( \lambda \). The value of \( \lambda \) is obtained using Reynolds 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:

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

where

- \( H_{Jn} \) = local loss (m)
- \( \zeta \) = 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:

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

where

- \( H_{Jn} \) = local loss (m)
- \( v_1 \) = flow velocity 1 (m/s)
- \( v_2 \) = 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 \( \frac{v^2}{2g} \). 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:

\[ H'_J = H_{Jn} \left( \frac{Q}{Q_1} \right)^2 \]
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
H₂ = Head losses, m

Example
Q = 12 l/s
D = 100 mm
v = 1.55 m/s
ζ = 0
H₂ = 0.6 m

Guide values for head losses in bends, valves, etc.
- Pipe bend, 90°, R/D = 1.6: 0.4
- Discharge loss, 1.0 (close without expansion)
- Swing check valve: 1.2
- Ball check valve: 0.1-1.2
- Gate valve: 0.4

(T-piece)

(Y-piece)
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
- $k$ = Pipe roughness, mm
- $H_u$ = Pipe losses, m/100 m

Example:
$Q = 12$ l/s
$D = 100$ mm
$H_u = 2.8$ m/100 m

<table>
<thead>
<tr>
<th>Pipe material</th>
<th>new pipe</th>
<th>old pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>plastic</td>
<td>0.01</td>
<td>0.25</td>
</tr>
<tr>
<td>drawn steel</td>
<td>0.1</td>
<td>1.0</td>
</tr>
<tr>
<td>welded steel</td>
<td>0.1</td>
<td>1.0</td>
</tr>
<tr>
<td>drawn stainless steel</td>
<td>0.05</td>
<td>0.25</td>
</tr>
<tr>
<td>welded stainless steel</td>
<td>0.1</td>
<td>0.25</td>
</tr>
<tr>
<td>cast iron</td>
<td>0.25</td>
<td>1.0</td>
</tr>
<tr>
<td>galvanized steel</td>
<td>0.15</td>
<td>1.0</td>
</tr>
<tr>
<td>bituminized cast iron</td>
<td>0.12</td>
<td>2.0</td>
</tr>
<tr>
<td>asbestos cement</td>
<td>0.025</td>
<td></td>
</tr>
</tbody>
</table>
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

Diverging flows

<table>
<thead>
<tr>
<th>Qh/Q</th>
<th>α = 90°</th>
<th>α = 45°</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>sh</td>
<td>s</td>
</tr>
<tr>
<td>0.0</td>
<td>0.95</td>
<td>0.04</td>
</tr>
<tr>
<td>0.2</td>
<td>0.88</td>
<td>-0.08</td>
</tr>
<tr>
<td>0.4</td>
<td>0.89</td>
<td>-0.05</td>
</tr>
<tr>
<td>0.6</td>
<td>0.95</td>
<td>0.07</td>
</tr>
<tr>
<td>0.8</td>
<td>1.10</td>
<td>0.21</td>
</tr>
<tr>
<td>1.0</td>
<td>1.28</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Merging flows

<table>
<thead>
<tr>
<th>Qh/Q</th>
<th>α = 90°</th>
<th>α = 45°</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>sh</td>
<td>s</td>
</tr>
<tr>
<td>0.0</td>
<td>-1.00</td>
<td>0.04</td>
</tr>
<tr>
<td>0.2</td>
<td>-0.40</td>
<td>0.17</td>
</tr>
<tr>
<td>0.4</td>
<td>0.08</td>
<td>0.30</td>
</tr>
<tr>
<td>0.6</td>
<td>0.47</td>
<td>0.41</td>
</tr>
<tr>
<td>0.8</td>
<td>0.72</td>
<td>0.51</td>
</tr>
<tr>
<td>1.0</td>
<td>0.91</td>
<td>0.60</td>
</tr>
</tbody>
</table>

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.
Local resistance factors

Bends

<table>
<thead>
<tr>
<th>R/D</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\zeta$</td>
<td>0.36</td>
<td>0.19</td>
<td>0.16</td>
<td>0.15</td>
<td>0.21</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>R/D</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\zeta$</td>
<td>0.27</td>
<td>0.32</td>
<td>0.35</td>
<td>0.39</td>
<td>0.41</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$\alpha$</th>
<th>$\zeta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°</td>
<td>0.07, 0.03, 0.03</td>
</tr>
<tr>
<td>40°</td>
<td>0.13, 0.06, 0.06</td>
</tr>
<tr>
<td>60°</td>
<td>0.20, 0.10, 0.09</td>
</tr>
<tr>
<td>80°</td>
<td>0.27, 0.13, 0.12</td>
</tr>
<tr>
<td>90°</td>
<td>0.32, 0.15, 0.13</td>
</tr>
<tr>
<td>120°</td>
<td>0.39, 0.19, 0.17</td>
</tr>
<tr>
<td>140°</td>
<td>0.46, 0.23, 0.20</td>
</tr>
<tr>
<td>160°</td>
<td>0.52, 0.26, 0.23</td>
</tr>
<tr>
<td>180°</td>
<td>0.60, 0.30, 0.26</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$\alpha$</th>
<th>$\zeta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°</td>
<td>0.03, 0.12, 0.24, 0.54, 0.74</td>
</tr>
<tr>
<td>90°</td>
<td>1.00, 1.86, 2.43, 3.00</td>
</tr>
<tr>
<td>180°</td>
<td>0.60, 0.30, 0.26</td>
</tr>
<tr>
<td>200°</td>
<td>0.46, 0.23, 0.20</td>
</tr>
<tr>
<td>160°</td>
<td>0.52, 0.26, 0.23</td>
</tr>
<tr>
<td>140°</td>
<td>0.46, 0.23, 0.20</td>
</tr>
<tr>
<td>120°</td>
<td>0.39, 0.19, 0.17</td>
</tr>
<tr>
<td>100°</td>
<td>0.32, 0.15, 0.13</td>
</tr>
<tr>
<td>80°</td>
<td>0.27, 0.13, 0.12</td>
</tr>
<tr>
<td>60°</td>
<td>0.20, 0.10, 0.09</td>
</tr>
<tr>
<td>40°</td>
<td>0.13, 0.06, 0.06</td>
</tr>
<tr>
<td>20°</td>
<td>0.07, 0.03, 0.03</td>
</tr>
</tbody>
</table>

