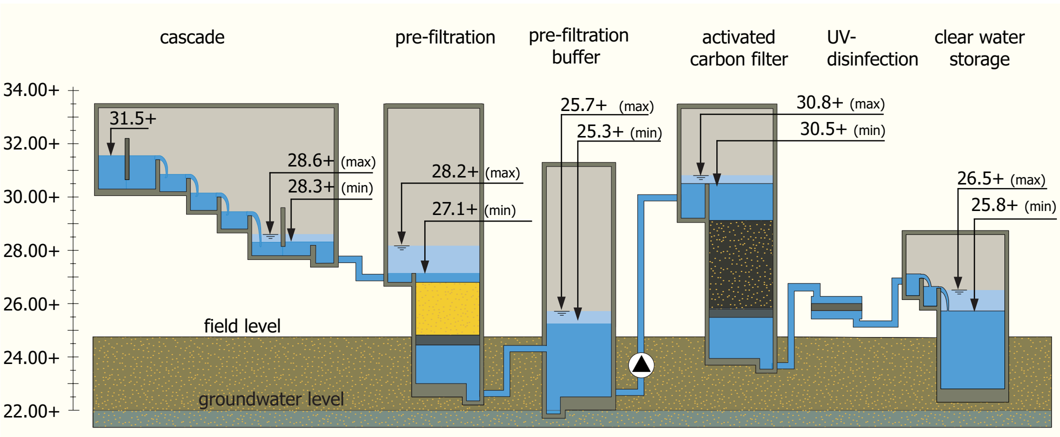
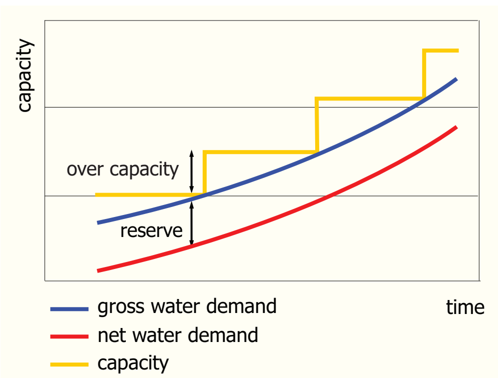
WATER COMPANIES

Planning and design





Framework

This module focuses on the planning and design aspects for constructing of the infrastructure for the public water supply. The main issue in this respect is the design of a production plant.

Introduction

This module has the following contents:

Study goals

After having studied this module, you will be able to:
- identify the different planning processes
- identify the different parts of the design process
- describe, explain and draw up the most important documents needed for the design

1. Introduction

Extensive preparations are necessary in order to build drinking water production plants. The government plays an important role in this planning process, as public health is one of the main issues concerned. However, water companies are responsible for the construction and operation of the infrastructure.

Usually, it takes many years from the time the first idea for expanding water production facilities comes up, until the completion and start-up of the new plant. During this period, a highly diverse development process is carried out, involving many different specialties. Among these are:

- mathematics (probability theory)
- treatment technology (physics, chemistry, microbiology)
- environmental science
- geohydrology (groundwater)
- hydrology (surface water)
- hydraulics (fluid mechanics)
- structural engineering (concrete, steel)
- architecture
- mechanical engineering
- electrical engineering
- process control engineering (instrumentation)
- law (property rights, user rights, contracts)
- economics (project finance, payments)

As a consequence of so many specialities being involved, expansion of the infrastructure for drinking water production requires a multi-disciplinary approach. To have a successful project, organization is of critical importance. The complexity of the project is further increased by the fact that the existing public water supply must not be obstructed or compromised during construction of the new infrastructure.

This module will address design aspects for (re)construction of drinking water infrastructure. First, the planning process for public water supply will be presented, ranging from national long-term plans to internal management plans for drinking water companies. It will continue by focusing on the infrastructure's life cycle, paying special attention to the design aspects of drinking water production facilities. Further on, the laws, permits and standards applying mainly to drinking water supply will be described. Finally, the different parts of the design process will be examined in more detail.

2. Planning process for public water supply

2.1 Process scheme

The planning process for a public water supply is embedded in the general spatial planning process. The primary structure of and the hierarchy in this process in the Netherlands are summarized in Table 1. Of course, the planning process needs to comply with the legal framework and show mutual consistency. As a legal framework, the Water Supply Act is especially important.

Within the Water Supply Act, a Committee for drinking water supply has been formed, which has to supervise all aspects concerning the public drinking water supply. This Committee is mainly advisory, but can operate as a mediator as well.

Table 1 - Hierarchical planning process for the public drinking water supply in the Netherlands

Planning level	Name	Timeframe (years)	Organization
National policy plan	Policy plan for drinking and industrial water supply	20 – 30	Ministry VROM
National section plan	Ten-year plan	5 – 10	VEWIN
Provincial plan	Provincial policy plans	5 – 10	Province
	Provincial management plans	5 – 10	Province
Regional plan	Regional plans	5 – 10	Province
Municipal plan	Land use plans	5 – 10	Municipality
Company plan	Water supply plan	10 – 30	Company
	Multi-year investment plan	5 – 10	Company
	Business plan	5	Company

2.2 Policy plan for drinking and industrial water supply

The process of formulating the policy plan for drinking and industrial water supply is recorded in the Water Supply Act (Chapter 4 - Preparation and accomplishment of water supply works - first part).

The national policy plan for drinking and industrial water supply is a sector plan on a national level, and includes background information and preferences for the desired long-term strategic development.

The policy plan makes a long-term estimate of future water needs, typically for a period of approximately 30 years. A description is made of the available water resources from both ground- and surface water, including the advantages and disadvantages concerning public health, spatial planning, the environment, the economy, and so on. Policy choices and priority settings are made with respect to the above aspects. Finally, the plan indicates what efforts will be undertaken to safeguard the drinking and industrial water supply over the relevant 30-year period, with regard to the available water resources. Together with some policy statements, this plan forms a national spatial planning key decision.

The policy plan has a dual effect. First, it indicates land claims for spatial planning and water management. These claims should be considered when appropriating land and water on national, provincial and municipal levels. Second, the policy plan guides the water supply sector. Only in urgent situations are the water companies allowed to deviate from this plan.