$R/D = 1, 1.5, \zeta = 0.4$

$R/D = 1, 1.5, \zeta = 0.7$

$R/D = 90°$

$\alpha$
Expansions and contractions

\[ H_m = \frac{(v_1^2 - v_2^2)}{2g} \]

Friction drag not included

<table>
<thead>
<tr>
<th>( \beta^* )</th>
<th>( k )</th>
<th>( \beta^* )</th>
<th>( k )</th>
<th>( \beta^* )</th>
<th>( k )</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.13</td>
<td>45</td>
<td>0.93</td>
<td>100</td>
<td>1.06</td>
</tr>
<tr>
<td>10</td>
<td>0.17</td>
<td>50</td>
<td>1.05</td>
<td>120</td>
<td>1.05</td>
</tr>
<tr>
<td>15</td>
<td>0.26</td>
<td>60</td>
<td>1.12</td>
<td>140</td>
<td>1.04</td>
</tr>
<tr>
<td>20</td>
<td>0.41</td>
<td>70</td>
<td>1.13</td>
<td>160</td>
<td>1.02</td>
</tr>
<tr>
<td>30</td>
<td>0.71</td>
<td>80</td>
<td>1.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>0.90</td>
<td>90</td>
<td>1.07</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Friction drag not included

\[ H_m = \frac{v_2^2}{2g} \]

\[ A_2/A_1 = 0 \quad 0.1 \quad 0.2 \quad 0.3 \quad 0.4 \]

\[ \zeta_2 = 0.50 \quad 0.46 \quad 0.41 \quad 0.36 \quad 0.30 \]

\[ A_2/A_1 = 0.5 \quad 0.6 \quad 0.7 \quad 0.8 \quad 0.9 \]

\[ \zeta_2 = 0.24 \quad 0.18 \quad 0.12 \quad 0.06 \quad 0.02 \]
\( \xi \)-values depend strongly on shape. Factory values should be used when available.

\( \xi \)-values above are valid for fully open valves. In partly open position, \( \xi \) 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.

- Gate valves without narrowing: \( \xi = 0.1 \ldots 0.3 \)
- Gate valves with narrowing: \( \xi = 0.3 \ldots 1.2 \)
- Ball non-return valves: \( \xi \approx 1.0 \) (fully open)
- Flap non-return valves: \( \xi = 0.5 \ldots 1.0 \) (fully open)
Appendix 2 - Grundfos products

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

Technical data:
• Column diameter: 20 - 72 in
• Full 50 and 60 Hz
• Voltage: 220-6,600 V
• Flow: 1,300 - 185,000 gpm
• Head: Up to 30 ft
• Power: 14 - 1,300 hp

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 harbor 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: 20 - 72 in
• Full 50 and 60 Hz
• Voltage: 220-6,600 V
• Flow: 1,300 - 105,000 gpm
• Head: Up to 160 ft
• Power: 14 - 1,300 hp

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 harbor 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. 40,000 gpm
- Head: max. 380 ft
- Liquid temp.: 32°F to 104°F
- Discharge dia.: DN 80 to DN 800
- Particle size: max. Ø 145.

**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.

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

### SL1/SLV and SE1/SEV
Heavy-duty submersible pumps

**Technical data:**
- Flow rate: max. 4,300 gpm
- Head: max. 230 ft
- Free passage: 50 mm to 160 mm
- pH range: pH 0 to 14
- Discharge dia.: DN 65 to DN 300.

**Features and benefits**
- Service friendly (smart design)
- 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.

**Applications**
- Drainage water and surface water
- Domestic and municipal wastewater
- Industrial wastewater.
Pomona
Portable, self-priming pumps for temporary or permanent installation

Technical data:
- Flow rate: max. 570 gpm
- Head: max. 105 ft
- Liquid temp.: 32°F to 176°F
- 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. 1,300 gpm
- Head: max. 330 ft
- Liquid temp.: 32°F to 104°F.

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. 1,900 gpm
Head: max. 335 ft
Liquid temp.: 32°F to 104°F
Installation depth: max. 85 ft.

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. 23,000 gpm
Head: max. 7 ft
Liquid temp.: 32°F to 104°F

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
Large axial, mixed flow and radial impeller vertical short setting line shaft pumps.

A turbine pump is installed below the pumping water level in the sump. The motor is not installed in the water.

Technical data:
- Flow: Max. 120,000 gpm
- Head: max. 100 ft
- Liquid temp.: max 140°F

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
- Cast iron or fabricated steel discharge head
- Handles pressures up to 200 ft
- Bronze impellers are standard construction
- Dual bowl bearings
- Bronze and rubber seal protect against wear
- Patented "double-seal" in bowls for high efficiency
- Optional materials and wear rings are available

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).
- Pressurized 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: 0.75-350 hp

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 set point 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 113
Input/Output Module

The IO 113 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 113 module. Together with the sensors, the IO 113 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 113 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 33 ft 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 optimization
- 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

The FlushJet is a hydroejector designed to automatically clean tanks used for the temporary storage of stormwater or wastewater so that odor 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/DIN 1.4301 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 customized solution of one or more FlushJets can easily be designed to clean detention, equalization or storm water tanks used for the storage of excess water in order to minimize 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.
Please visit Grundfos.com/flood-control for reference list and case stories as well as films from our many projects around the world.