The procedure for preparing a policy plan is regulated, in large part, by the Spatial Planning Act. This procedure is comparable to the process of adopting a new regulation:

- preparation of a draft plan in interdepartmental consultation
- publication of the draft plan; inviting response
- authorization by the Second and First Chambers of the Dutch Parliament

2.3 Association of Dutch Water Companies' ten-year plan

The procedure for formulating the Association of Dutch Water Companies' ten-year plan is recorded in the Water Supply Act. The plan is referred to by law as a "medium-term plan" to be drawn up by a "representative association of water companies" (Chapter 4 - Preparation and construction of water works - second part).

The ten-year plan is a medium-term plan that is prepared by the Association of Dutch Water Companies (VEWIN). When the Water Supply Act was first adopted, it was unusual to have such a national plan formulated by the involved companies and regulated in this way by law. Nowadays, the "retreating government' policy has caused this kind of regulation to be used more often.

All projects for the abstraction, storage and transportation of water that the water companies intend to undertake in the coming ten years should be recorded in this plan. Studies and research programs which will be executed over the same period should also be recorded. In this way, all water companies are closely involved in the integral planning process, because the companies themselves are expected to take the lead in proposing and preparing new projects.

The proposed ten-year plan is presented to the minister for Housing, Spatial Planning and the Environment for authorization. In deciding whether the plan will be approved, the minister needs to consider the policy plan.

The period from the 1970s to the 1990s saw the heyday of the ten-year plan, when over 100 (mainly municipal) water companies existed. Today, most water companies operate on the provincial, or even super-provincial, level. This causes the chief aim of the ten-year plan - fine tuning the production capacity of the different water companies - to decline. Thus, the importance of the ten-year plan has decreased and part of its goal is now absorbed by policy plans of either the provinces or the individual companies.

2.4 Provincial planning

As the formulation of the ten-year plan is discussed with the provinces the provincial policy can be adapted to the plan's eventual consequences.
Space for projects mentioned in the ten-year plan can be reserved in good time.

Significant provincial plans are:
- provincial groundwater management
- provincial policy plan for protection of groundwater for drinking water supply
- provincial water management plan
- provincial environmental policy plan
- provincial environmental decrees
- regional plans of the respective provinces

There is little consistency in the different ways of naming plans by the provinces, caused, in part, by the titles being adapted to the changing legal framework.

2.5 Municipal planning

All construction plans should ultimately be included in the municipal land-use plans.
In these plans specific parcels can be designated for public water supply.
The following items will be registered for the chosen parcel:
- the kind of construction allowed (reservoirs, treatment and pumping plants, workshops, company housing, etc.)
- the boundaries indicated for the buildings
- the building height allowed for the construction

A permit for (re)construction of any building is only allowed to be issued by the municipal government if the building scheme is in compliance with the land-use plan. Therefore, these activities should be coordinated in advance, even when the draft schemes for construction are not fully known.

2.6 Company planning

Of course, (re)construction plans are included in the water companies' own planning process as well. Important partial plans are:
- water supply plan
- multi-year investment plan
- business plan

Water supply plan

The water supply plan indicates the ways in which present and future water plants will meet water needs over the next 10 - 30 years.
Sometimes, regional supply plans are formulated separately, especially when a transportation infrastructure is expected to hinder supply over regional boundaries.

Multi-year investment plan

The multi-year investment plan consists of all planned investments for the next 5 - 10 years.
In addition, this plan is used for predicting future water use rates.

Water companies' business plans

Within the framework of the revision of the Water Supply Act, a proposal to have Business plans for water companies drawn up by the water companies themselves is included. These plans should supplement or replace the VEWIN ten-year plan. Every four years such an investment plan, which is coordinated with the provinces, should be made and approved by the Ministry of Environment, Planning and Housing.
This plan will provide a clear and complete overview of the investments needed for expansion or replacement to improve or maintain the quality and reliability of the water supply.

3. Design activities in the infrastructure's life cycle

3.1 Overview of the infrastructure's life cycle

The hydrologic cycle is a well-known concept for any water company. A similar concept is that of the materials cycle and is important in designing infrastructural works (Figure 1).
During the cycle, the construction itself will generally pass through the following phases:
- planning and design
- construction

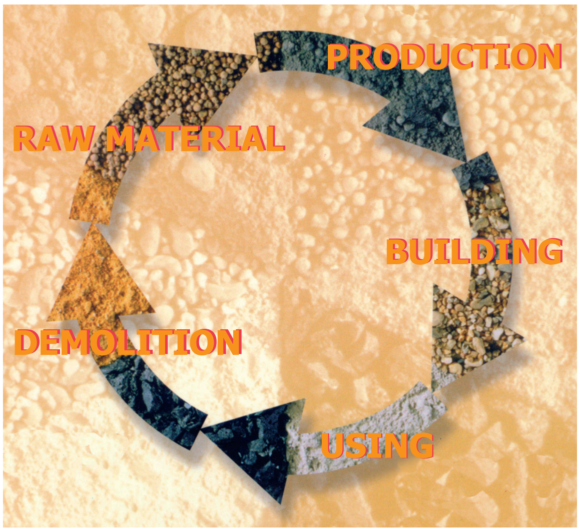


Figure 1 - The recycling of materials alongside the life cycle of buildings

- operation and use
- demolition

In practice, different sub-phases can be discerned throughout this process.

Between the different phases, no definite boundaries exist. By choosing a different way of constructing (e.g., turnkey), a different clustering will develop. However, the same elements will be present in any construction's life cycle.

Usually, the initial phase will be part of the normal business of a water company and, of course, this holds for the operation and use phase as well.
During the construction and demolition phases, most attention is paid to activities which are not part of the typical business of the water company.
Because the construction phase is of a temporary nature, having a limited and well-defined time process, the building sub-phase is extremely well suited for working with a separate project organization. This organization, then, will consist of some specialists who, in their turn, will conduct a team of designers, contractors, subcontractors, etc.

Water companies' production plants feature design and use phases that are totally different from the construction phase.
The construction of any water production plant is much like the construction of any other civil work, like buildings or bridges, but the plant itself is more like a large-scale chemical industrial plant.