<table>
<thead>
<tr>
<th>Completion YEAR</th>
<th>Quantity</th>
<th>Motor output (kW)</th>
<th>Model</th>
<th>Job Site</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>2</td>
<td>600</td>
<td>KPL</td>
<td>BMA</td>
<td>Thailand</td>
</tr>
<tr>
<td>2012</td>
<td>2</td>
<td>420</td>
<td>KPL</td>
<td>KSA</td>
<td>Dubai</td>
</tr>
<tr>
<td>2012</td>
<td>1</td>
<td>300</td>
<td>KPL</td>
<td>Myung Byun P/S</td>
<td>Korea</td>
</tr>
<tr>
<td>2012</td>
<td>4</td>
<td>300</td>
<td>KPL</td>
<td>Changqiao</td>
<td>China</td>
</tr>
<tr>
<td>2012</td>
<td>4</td>
<td>260</td>
<td>KPL</td>
<td>Mun San P/S</td>
<td>Korea</td>
</tr>
<tr>
<td>2012</td>
<td>1</td>
<td>210</td>
<td>KWM</td>
<td>Gaechook</td>
<td>Korea</td>
</tr>
<tr>
<td>2012</td>
<td>1</td>
<td>140</td>
<td>KPL</td>
<td>PTIAM</td>
<td>Malaysia</td>
</tr>
<tr>
<td>2012</td>
<td>20</td>
<td>130</td>
<td>KPL</td>
<td>RID</td>
<td>Thailand</td>
</tr>
<tr>
<td>2012</td>
<td>20</td>
<td>130</td>
<td>KPL</td>
<td>RID</td>
<td>Thailand</td>
</tr>
<tr>
<td>2012</td>
<td>1</td>
<td>130</td>
<td>KWM</td>
<td>RID</td>
<td>Philippines</td>
</tr>
<tr>
<td>2012</td>
<td>1</td>
<td>120</td>
<td>KPL</td>
<td>PTIAM</td>
<td>Malaysia</td>
</tr>
<tr>
<td>2012</td>
<td>1</td>
<td>110</td>
<td>KPL</td>
<td>RID</td>
<td>New Zealand</td>
</tr>
<tr>
<td>2012</td>
<td>2</td>
<td>110</td>
<td>KPL</td>
<td>BITEC</td>
<td>Thailand</td>
</tr>
<tr>
<td>2012</td>
<td>1</td>
<td>90</td>
<td>KWM</td>
<td>No Gok P/S</td>
<td>Korea</td>
</tr>
<tr>
<td>2012</td>
<td>1</td>
<td>90</td>
<td>KWM</td>
<td>No Gok P/S</td>
<td>Korea</td>
</tr>
<tr>
<td>2012</td>
<td>2</td>
<td>90</td>
<td>KPL</td>
<td>San Juan</td>
<td>Philippines</td>
</tr>
<tr>
<td>2012</td>
<td>1</td>
<td>75</td>
<td>KPL</td>
<td>Yeon Pung P/S</td>
<td>Korea</td>
</tr>
<tr>
<td>2012</td>
<td>4</td>
<td>75</td>
<td>KPL</td>
<td>Yeon Pung P/S</td>
<td>Korea</td>
</tr>
<tr>
<td>2012</td>
<td>2</td>
<td>75</td>
<td>KPL</td>
<td>Yeon Pung P/S</td>
<td>Korea</td>
</tr>
<tr>
<td>2011</td>
<td>5</td>
<td>75</td>
<td>KPL</td>
<td>BITEC</td>
<td>Thailand</td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>550</td>
<td>KWM</td>
<td>Han An P/S</td>
<td>Korea</td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>550</td>
<td>KPL</td>
<td></td>
<td>India</td>
</tr>
<tr>
<td>2011</td>
<td>5</td>
<td>465</td>
<td>KPL</td>
<td>Bossuit</td>
<td>Belgium</td>
</tr>
<tr>
<td>2011</td>
<td>1</td>
<td>450</td>
<td>KWM</td>
<td>Ham An P/S</td>
<td>Korea</td>
</tr>
<tr>
<td>2011</td>
<td>9</td>
<td>400</td>
<td>KWM</td>
<td>IDOT #27</td>
<td>USA</td>
</tr>
<tr>
<td>2011</td>
<td>1</td>
<td>370</td>
<td>KWM</td>
<td>Gu Ri</td>
<td>Korea</td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>350</td>
<td>KPL</td>
<td>Gu Ri</td>
<td>Korea</td>
</tr>
<tr>
<td>Completion YEAR</td>
<td>Quantity</td>
<td>Motor output (kW)</td>
<td>Model</td>
<td>Job Site</td>
<td>Country</td>
</tr>
<tr>
<td>----------------</td>
<td>----------</td>
<td>-------------------</td>
<td>-------</td>
<td>----------</td>
<td>---------</td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>300</td>
<td>KPL</td>
<td>Myung Ryun P/S</td>
<td>Korea</td>
</tr>
<tr>
<td>2011</td>
<td>5</td>
<td>210</td>
<td>KPL</td>
<td>Moen</td>
<td>Belgium</td>
</tr>
<tr>
<td>2011</td>
<td>4</td>
<td>200</td>
<td>KPL</td>
<td>Omnoi</td>
<td>Thailand</td>
</tr>
<tr>
<td>2011</td>
<td>1</td>
<td>190</td>
<td>KWM</td>
<td>Malaysia</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>185</td>
<td>KWM</td>
<td>Buyeo</td>
<td>Korea</td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>180</td>
<td>KPL</td>
<td>USA</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>6</td>
<td>175</td>
<td>KPL</td>
<td>TJ</td>
<td>China</td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>150</td>
<td>KPL</td>
<td>Pa Ju P/S</td>
<td>Korea</td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>150</td>
<td>KPL</td>
<td>Pa Ju P/S</td>
<td>Korea</td>
</tr>
<tr>
<td>2011</td>
<td>1</td>
<td>130</td>
<td>KWM</td>
<td>Yang San City</td>
<td>Korea</td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>110</td>
<td>KWM</td>
<td>Gyung Ju</td>
<td>Korea</td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>110</td>
<td>KWM</td>
<td>Sok Cho</td>
<td>Korea</td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>110</td>