Table 2 - Life cycle of the infrastructural projects for the drinking water supply

Phase	Sub-phase	Typical activity
Initiative	Identification	Orientation Consideration of options Pilot plant research
	Definition	Definition of project Sketch design Building plan
Construction	Design contract	Preliminary design Final design Detailed design
	Contract	Contract documents
	Building	Management supervision Building process Ground work Main structure Process units Finishing elements Testing Delivery/take-over
Operation and use	Start up	Start-up Optimization Measurement guarantee
	Operation	Operation Adaptation Renewal of parts
Demolition		Taking out of operation Installation removal

The main part of the investment costs is relegated to construction work (e.g., reservoirs, sand filters). However, most attention is paid during design, construction, delivery, start-up and operation, to the process, including the operation and control systems.
For drinking water plants, it is a requirement that the water supply may not be obstructed, neither during construction nor during the transition from the old to the new plant.
In the following sections, each phase in the infrastructural life cycle (Table 2) will be elaborated upon separately. Aspects not directly relevant to the construction of drinking water plants will be addressed superficially. These aspects can be found in general literature on construction.

3.2 Identification

A construction project for public water supply can be initiated by different motivations. Because this project is meant to solve one or more problems, these problems need to be examined first.
Typical problems for a water supply company are:

Figure 2 - Solutions can not always be realized

- insufficient capacity due to growing demand
- decrease of production capacity due to a different source policy (i.e., reduction in groundwater abstraction)
- considerations from business economics: scaling up of plants
- technical obsolescence of current installations
- new requirements regarding the treatment process (more stringent quality levels or changing raw water quality)

All existing water supply companies have been, or will be, confronted with one of these problems. Therefore, initiating construction projects is practically part of a water company's regular business.

Preliminary studies

Within the water supply plan and the multi-year investment plan, possible solutions are drawn up and provisional decisions are made. This will be done based on feasibility studies which compare several alternatives. Technological research will lead to a general direction for the desired treatment process. Prior to the construction process, the following questions need to be answered:

- what, where, and what capacity needs to be constructed?
- when should it be completed?
- what needs to be achieved?
- what are the estimated costs?

These questions are answered in several preliminary studies, like:

- feasibility studies (technological, technical, financial, economic, environmental impact)
- location studies (possibility of land acquisition)
- literature studies
- project comparisons by site visits
- specialist research (hydraulics, (soil) mechanics, ergonomics, material science, control engineering, physics, chemistry, environmental science, social aspects, etc.)
- system design studies (comparison of different treatment methods)

Data gathering

During these preliminary studies, data which will be useful during the further process of designing and constructing will be collected. Among these are:

- data on existing plants (raw water source, process flow diagram, hydraulic scheme, drawings, operating experiences)
- data on the surrounding area (drawings, descriptions, measurements, photographs) concerning foundations, soil conditions, groundwater levels, wires, pipes, roads, working areas, property rights, obligation, utility company connections, etc.)
- data concerning necessary permits (provincial, municipal, water boards, spatial planning legislation, utility companies, public services, etc.)

3.3 Definition

The final part of the identification phase is the decision to start a new construction project. To be able to begin such a project, a few documents need to be drawn up during the definition phase:

- requirements program
- draft design
- building scheme

These documents are often formulated consecutively, but need to have good mutual coherence. This will make them suitable as basic documents for collecting employees' viewpoints and for supporting management's decisions.
Finally, these documents will, together with possible adaptations, be used for external communications as well (e.g., for permits, to consumers, etc.).

It is not wise however, to draw up the definition phase documents as contract documents. The legal wording in such documents does not lend itself to a public description of wishes, side purposes, considerations, and the like.

Requirements program
The term "requirements program" is broadly used and has many different meanings, varying from a precize contract document to a general wish list. It is also applied to the collection of documents in the construction phase.
A requirements program is, preferably, limited to the purpose and outlines of the construction project. This program considers the following aspects:
- motivation for the project
- summary of preliminary studies
- purpose of the project
- wishes and side purposes
- future developments after construction

Based on the requirements program, a draft design can be formulated.

Sketch design
In the sketch design, general options are considered, and the option finally chosen will be sketched in its technical, as well as in its spatial, outline. A sketch design can consist of the collection of relevant preliminary studies and reviews, as well as a more in-depth elaboration of the design represented by:
- treatment scheme (i.e., block diagram)
- rough hydraulic line scheme
- rough terrain arrangement
- phasing of construction
- cost estimation

A sketch design gives a good indication of the dimensions of the construction project. In it, not only is the future construction phase included, but parts planned for a later phase and terrain arrangements for future expansions are represented as well. This design is important for informing all parties involved in the project's next phases.
The building scheme can be formulated on the basis of the sketch design.

Building scheme
The building scheme is the general project plan, covering all aspects of the construction phase. It contains the full project definition and consists of:
- requirements program
- sketch design
- time schedule for design, contracting and construction
- design of the project organization (task setting between different parties involved in future studies and construction)
- estimation of investment costs (total project costs)

The building scheme is also important for internal decision making by the water company itself, including such considerations as the project mandate for organizational, technical, contractual and financial aspects.

Form of contract
During the definition phase, the project will be drawn up so that it is possible to setup the construction project (including the necessary contract documents) to be executed by a form of contract combining both design and construction, possibly even operation. Such a working method is useful if the principal does not want to bother himself with the construction process. In situations where the principal himself will be responsible for the operation of the plant after construction, such a hands-off approach is quite ineffective.
Combining the complexity of a water production plant with the great freedom during the design phase, it is difficult to formulate efficient and effective contracts. Plant operation has even more impact on product quality than the design does,