<td>KWM</td>
<td>Young Ju</td>
<td>Korea</td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>110</td>
<td>KPL</td>
<td>Thailand</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>1</td>
<td>90</td>
<td>KPLX</td>
<td>USA</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>3</td>
<td>90</td>
<td>KWM</td>
<td>Malaysia</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>1</td>
<td>90</td>
<td>KPL</td>
<td>Australia</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>1</td>
<td>90</td>
<td>KPL</td>
<td>Hemaraj</td>
<td>Thailand</td>
</tr>
<tr>
<td>2011</td>
<td>3</td>
<td>90</td>
<td>KPL</td>
<td>Indonesia</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>90</td>
<td>KPL</td>
<td>Pasadena</td>
<td>USA</td>
</tr>
<tr>
<td>2011</td>
<td>4</td>
<td>75</td>
<td>KWM</td>
<td>Busan</td>
<td>Korea</td>
</tr>
<tr>
<td>2011</td>
<td>8</td>
<td>75</td>
<td>KPL</td>
<td>Omnoi</td>
<td>Thailand</td>
</tr>
<tr>
<td>2011</td>
<td>8</td>
<td>75</td>
<td>KPL</td>
<td>IKEA</td>
<td>Thailand</td>
</tr>
<tr>
<td>2011</td>
<td>4</td>
<td>65</td>
<td>KWM</td>
<td>Slovakia</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>65</td>
<td>KPL</td>
<td>Hungary</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>6</td>
<td>65</td>
<td>KPL</td>
<td>KMITL</td>
<td>Thailand</td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>63</td>
<td>KPL</td>
<td>Merwen</td>
<td>USA</td>
</tr>
<tr>
<td>2011</td>
<td>3</td>
<td>55</td>
<td>KWM</td>
<td>Mu Lim P/S</td>
<td>Korea</td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>55</td>
<td>KWM</td>
<td>Russia</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>55</td>
<td>KPL</td>
<td>Italy</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>4</td>
<td>55</td>
<td>KPL</td>
<td>Australia</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>55</td>
<td>KPL</td>
<td>Ratchapeuk</td>
<td>Thailand</td>
</tr>
<tr>
<td>Completion Year</td>
<td>Quantity</td>
<td>Motor Output (KW)</td>
<td>Model</td>
<td>Job Site</td>
<td>Country</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------</td>
<td>-------------------</td>
<td>-------</td>
<td>------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>2009</td>
<td>3</td>
<td>550</td>
<td>KPL</td>
<td>Mumbai</td>
<td>India</td>
</tr>
<tr>
<td>2009</td>
<td>9</td>
<td>300</td>
<td>KPL</td>
<td>Surabaya</td>
<td>Indonesia</td>
</tr>
<tr>
<td>2009</td>
<td>3</td>
<td>130</td>
<td>KPL</td>
<td>Surabaya</td>
<td>Indonesia</td>
</tr>
<tr>
<td>2009</td>
<td>3</td>
<td>90</td>
<td>KPL</td>
<td>Surabaya</td>
<td>Indonesia</td>
</tr>
<tr>
<td>2009</td>
<td>3</td>
<td>55</td>
<td>KWM</td>
<td>Surabaya</td>
<td>Indonesia</td>
</tr>
<tr>
<td>2009</td>
<td>2</td>
<td>55</td>
<td>KPL</td>
<td>Kelantan</td>
<td>Italy</td>
</tr>
<tr>
<td>2009</td>
<td>2</td>
<td>55</td>
<td>KPL</td>
<td>Malaysia</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>8</td>
<td>680</td>
<td>KPL</td>
<td>Gummi P/S</td>
<td>Korea</td>
</tr>
<tr>
<td>2007</td>
<td>3</td>
<td>710</td>
<td>KPL</td>
<td>Pa-Ju P/S</td>
<td>Korea</td>
</tr>
<tr>
<td>2007</td>
<td>4</td>
<td>620</td>
<td>KPL</td>
<td>Yeonchun P/S</td>
<td>Korea</td>
</tr>
<tr>
<td>2007</td>
<td>1</td>
<td>220</td>
<td>KWM</td>
<td>Kudu P/S</td>
<td>Indonesia</td>
</tr>
<tr>
<td>2007</td>
<td>2</td>
<td>110</td>
<td>KPL</td>
<td>Jakarta</td>
<td>Indonesia</td>
</tr>
<tr>
<td>2007</td>
<td>2</td>
<td>75</td>
<td>KPL</td>
<td>Parit Lima &amp; SangJang</td>
<td>Malaysia</td>
</tr>
<tr>
<td>2007</td>
<td>3</td>
<td>55</td>
<td>KPL</td>
<td>Jakarta</td>
<td>Indonesia</td>
</tr>
<tr>
<td>2007</td>
<td>2</td>
<td>55</td>
<td>KPL</td>
<td>Parit Lima &amp; SangJang</td>
<td>Malaysia</td>
</tr>
<tr>
<td>2007</td>
<td>2</td>
<td>45</td>
<td>KPL</td>
<td>Rome</td>
<td>Italy</td>
</tr>
<tr>
<td>2006</td>
<td>1</td>
<td>530</td>
<td>KWM</td>
<td>Tala P/S</td>
<td>India</td>
</tr>
<tr>
<td>2006</td>
<td>6</td>
<td>400</td>
<td>KPL</td>
<td>Songnam P/S</td>
<td>China</td>
</tr>
<tr>
<td>2006</td>
<td>4</td>
<td>350</td>
<td>KPL</td>
<td>Johobaru</td>
<td>Malaysia</td>
</tr>
<tr>
<td>2006</td>
<td>6</td>
<td>310</td>
<td>KPL</td>
<td>Shouyang P/S</td>
<td>China</td>
</tr>
<tr>
<td>2006</td>
<td>4</td>
<td>300</td>
<td>KWM</td>
<td>Drydocks</td>
<td>Dubai</td>
</tr>
<tr>
<td>2006</td>
<td>6</td>
<td>300</td>
<td>KPL</td>
<td>S.Jiangyang P/S</td>
<td>China</td>
</tr>
<tr>
<td>2006</td>
<td>6</td>
<td>260</td>
<td>KPL</td>
<td>Minzhu P/S</td>
<td>China</td>
</tr>
<tr>
<td>2006</td>
<td>3</td>
<td>250</td>
<td>KWM</td>
<td>Chung Yang</td>
<td>Korea</td>
</tr>
<tr>
<td>2006</td>
<td>4</td>
<td>180</td>
<td>KPL</td>
<td>Zhangmuo P/S</td>
<td>China</td>
</tr>
<tr>
<td>2006</td>
<td>1</td>
<td>190</td>
<td>KWM</td>
<td>Jakarta</td>
<td>Indonesia</td>
</tr>
<tr>
<td>2006</td>
<td>1</td>
<td>160</td>
<td>KWM</td>
<td>Chung Yang</td>
<td>Korea</td>
</tr>
<tr>
<td>2006</td>
<td>2</td>
<td>150</td>
<td>KPL</td>
<td>Hannam P/S</td>
<td>Korea</td>
</tr>
<tr>
<td>2006</td>
<td>1</td>
<td>140</td>
<td>KPL</td>
<td>E.N.S.P.M.</td>
<td>Korea</td>
</tr>
<tr>
<td>2006</td>
<td>3</td>
<td>110</td>
<td>KPL</td>
<td>Gu Wal P/S</td>
<td>Korea</td>
</tr>
<tr>
<td>Completion YEAR</td>
<td>Quantity</td>
<td>Motor output (KW)</td>
<td>Model</td>
<td>Job Site</td>
<td>Country</td>
</tr>
<tr>
<td>----------------</td>
<td>----------</td>
<td>-------------------</td>
<td>-------</td>
<td>----------</td>
<td>---------</td>
</tr>
<tr>
<td>2004</td>
<td>2</td>
<td>300</td>
<td>KPL</td>
<td>Jinju City</td>
<td>Korea</td>
</tr>
<tr>
<td>2004</td>
<td>2</td>
<td>300</td>
<td>KPL</td>
<td>Keelung</td>
<td>Taiwan</td>
</tr>
<tr>
<td>2004</td>
<td>4</td>
<td>280</td>
<td>KPL</td>
<td>Nan Ging</td>
<td>China</td>
</tr>
<tr>
<td>2004</td>
<td>1</td>
<td>230</td>
<td>KPL</td>
<td>Incheon City</td>
<td>Korea</td>
</tr>
<tr>
<td>2004</td>
<td>4</td>
<td>220</td>
<td>KPL</td>
<td>Tainan</td>
<td>Taiwan</td>
</tr>
<tr>
<td>2004</td>
<td>1</td>
<td>190</td>
<td>KWM</td>
<td>Surabaya</td>
<td>Indonesia</td>
</tr>
<tr>
<td>2004</td>
<td>2</td>
<td>150</td>
<td>KPL</td>
<td>Surabaya</td>
<td>Indonesia</td>
</tr>
<tr>
<td>2004</td>
<td>2</td>
<td>130</td>
<td>KPL</td>
<td>Pohang Industry</td>
<td>Korea</td>
</tr>
<tr>
<td>2004</td>
<td>3</td>
<td>130</td>
<td>KPL</td>
<td>Surabaya</td>
<td>Indonesia</td>
</tr>
<tr>
<td>2004</td>
<td>3</td>
<td>110</td>
<td>KPL</td>
<td>Hamaxin</td>
<td>Taiwan</td>
</tr>
<tr>
<td>2004</td>
<td>1</td>
<td>100</td>
<td>KPL</td>
<td>Yungduk City</td>
<td>Korea</td>
</tr>
<tr>
<td>2004</td>
<td>2</td>
<td>90</td>
<td>KWM</td>
<td>Tianlin Power plant</td>
<td>China</td>
</tr>
<tr>
<td>2004</td>
<td>3</td>
<td>90</td>
<td>KPL</td>
<td>Xinxin</td>
<td>Taiwan</td>
</tr>
<tr>
<td>2004</td>
<td>3</td>
<td>75</td>
<td>KWM</td>
<td>Dongdaemun, Seoul City</td>
<td>Korea</td>
</tr>
<tr>
<td>2004</td>
<td>1</td>
<td>75</td>
<td>KWM</td>
<td>Gong, Seoul City</td>
<td>Korea</td>
</tr>
<tr>
<td>2004</td>
<td>6</td>
<td>75</td>
<td>KWM</td>
<td>Illinois, D.O.T.</td>
<td>USA</td>
</tr>
<tr>
<td>2003</td>
<td>5</td>
<td>115</td>
<td>KPL</td>
<td>Misung Machine</td>
<td>Korea</td>
</tr>
<tr>
<td>2003</td>
<td>4</td>
<td>300</td>
<td>KWM</td>
<td>SAPPS, Kolkata</td>
<td>India</td>
</tr>
<tr>
<td>2003</td>
<td>1</td>
<td>230</td>
<td>KPL</td>
<td>Incheon City</td>
<td>Korea</td>
</tr>
<tr>
<td>2003</td>
<td>1</td>
<td>230</td>
<td>KPL</td>
<td>Incheon City</td>
<td>Korea</td>
</tr>
<tr>
<td>2003</td>
<td>2</td>
<td>220</td>
<td>KPL</td>
<td>Da-Shir P/S</td>
<td>Taiwan</td>
</tr>
<tr>
<td>2003</td>
<td>3</td>
<td>190</td>
<td>KPL</td>
<td>Bangkok Metropolitan</td>
<td>Thailand</td>
</tr>
<tr>
<td>2003</td>
<td>1</td>
<td>175</td>
<td>KWM</td>
<td>Osaka</td>
<td>Japan</td>
</tr>
<tr>
<td>2003</td>
<td>1</td>
<td>150</td>
<td>KPL</td>
<td>Texas, D.O.T.</td>
<td>USA</td>
</tr>
<tr>
<td>2003</td>
<td>18</td>
<td>130</td>
<td>KPL</td>
<td>Surabaya</td>
<td>Indonesia</td>
</tr>
<tr>
<td>2003</td>
<td>2</td>
<td>110</td>
<td>KPL</td>
<td>Surabaya</td>
<td>Indonesia</td>
</tr>
<tr>
<td>2003</td>
<td>1</td>
<td>100</td>
<td>KPL</td>
<td>Yungduk City</td>
<td>Korea</td>
</tr>
<tr>
<td>2003</td>
<td>2</td>
<td>90</td>
<td>KPL</td>
<td>Yungduk City</td>
<td>Korea</td>
</tr>
<tr>
<td>2003</td>
<td>3</td>
<td>75</td>
<td>KPL</td>
<td>Surabaya</td>
<td>Indonesia</td>
</tr>
<tr>
<td>2002</td>
<td>1</td>
<td>355</td>
<td>KPL</td>
<td>ChunCheoun City</td>
<td>Korea</td>
</tr>
<tr>
<td>2002</td>
<td>1</td>
<td>350</td>
<td>KPL</td>
<td>Daesung Pump</td>
<td>Korea</td>
</tr>
<tr>
<td>2002</td>
<td>2</td>
<td>350</td>
<td>KPL</td>
<td>Daesung Pump</td>
<td>Korea</td>
</tr>
</tbody>
</table>