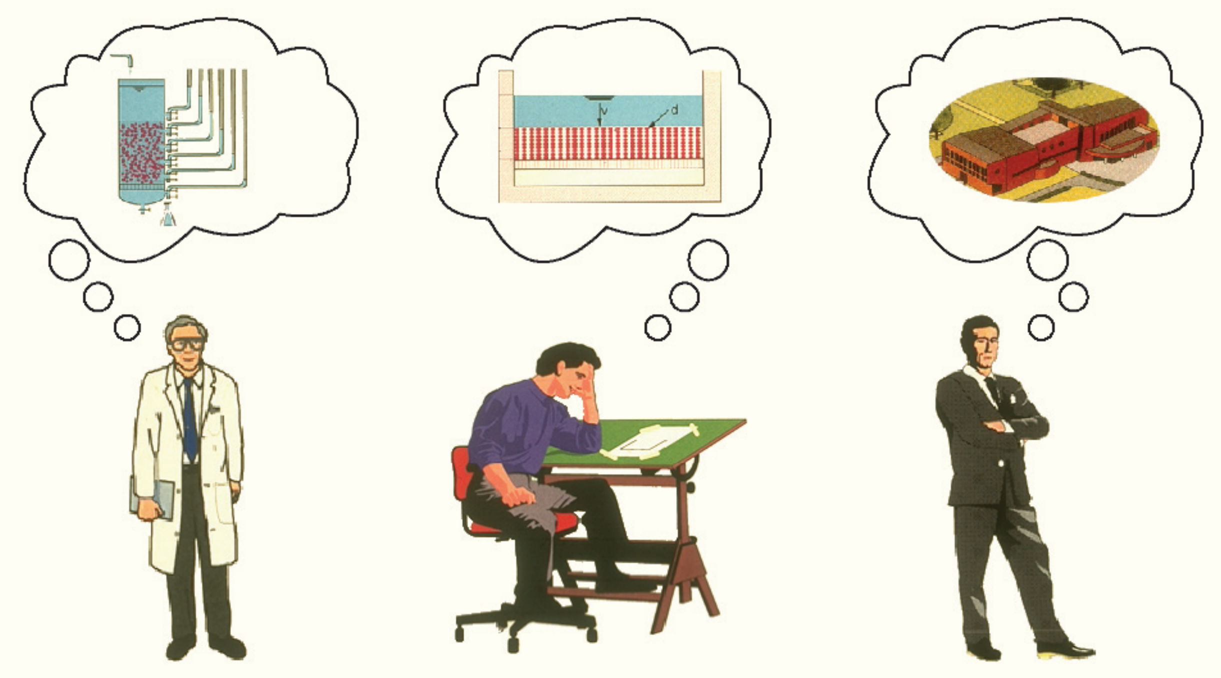


Figure 3 - A rapid sand filter as seen by a researcher, a designer and the director of the water supply company

especially when the source water has a variable quality.

Outsourcing a combination of design, construction and operation activities might be able to correct this. However, this will make it impossible to balance costs and product quality. Instead, this will lead to exhaustive discussions on causes, effects and cost sharing, instead of solving the problem. In view of the social importance of a drinking water supply, this situation is highly undesirable.

However, outside of the Netherlands, contracts that combine design, construction and even operation are widely used. This option is chosen due to limitations within the water company itself because of:

- insufficient knowledge to operate the system
- insufficient possibilities for financing new plants
- insufficient management

Thanks to increases in scale due to the merging of different companies, Dutch water companies are less affected by these issues. This very scaling up of companies was actually initiated because of the increased complexity of providing a public water supply. Complexity is mainly caused by increasing distances between the source and consumers, expanding treatment processes, increasing scale of new constructions, etc.

3.4 Design

Designing a water construction plant is a creative process, influenced by several factors, which all having a different importance and typically subject to personal preferences. These differences cause people to conceive of different results. Thus, the design will need to be negotiated. The final design will, of course, be a compromise between the parties involved (e.g., managers, economists, ecologists, PR-officers, designers, builders, etc.).
During the design process, it is important that the motivation for selecting the chosen solution be made clear to third parties as well. The large number of parties involved necessitates an open planning process. In this way, different parties will have timely insight into the progress and development of the design and its associated effects on their own roles. A phased procedure, including a characteristic coarse-to-fine approach, therefore, is necessary.

At the end of every design phase, a complete image of the construction should be presented.

Figure 4 - Harderbroek production plant (Flevoland)

This will make clear not only the progress in that specific design phase, but also the way in which the design might have been modified from prior design phases. Often, besides the sketch design phase, one can discern three other design phases:

- preliminary design
- final design
- detailed design

Because it is a creative process, designing is not an easily recorded activity. Thus, it is quite difficult to define in terms of contracting to the external designer offering the lowest price. Besides, the value of an intermediate, or even of a final, result is only quantifiable during or after construction, which means this will be quite some time after the design phase. In the past, water companies attempting inexpensive design projects saw that the end-product was more in line with its price and less with its desired or necessary quality.

Changing the design

The coarse-to-fine approach is inspired by the need for changeability in the design. Passing through the construction process from identification to start-up, the project proceeds within smaller and smaller boundaries. This is expressed in:

- more precise estimations of costs
- more expensive design changes
- less freedom to change plans

In Table 3 some characteristic phases in the construction process have been quantified. The given values are indicative for a drinking water production plant.

Table 3 - Sketch of the construction process, upon completion of the different phases

Phase	Accuracy of costs	Changeability of design	Change in costs
Identification	± 50%	-	-
Sketch design	± 30%	100%	1%
Preliminary design	± 25%	40%	5%
Final design	± 15%	10%	10%
Detailed design	± 5%	2%	25%
Building	± 1%	-	100%

Design documents

During the design process, a number of documents are prepared. It is desirable that these documents remain up to date, because one would want them to be reliable images of the completed construction during later phases (not only during construction, but during actual operation as well). Figure 5 shows a diagram of the information flow during the construction's life cycle. It should be noted that most of the information related to the various stages of the design is recorded in the design documents.