**Completion YEAR** | **Quantity** | **Motor output (KW)** | **Model** | **Job Site** | **Country** |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>6</td>
<td>335</td>
<td>KPL</td>
<td>Pohang City</td>
<td>Korea</td>
</tr>
<tr>
<td>2002</td>
<td>2</td>
<td>210</td>
<td>KPL</td>
<td>Yesan County</td>
<td>Korea</td>
</tr>
<tr>
<td>2002</td>
<td>6</td>
<td>190</td>
<td>KPL</td>
<td>Bangkok Metropolitan</td>
<td>Thailand</td>
</tr>
<tr>
<td>2002</td>
<td>1</td>
<td>130</td>
<td>KPL</td>
<td>Daesung Pump</td>
<td>Korea</td>
</tr>
<tr>
<td>2002</td>
<td>3</td>
<td>125</td>
<td>KPL</td>
<td>Surabaya</td>
<td>Indonesia</td>
</tr>
<tr>
<td>2002</td>
<td>3</td>
<td>110</td>
<td>KPL</td>
<td>Hanyoung</td>
<td>Korea</td>
</tr>
<tr>
<td>2002</td>
<td>2</td>
<td>90</td>
<td>KPL</td>
<td>Surabaya</td>
<td>Indonesia</td>
</tr>
<tr>
<td>2002</td>
<td>1</td>
<td>75</td>
<td>KPL</td>
<td>Hanyoung</td>
<td>Korea</td>
</tr>
<tr>
<td>2002</td>
<td>1</td>
<td>75</td>
<td>KWMA</td>
<td>Environmental Corp.</td>
<td>Korea</td>
</tr>
<tr>
<td>2002</td>
<td>3</td>
<td>75</td>
<td>KWMA</td>
<td>Iksan City</td>
<td>Korea</td>
</tr>
<tr>
<td>2001</td>
<td>3</td>
<td>400</td>
<td>KPL</td>
<td>Kaohsiung County</td>
<td>Taiwan</td>
</tr>
<tr>
<td>2001</td>
<td>1</td>
<td>230</td>
<td>KPL</td>
<td>Inchon City</td>
<td>Korea</td>
</tr>
<tr>
<td>2001</td>
<td>6</td>
<td>200</td>
<td>KPL</td>
<td>Daen Construction</td>
<td>Korea</td>
</tr>
<tr>
<td>2001</td>
<td>5</td>
<td>190</td>
<td>KPL</td>
<td>Keumjun</td>
<td>Korea</td>
</tr>
<tr>
<td>2001</td>
<td>1</td>
<td>160</td>
<td>KWMA</td>
<td>Kumduk Pump</td>
<td>Korea</td>
</tr>
<tr>
<td>2001</td>
<td>5</td>
<td>150</td>
<td>KPL</td>
<td>Keumjun</td>
<td>Korea</td>
</tr>
<tr>
<td>2001</td>
<td>1</td>
<td>150</td>
<td>KPL</td>
<td>Texas, D.O.T.</td>
<td>USA</td>
</tr>
<tr>
<td>2001</td>
<td>2</td>
<td>130</td>
<td>KWMA</td>
<td>SungHeung</td>
<td>Korea</td>
</tr>
<tr>
<td>2000</td>
<td>5</td>
<td>550</td>
<td>KPL</td>
<td>Keumchon P.S</td>
<td>Korea</td>
</tr>
<tr>
<td>2000</td>
<td>5</td>
<td>450</td>
<td>KPL</td>
<td>Bonglichun P.S</td>
<td>Korea</td>
</tr>
<tr>
<td>2000</td>
<td>4</td>
<td>300</td>
<td>KWMA</td>
<td>Bangkok Metropolitan</td>
<td>Thailand</td>
</tr>
<tr>
<td>2000</td>
<td>3</td>
<td>200</td>
<td>KWMA</td>
<td>Chulwon County</td>
<td>Korea</td>
</tr>
<tr>
<td>2000</td>
<td>6</td>
<td>190</td>
<td>KWMA</td>
<td>Bonglichun P.S</td>
<td>Korea</td>
</tr>
<tr>
<td>2000</td>
<td>4</td>
<td>190</td>
<td>KWMA</td>
<td>Sunyu P.S</td>
<td>Korea</td>
</tr>
<tr>
<td>2000</td>
<td>4</td>
<td>190</td>
<td>KWMA</td>
<td>Paju City</td>
<td>Korea</td>
</tr>
<tr>
<td>2000</td>
<td>5</td>
<td>167</td>
<td>KPL</td>
<td>Munnak WWTP</td>
<td>Korea</td>
</tr>
<tr>
<td>2000</td>
<td>3</td>
<td>160</td>
<td>KPL</td>
<td>Penang P.S</td>
<td>Malaysia</td>
</tr>
<tr>
<td>2000</td>
<td>1</td>
<td>150</td>
<td>KWMA</td>
<td>Orim Construction</td>
<td>Korea</td>
</tr>
<tr>
<td>2000</td>
<td>3</td>
<td>135</td>
<td>KPL</td>
<td>Keumjun</td>
<td>Korea</td>
</tr>
<tr>
<td>2000</td>
<td>5</td>
<td>130</td>
<td>KPL</td>
<td>Bangkok Metropolitan</td>
<td>Thailand</td>
</tr>
<tr>
<td>2000</td>
<td>2</td>
<td>110</td>
<td>KPL</td>
<td>Surabaya</td>
<td>Indonesia</td>
</tr>
<tr>
<td>2000</td>
<td>2</td>
<td>90</td>
<td>KPL</td>
<td>Bangkok Metropolitan</td>
<td>Thailand</td>
</tr>
<tr>
<td>Completion Year</td>
<td>Quantity</td>
<td>Motor output (KW)</td>
<td>Model</td>
<td>Job Site</td>