Preliminary design

The preliminary design is intended to give a rough layout of the plant elements, including their mutual coherence (i.e., location and size of buildings) and a description of any large mechanical or electronic devices needed by the plant during operation.
Also during this phase, the different construction forms for the desired process will be considered,

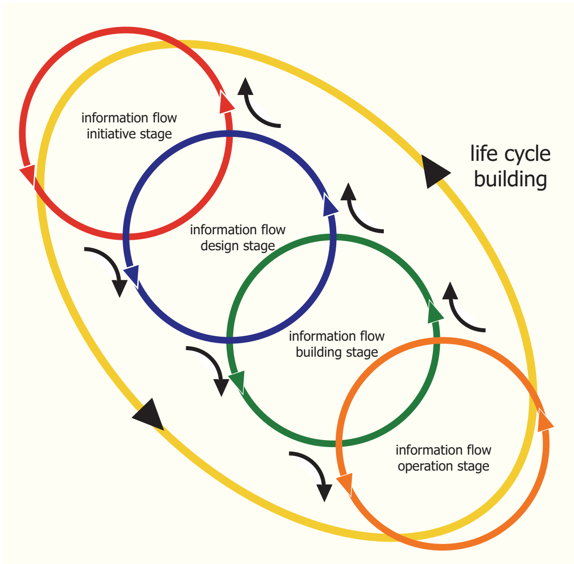


Figure 5 - Design documents provide information for the building and operation phases

possibly including a detailed preliminary design of the options to be considered. A consideration of costs, operation, flexibility, robustness, etc. makes these details necessary.

Activities for the preliminary design include:
- processing of responses to the sketch design
- discussing the design with other partners, government agencies, suppliers, third parties
- formulating process descriptions and considering alternatives
- formulating the necessary technical design drawings for the different operating conditions (minimal, maximal and normal capacity) among which are:
  - process flow diagram (PFD) (including rough balance sheets of water, energy and chemicals)
  - hydraulic line scheme
  - rough design of buildings (necessary space, building height)
- calculating rough dimensions of buildings and determining their sizes
- formulating construction drawings (floor plans, sections, views)
- specifying main components of (civil) structure (foundation, materials, architecture, spatial coding)
- specifying main components of mechanical installations (capacity, number, type, material)
- specifying main components of electrical installations, instruments and control systems
- formulating rough estimates of:
  - construction costs
  - operation costs
  - construction time
- handing out documents for approval of the results of the preliminary design

Final design

The final design follows directly from the preliminary design. This design is more detailed and contains construction drawings and the calculations of those parts which were considered “black boxes” during earlier phases. Examples of these former “unknowns” are those components not immediately involved in the treatment process, like heating, air-conditioning, pressurized air facilities, control installations, workshops, etc. Characteristic for this phase is the check to make sure everything will fit in, not only after, but during construction as well (i.e., space for transport and assembling).
Activities for the final design consist of the following elements:
- processing responses to the preliminary design
- discussing the design with other partners, government agencies, suppliers, third partners
- calculating final capacity and dimensions
- elaborating preliminary designs into final construction drawings
- formulating:
  - process flow diagrams (PFD) for mainstream and secondary flows (chemicals, energy, sludge treatment, backwash water treatment)
  - hydraulic line scheme
  - piping and instrument diagrams (P&ID)
  - control schemes based on an automatization master plan
- deciding on necessary space for auxillary facilities
- preparing requisitions for technical details and prices of necessary installations
- preparing requisitions for necessary permits including completing necessary documents
- discussing financial topics and contracts
- discussing the method of contracting
- estimating investment costs and completion time
- handing out documents for approval of the final design

Detailed design

The detailed design is chiefly aimed at the construction part of the project. For the concrete structure, this refers to reinforcement calculations and form drawings, as well as to the several finishing elements (façades, window frames, partition walls, roofing, etc.).
The mechanical part of the installation is elaborated upon with respect to the pipes (support constructions, division of pipeline parts, detailed design of vessels and appurtenances).
The electrical installation deals with cable calculations and control board design, for example.

The control system is concerned with the design of control and computer programs, and the like.

The detailed design of the structure is sometimes developed by the contractor himself.
It is important to remember that even during the detailed design phase, choices need to be made that will have a major impact on costs and quality. Therefore, it is necessary for the principal to agree with the considerations made and to be able to determine afterwards whether the construction, as it was delivered, was built as it was negotiated.

3.5 Contract

In almost every project, the actual building is done by contractors and suppliers.
This makes it important, then, that the principal be provided with the expected construction and goods of the required quality, at the agreed upon price, and at the pre-set time. Therefore, offers need to be requested that can serve as future contract documents, and later checked to determine whether the delivered items agrees with the negotiations and what the consequences will be for diverging from those plans.

Commonly, contracts are agreed upon with many bidders. This is because most bidders only can deliver within a very specific range or because they cannot guarantee quality for the entire project.
This is important, because a drinking water production plant is a factory with several specific parts, in a hygienic, quality-controlled environment.
Besides, for a water company managing the installations themselves, it is important to have direct knowledge of the products, for reasons of service, follow-up care, reparations, etc.

Though a great variety of contracts exist, both in type and in range, the following steps can always be expected:
- formulating contract documents (specifications)
- requesting bids
- granting bids

Due to the large number and variety of contracts and to the necessity of monitoring all forms of progress, a separate department is charged with contract writing.
A contract is influenced by a wide variety of statutory regulations and judicial standards.
For the construction of drinking water facilities, the following should apply:
- 93/38/EEG for supplies, works and services in the utilities sectors
- regulations for the relationship between contractor and engineering firm
- conditions for the legal relationship between client and architect
- uniform procurement regulations
- general conditions for construction

In practice, several forms of contracts (turnkey, design directed building, etc.) and several forms of tendering (public, by invitation, pre-selected, with price request, etc.) are used.
Because of the special nature of water companies (construction by a third party; operation by the company itself; special requirements regarding quality), not all of those forms are suitable.
More information on those forms can be found in the extensive literature on this issue.

Specifications

The specifications consist of a detailed description and drawings of the plant. The goal is to give as accurate a picture as possible of the various parts of the plant.
The specifications should explain the different parts so clearly that contractors and subcontractors can hand in their commercial and competitive offers on a technologically equal base. The more detailed the specifications are, the better and more carefully prepared the offers can be.

Thus, the specifications have the following functions:
- it is the chief source of information for describing the work to be conducted, so an accurate price can be set
- it is one of the instruments for steering, controlling and supervising the building process
- it is part of the contract, together with a description of tasks, rights and obligations of both parties

In the practice of designing, specifications are often used to further describe the design. However, it is advisable to keep the contract documents strictly separated from the design documents. The former are only relevant during construction and start-up, while the latter are important during the lifetime of the installation (if they are kept up to date).
The separation of documents is easily accomplished when using standardized specifications. For the construction of a production plant with its necessary above-ground facilities, the standard specifications for civil and utility buildings are typically used. For the construction of transport and distribution piping, similar specifications are used.