<td>Country</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------</td>
<td>-------------------</td>
<td>-------</td>
<td>----------</td>
<td>---------</td>
</tr>
<tr>
<td>2000</td>
<td>3</td>
<td>75</td>
<td>KPL</td>
<td>Surabaya</td>
<td>Indonesia</td>
</tr>
<tr>
<td>2000</td>
<td>2</td>
<td>75</td>
<td>KPL</td>
<td>Surabaya</td>
<td>Indonesia</td>
</tr>
<tr>
<td>2000</td>
<td>1</td>
<td>75</td>
<td>KPL</td>
<td>Penang P/S</td>
<td>Malaysia</td>
</tr>
<tr>
<td>2000</td>
<td>7</td>
<td>55</td>
<td>KPL</td>
<td>Surabaya</td>
<td>Indonesia</td>
</tr>
<tr>
<td>1999</td>
<td>3</td>
<td>260</td>
<td>KPL</td>
<td>Yeoncheon County</td>
<td>Korea</td>
</tr>
<tr>
<td>1999</td>
<td>3</td>
<td>260</td>
<td>KWM</td>
<td>Gumi City</td>
<td>Korea</td>
</tr>
<tr>
<td>1999</td>
<td>6</td>
<td>240</td>
<td>KPL</td>
<td>Songlongchun P.S</td>
<td>Korea</td>
</tr>
<tr>
<td>1999</td>
<td>2</td>
<td>185</td>
<td>KWM</td>
<td>Gumi City</td>
<td>Korea</td>
</tr>
<tr>
<td>1999</td>
<td>10</td>
<td>175</td>
<td>KPL</td>
<td>Bangkok Metropolitan</td>
<td>Thailand</td>
</tr>
<tr>
<td>1999</td>
<td>2</td>
<td>130</td>
<td>KPL</td>
<td>Yeoncheon County</td>
<td>Korea</td>
</tr>
<tr>
<td>1999</td>
<td>20</td>
<td>130</td>
<td>KPL</td>
<td>Bangkok Metropolitan</td>
<td>Thailand</td>
</tr>
<tr>
<td>1999</td>
<td>5</td>
<td>130</td>
<td>KPL</td>
<td>Bangkok Metropolitan</td>
<td>Thailand</td>
</tr>
<tr>
<td>1999</td>
<td>6</td>
<td>110</td>
<td>KPL</td>
<td>Yeoncheon County</td>
<td>Korea</td>
</tr>
<tr>
<td>1999</td>
<td>1</td>
<td>90</td>
<td>KPL</td>
<td>Yeoncheon County</td>
<td>Korea</td>
</tr>
<tr>
<td>1998</td>
<td>4</td>
<td>560</td>
<td>KPL</td>
<td>Haesung Ebara</td>
<td>Korea</td>
</tr>
<tr>
<td>1998</td>
<td>6</td>
<td>520</td>
<td>KWM</td>
<td>Bangkok Metropolitan</td>
<td>Thailand</td>
</tr>
<tr>
<td>1998</td>
<td>4</td>
<td>400</td>
<td>KPL</td>
<td>Wonhong Ind</td>
<td>Korea</td>
</tr>
<tr>
<td>1998</td>
<td>4</td>
<td>375</td>
<td>KPL</td>
<td>Bangkok Metropolitan</td>
<td>Thailand</td>
</tr>
<tr>
<td>1998</td>
<td>1</td>
<td>250</td>
<td>KPL</td>
<td>Daejeong Ind</td>
<td>Korea</td>
</tr>
<tr>
<td>1998</td>
<td>4</td>
<td>200</td>
<td>KPL</td>
<td>Bangkok Metropolitan</td>
<td>Thailand</td>
</tr>
<tr>
<td>1998</td>
<td>2</td>
<td>175</td>
<td>KPL</td>
<td>Bangkok Metropolitan</td>
<td>Thailand</td>
</tr>
<tr>
<td>1998</td>
<td>3</td>
<td>160</td>
<td>KWM</td>
<td>Daewoo</td>
<td>Korea</td>
</tr>
<tr>
<td>1998</td>
<td>2</td>
<td>150</td>
<td>KPL</td>
<td>Pohang City</td>
<td>Korea</td>
</tr>
<tr>
<td>1998</td>
<td>4</td>
<td>150</td>
<td>KPL</td>
<td>Ulsan City</td>
<td>Korea</td>
</tr>
<tr>
<td>1998</td>
<td>2</td>
<td>110</td>
<td>KPL</td>
<td>Bangkok Metropolitan</td>
<td>Thailand</td>
</tr>
<tr>
<td>1997</td>
<td>5</td>
<td>220</td>
<td>KPL</td>
<td>Nonsan City</td>
<td>Korea</td>
</tr>
<tr>
<td>1997</td>
<td>3</td>
<td>175</td>
<td>KWM</td>
<td>Keumjuang P.M</td>
<td>Korea</td>
</tr>
<tr>
<td>1997</td>
<td>2</td>
<td>110</td>
<td>KWM</td>
<td>Gapyeong Gun</td>
<td>Korea</td>
</tr>
<tr>
<td>1997</td>
<td>2</td>
<td>90</td>
<td>KPL</td>
<td>Yeongdeok Gun</td>
<td>Korea</td>
</tr>
<tr>
<td>1997</td>
<td>2</td>
<td>75</td>
<td>KWM</td>
<td>Gapyeong Gun</td>
<td>Korea</td>
</tr>
<tr>
<td>1997</td>
<td>2</td>
<td>63</td>
<td>KPL</td>
<td>Keumjuang P.M</td>
<td>Korea</td>
</tr>
<tr>
<td>1996</td>
<td>2</td>
<td>600</td>
<td>KPL</td>
<td>Chungwon</td>
<td>Korea</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Completion Year</th>