Project organization

Several project formats can be used for the construction of drinking water production plants. The most important are:

- assignment to one single main contractor
- assignment to multiple contractors (with purchase by contractors)
- assignment to multiple contractors with majority purchase by principal

When assigning the project to a single contracting company, the coordination of the construction needs to be done by the contractor who directs the subcontractors.
Because of the division of the building costs, this main contractor is, in almost every case, a civil contractor. For the building of a drinking water plant this method is less suitable, because most disputes between the water company and the contractor concern the mechanical and electrical parts of the plant. The main contractor is, in this case, the contracting party, but he is not competent in those other fields.

When assigning work to multiple contractors a direct relationship between the water company and the specific contractor must be maintained.
Wtih this organization it is possible for the water company to purchase the most important and most expensive parts directly from the manufacturer (e.g., pumps, ozone generators, emergency aggregates, valves, activated carbon, etc.) and require the contractor to take responsibility for the assembly of those. This will create an even more direct relationship between the water company and subcontractors, which will benefit the price-to-quality relationship, as well as support with the normal operation. When assigning to multiple contractors, it is possible to have a better phased design process as well. This implies constructing the civil buildings first, after which the installation parts are assembled. Of course, this requires a sufficiently complete design at the start of construction. It is necessary that installation parts not only fit in, but that there is enough space for assembly, as well.

Construction by multiple parties

Whatever project organization will be used to complete a production plant, it will always involve more than one party. All those parties need information and they need to provide information.
For mutual information interchange, a central project database is a desirable tool (Figure 6). Some of the information in this database (detailed designs, specifications, maintenance schemes) is also necessary during normal operation, making it necessary to keep the information available after the construction process is finished.

Directive for the utility sector

In assigning construction work and services, water companies are committed to the European Directive for the Utility sector (93/98/EEC).

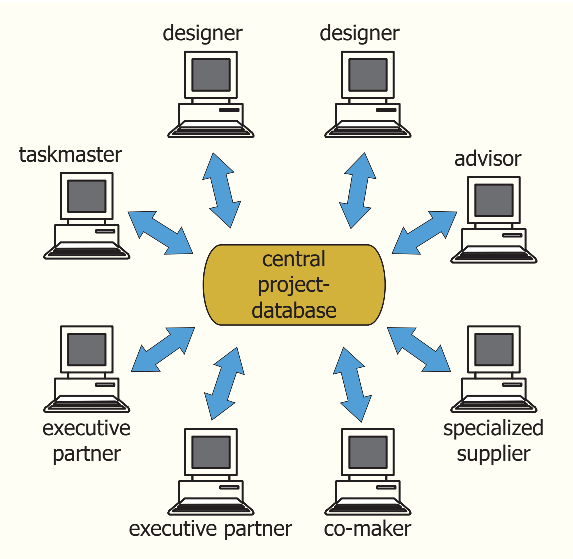


Figure 6 - Parties involved in the construction of a plant

This directive describes the manner in which contracts need to be assigned. A facility or administrative contract can consist of a preliminary study, a preliminary design or the final design. A work contract includes the construction of a plant. The criterion determining whether a project needs to be assigned by this European method is the size of the project.

For a facility or administrative project, the criterion is €400,000 per fiscal year and/or the full construction period. For a construction project contract, the limiting value is €5,000,000 for the total set of assignments for the completion of the work.
An assignment by the European rules implies that a fully open procedure needs to be followed, from advertising to selection, leaving everyone free to apply. Selection needs to proceed according to well-defined and objective criteria.

3.6 Construction

After the project has been assigned, construction begins. Only seldom is a structure built on a location where no disturbance of the present production takes place (Figure 7).
Because of the hygienic nature of drinking water supply, special measures to prevent contamination of the operation's production process need to be taken.

It is always necessary to work clean during the construction. A dirty building place will contaminate new parts of the plant as well. At the start-up, such contamination can be quite troublesome, making it difficult to attain the required microbiological quality of the drinking water being produced.

The main tasks for the water company during construction are:
- direction of the construction process

Figure 7 - The building area is 3-6 times larger than the building

- supervision of the construction process
- conduction of guarantee measurements and takeover

Directing

The direction on behalf of the principal consists of the following tasks:

- attending building meeting
- instructing (daily) supervisors
- supervising the building place daily, as well as the construction of smaller parts
- formulating plans and attending to, detail supervising and coordination
- controlling progress
- controlling costs
- evaluating the amount of additional or less work needed
- ordering work for the reimbursables
- advising regarding the payment terms
- executing inspections and examinations of the installations
- creating a book of measurements and calibrations

Supervision

Supervision includes a daily check on the building's construction progress. Supervision functions as the primary adjustment tool between contractor and principal. Contractual decisions will, however, not be made by the supervisor but by the principal.

Delivery and takeover

Delivery and takeover includes the verification of the completeness and correct operation of the installation. Delivery and takeover activities include:

- assisting start-up
- examining the work and verifying requested guarantees
- registering the maintenance activities
- creating or verifying the operation procedures
- starting up the process, sampling and testing
- instructing the operating personnel
- paying off the constructing sum, reimbursables, levelling costs, extra or less work, reductions, bonuses, etc.
- drawing up revision schemes
- checking third party's revision schemes

3.7 Start-up

At takeover, the water company begins handling the plant's operation. This includes the start-up of the production process.

Only after it has been proved that the plant truly produces reliable drinking water, can the water be supplied to the distribution network.

During this introductory phase, the operators need to become familiar with the installation.

At delivery, often a maintenance and warranty term (e.g., one year) between the principal and the contractor is agreed upon. The purpose is to locate possible flaws which might actually occur during normal operation. The contractor is obliged to repair the flaws or to replace the specific component.

Activities for maintenance and warranty include:

- examining the requested project warranties
- inspecting the work at the end of the maintenance term in order to check whether the contractor has successfully completed his job
- supervising reparations of flaws and failures during the warranty period
- advising on future maintenance
- advising on the final balance sheet of the work

3.8 Operation

After the start-up, the new plant will be included in the normal operation of the water company. During the production period it is not uncommon to replace whole installation components, due to technological obsolescence. Examples include the replacement of the electrical and control installations after 10 to 20 years of operation. Such intended replacements are of the same nature as a new construction project.

The main mechanical parts are seldom replaced. Rather, a whole new plant will be constructed.

3.9 Demolition

When a plant neither meets the specified requirements anymore nor can be modified to do so in

Figure 8 - Demolition has the same characteristics as a construction project

an economically feasible way, the plant will be demolished (Figure 8).

4. Laws, permits and standards

4.1 Laws and permits

Building a production plant for drinking water supply is bound to normal legal obligations. Many of those regulations are carried out by permit procedures. Those require the intended activity to be specified, including the way it will comply with the relevant legislation. After the competent authority has approved the application, the legal requirement will have been fulfilled.

Typical permits for normal construction work are:

- tree cutting permit (making the area construction ready)
- building permit (for construction)
- environmental permit (for operation)
- draining permit (for discharge of drain water)
- abstraction permit for groundwater

The specific backgrounds of these laws and permits will not be dealt with here. If interested, one should read the extensive literature on this subject.
The specific statutory aspects of and permits for drinking water facilities have partly been described above. Additional information is dealt within the chapters on water quality, groundwater, surface water, and distribution.

For building a drinking water production plant, many permits may be significant. For example, for a new surface water project including a reservoir and soil aquifer recharge, 75 permits need to be granted. The procedures for obtaining those permits vary from long procedures via the Council of State to a simple written response to an application for a permit.

Permit procedures create a complex load on the design process. Because procedures take a long time, these permits often set the pace for the design process. Besides, these procedures require many external parties to be involved in the design process, and they all need to be informed of the background of the design for each specific permit.
Time-consuming permit applications include, for example, the Environmental Impact Assessment (EIA) permits, which are necessary in cases where more than 3 million m^3 of groundwater are abstracted, where a large reservoir is constructed, or where long and large distribution pipes are constructed.
Even simple permits can require very long processing time when a challenge to the permit is made.

The number of permits required gives the permit planning phase quite an important role in the design process. Because of this, at the start of the design phase, a complete list of the necessary permits should be formulated. One can supervise the permit process by way of a timetable, which enables supervisors to obtain a reliable impression of the progress of the procedures.

4.2 Standards

Many permit procedures require the design to comply with specific standards. These standards make up a rather complex system of technical directives and obligations.

Even when the permit does not necessitate it, testing the design against the standards is desirable in almost any case. On the one hand, this is because standards define several quality levels for the construction and, on the other hand, the standards create a more uniform design process. This will improve the quality of the design and the efficiency of the design process.
Standards are important in regulating responsibility for the design. They also play an important role in fostering good communication between the different parties involved in a construction project, as standards define the meaning of specific concepts as well.

General standards

There exist several systems of standards, which are valid for different specialties.
Within the Netherlands, the national standards are managed by the Netherlands Normalization Institute and published as NEN-standards.
European standards are managed by the CEN and published as EN-standards. Global standards are defined by the International Organization for Standardization (ISO-standards), an organization encompassing over 146 national standardization institutes. The Netherlands translates some of those ISO-standards in order to publish them as NEN-standards.
Both the CEN and the ISO revalue many national standards to European or worldwide standards as well. Important are the German Industrial Standards (Deutsche Industrie Normen (DIN)), which, taken together, form a thorough system of standards.
Besides standards, the organizations define practical directives as well. These are elaborations and applications of certain standards for specific specialties.
In designing a drinking water production plant, for example, the “Directives for the application and drawing of process flow diagrams’ (NPR 2196) is important. This directive has been replaced by the ISO/NEN 10628:2001 “Flow diagrams for process plants - General rules’ standard.

Figure 9 - The ISO standards become even more important once incorporated into national standardization

Also the publications on labor conditions, specifically the labor policy rules, are important for the design of drinking water production plants. These policy rules are especially aimed at the safety of operating personnel.

For international projects the British Standards, the standards of the American National Standards Institute (ANSI-standards) and the standards of the American Society for Testing and Materials (ASTM-standards) can apply.

Standards for drinking water supply

There are some standards specifically related to drinking water supply. They are not always included in the systems of standards described above. Generally, they supplement those standards.

For the Dutch drinking water supply, NEN-standard 1006 (General prescriptions for drinking water installations, AVWI 2002) is important. These prescriptions include requirements for mainly indoor installations, but it should be clear that the requirements for the production of drinking water must also abide by this standard. In addition, the Association of Dutch Water Companies (VEWIN) publishes the so-called VEWIN sheets. Table 4 gives an overview of these sheets insofar as they are concerned with the design of production plants.

In the Netherlands, the directives and recommendations of the following institutions are significant:

Table 4 - VEWIN sheets relevant to drinking water production plants

Sheet	Description
2.3	Execution of pressure test
2.4	Flushing and disinfection of drinking water installations
3.3	Construction of drinking water installations; isolation and drain possibilities
3.4	Construction of drinking water installations; pipes in buildings
3.8	Security of appliances
4.1	Reservoirs to feed drinking water installations
4.2	Storage tanks and break pressure tanks; not intended for drinking water
4.3	Installations to increase the pressure
4.5	Installation for firefighting

- Ministry of Housing, Spatial Planning and the Environment (VROM)
- Association of Dutch Water Companies (VEWIN)
- Kiwa

In other countries similar directives of government or branch associations apply. The following institutions are highly respected worldwide:
- American Water Works Association (AWWA)
- German Technical and Scientific Association for Gas and Water (DVGW).

Some of the directives that apply to the design of drinking water production plants will be investigated in more detail in the following subsections.

Ministry of Housing, Spatial Planning and the Environment (VROM) protection plan
Required specifications can also be part of statutory regulations. For example, the "Directive for the protection plan of water companies' (VROM March 1991) does state several technical design requirements for the protection of drinking water production plants during war or in case of sabotage. The protection plans, which need to be formulated by the water companies themselves, are supervised by the VROM inspector.
A protection plan describes all relevant procedures, measures and technical facilities, as well as the design of the protection organization; and, it specifies responsibilities.