<th>Quantity</th>
<th>Motor output (KW)</th>
<th>Model</th>
<th>Job Site</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>6</td>
<td>210</td>
<td>KPL</td>
<td>Chungwon</td>
<td>Korea</td>
</tr>
<tr>
<td>1996</td>
<td>1</td>
<td>200</td>
<td>KWM</td>
<td>Dongdaemun</td>
<td>Korea</td>
</tr>
<tr>
<td>1996</td>
<td>1</td>
<td>150</td>
<td>KPL</td>
<td>Dongjin</td>
<td>Korea</td>
</tr>
<tr>
<td>1996</td>
<td>3</td>
<td>110</td>
<td>KPL</td>
<td>Youngpoong</td>
<td>Korea</td>
</tr>
<tr>
<td>1995</td>
<td>3</td>
<td>500</td>
<td>KPL</td>
<td>Busan City</td>
<td>Korea</td>
</tr>
<tr>
<td>1995</td>
<td>1</td>
<td>190</td>
<td>KPL</td>
<td>Busan City</td>
<td>Korea</td>
</tr>
<tr>
<td>1994</td>
<td>1</td>
<td>300</td>
<td>KWM</td>
<td>Dongdaemun</td>
<td>Korea</td>
</tr>
<tr>
<td>1993</td>
<td>2</td>
<td>375</td>
<td>KPL</td>
<td>Pohang City</td>
<td>Korea</td>
</tr>
<tr>
<td>1993</td>
<td>2</td>
<td>190</td>
<td>KWM</td>
<td>KAMAES</td>
<td>Korea</td>
</tr>
<tr>
<td>1993</td>
<td>1</td>
<td>190</td>
<td>KPL</td>
<td>Yeongdeungpo ward office</td>
<td>Korea</td>
</tr>
<tr>
<td>1993</td>
<td>3</td>
<td>115</td>
<td>KWM</td>
<td>Mokpo City</td>
<td>Korea</td>
</tr>
<tr>
<td>1993</td>
<td>2</td>
<td>132</td>
<td>KPL</td>
<td>Sangwoo</td>
<td>Korea</td>
</tr>
<tr>
<td>1992</td>
<td>5</td>
<td>355</td>
<td>KPL</td>
<td>Chuncheon City</td>
<td>Korea</td>
</tr>
<tr>
<td>1992</td>
<td>2</td>
<td>300</td>
<td>KWM</td>
<td>Busan City</td>
<td>Korea</td>
</tr>
<tr>
<td>1992</td>
<td>2</td>
<td>236</td>
<td>KPL</td>
<td>Chuncheon City</td>
<td>Korea</td>
</tr>
<tr>
<td>1992</td>
<td>3</td>
<td>190</td>
<td>KPL</td>
<td>Yeongdeungpo ward office</td>
<td>Korea</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Completion Year</th>
<th>Quantity</th>
<th>Motor output (KW)</th>
<th>Model</th>
<th>Job Site</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>6</td>
<td>210</td>
<td>KPL</td>
<td>Chungwon</td>
<td>Korea</td>
</tr>
<tr>
<td>1996</td>
<td>1</td>
<td>200</td>
<td>KWM</td>
<td>Dongdaemun</td>
<td>Korea</td>
</tr>
<tr>
<td>1996</td>
<td>1</td>
<td>150</td>
<td>KPL</td>
<td>Dongjin</td>
<td>Korea</td>
</tr>
<tr>
<td>1996</td>
<td>3</td>
<td>110</td>
<td>KPL</td>
<td>Youngpoong</td>
<td>Korea</td>
</tr>
<tr>
<td>1995</td>
<td>3</td>
<td>500</td>
<td>KPL</td>
<td>Busan City</td>
<td>Korea</td>
</tr>
<tr>
<td>1995</td>
<td>1</td>
<td>190</td>
<td>KPL</td>
<td>Busan City</td>
<td>Korea</td>
</tr>
<tr>
<td>1994</td>
<td>1</td>
<td>300</td>
<td>KWM</td>
<td>Dongdaemun</td>
<td>Korea</td>
</tr>
<tr>
<td>1993</td>
<td>2</td>
<td>375</td>
<td>KPL</td>
<td>Pohang City</td>
<td>Korea</td>
</tr>
<tr>
<td>1993</td>
<td>2</td>
<td>190</td>
<td>KWM</td>
<td>KAMAES</td>
<td>Korea</td>
</tr>
<tr>
<td>1993</td>
<td>1</td>
<td>190</td>
<td>KPL</td>
<td>Yeongdeungpo ward office</td>
<td>Korea</td>
</tr>
<tr>
<td>1993</td>
<td>3</td>
<td>115</td>
<td>KWM</td>
<td>Mokpo City</td>
<td>Korea</td>
</tr>
<tr>
<td>1993</td>
<td>2</td>
<td>132</td>
<td>KPL</td>
<td>Sangwoo</td>
<td>Korea</td>
</tr>
<tr>
<td>1992</td>
<td>5</td>
<td>355</td>
<td>KPL</td>
<td>Chuncheon City</td>
<td>Korea</td>
</tr>
<tr>
<td>1992</td>
<td>2</td>
<td>300</td>
<td>KWM</td>
<td>Busan City</td>
<td>Korea</td>
</tr>
<tr>
<td>1992</td>
<td>2</td>
<td>236</td>
<td>KPL</td>
<td>Chuncheon City</td>
<td>Korea</td>
</tr>
<tr>
<td>1992</td>
<td>3</td>
<td>190</td>
<td>KPL</td>
<td>Yeongdeungpo ward office</td>
<td>Korea</td>
</tr>
</tbody>
</table>
Appendix 4: Lloyd certificate