In case the public drinking water supply is no longer available, it is necessary to shift to the use of an emergency water supply.

A distinction is made between technical requirements and operational matters. Technical requirements are prescribed for the necessary level of protection against:
- emission of dangerous materials
- shock waves caused by an explosion
- sabotage

Operational matters are important for the rooms housing the plant's vital functions during unusual circumstances and include:
- connections
- electricity, including emergency supplies
- operations and residence rooms
- storerooms
- kitchen facilities, sanitary facilities, dormitories

In the technical field, some concrete examples are described so that a protection level as high as possible against external influences can be attained. Many of these measures are desirable so as to guarantee a stable operation under normal circumstances, such as:
- segmenting the infrastructure (treatment trains)
- linking transport and distribution networks to adjacent production areas
- making temporary connections with hygienic, reliable, non-public water facilities, like those at factories, large institutions, etc.
- purifying the air for aeration, backwash air for the filters, air for clean water reservoirs, etc.
- providing for the storage of chemicals, disinfectants, fuel, lubricants, etc. for at least a ten-days' supply, and guaranteeing a continuous 50% filling of storage tanks
- having a mobile or permanent disinfection installation available for disinfecting outgoing water
- installing burglary protection and alarm systems
- providing for the manual operation of process components, without using control systems
- putting lightning rods on the plants

- providing an independent energy supply by means of a ready-to-use emergency power aggregate, diesel-driven pumps, etc.
- having spare parts available
- having a crisis coordination center available
- creating emergency exits in relevant buildings
- creating special, fragment-free and bomb-resistant shelters

Association of Dutch Water Companies' policy recommendations

Until recently, the Association of Dutch Water Companies (VEWIN) published the "VEWIN recommendations for technical and hygienic policy." These recommendations are normative, because the public water companies associated in the VEWIN declare publicly what they deem are the best technical and hygienic policies.

Regarding quality the Association of Dutch Water Companies' recommendations have stricter guidelines than the Water Supply Act. The reasons for this are indicated in the publication.
Effective pressure needs to amount to at least 100 kPa at all taps, until a height of ten meters above ground level. This corresponds to a minimum pressure of 200 kPa above ground level everywhere. In the main network the pressure needs to be at least 250 kPa.
Uncomfortable pressure fluctuations should be prevented (Art. b.1.1). This might require the use of surge tanks or speed controlled pumps.

The water company needs to be organized in such a way as to be able to supply the necessary water in the supply area during the "design day." The "design day" means that the water demand has a 0.1 probability to be exceeded during a year (this means it should be exceeded less than once every ten years) (Art. c.1.2).

Figure 10 - The VEWIN coordinates the Dutch directives on drinking water

Provisions need to be made so that it is possible for the company to satisfy the requirement of an undisturbed water supply in case of a failure (Art. c.1.3). This is only attainable if there is a sufficient number of connections between adjacent supply areas, or if there are measures taken in order to continue production in case of failure somewhere in the system.
There should be a way to decrease or stop the direct input of surface water without unfavorable effects to the drinking water supply (Art. c.2.2). This means, in practice, that any surface water plant is required to have a protected reservoir containing storage for at least a few days, in order to let poisonous waves flow past. Also underground storage of treated water is possible.

To check on changes in the hydrological and qualitative aspects of the water, sufficient permanent measurement facilities need to be present (Art. c.5.5). Therefore, every well needs to be supplied with sampling taps, and every abstraction area needs to have sufficient monitoring wells.
It is preferable that the treatment system be tested in a pilot plant on a semi-technical scale (Art. c.6.1).

When aeration/degasification is applied, the necessary air should be filtered. Installations for aeration/degasification need to be accessible for inspections and cleaning (Art. c.6.2). It should be possible to disinfect all water to be supplied (Art. c.6.5). A connection for emergency chlorination needs to be available.

When the failure of a main distribution pipe is unacceptable for the drinking water supply in a certain area, the water company needs to make provisions for reducing the effect to acceptable levels.
The criteria are:
- the duration of the failure
- the spare supply capacity in the area
- the size of the respective area (Art. c.9.2)

In the main distribution network there should be as few pipes as possible having only a minimum flow through them (Art. c.9.3). Measurements need to be taken in order to prevent disadvantageous water hammer effects. Disadvantageous effects include:

- low pressure causing contaminated groundwater to be sucked into the network
- low pressure causing cavities, which cause pressure waves and possible pipe failure

When preparing sufficient, ready-to-use spare energy installations, pressure in the distribution network should not fall in case of an energy failure (Art. c.8.1).

Clean water tanks and accompanying installations need to be built, arranged and maintained in such a way as to prevent the contamination of drinking water. Entrances, overflow pipes and ventilation openings especially need to be attended to (Art. c.7.1). Clean water tanks need to be above groundwater level (Art. c.7.2). The tanks should not have a common wall with any buildings for non-hygienic water (Art. c.7.3).

Kiwa quality declaration

Kiwa was originally founded as an examination institute for drinking water appliances. It examined the different products to be used in the public water supply.

It has expanded to an institute not only examining products, but also standardizing water practices and certifying quality. Basically, it has grown into a research institute for the joint Dutch water companies.

Within the certifying activities of Kiwa are its declarations or recommendations of quality. Some of those activities are described below.

The “Toxological Aspects Certificate’ (TAC) indicates that a specified product does not add components to the drinking water that would be damaging to public health. Standardization for the TACs is done by a committee on health aspects of chemicals and materials for the water supply, which falls under the general directorate for environmental hygiene.

TACs have been formulated for all chemicals which are allowed in drinking water production.

A Kiwa-certificate concerns the installing, monitoring, cleaning up and cathodic protection of storage tanks, underground tanks and accompanying pipelines. These are tanks for storage of fluid petrol products and liquified petrol gases, as well as for fuel oil.

An examination report describes the results of a sample examination, which is formulated by Kiwa for the principal, and as a service to the water companies. The requirements for a sample examination, the sample requirements, are usually formulated by the principal himself and are dependent on the desired application. So, the requirements may differ for different sample examinations. Generally, Kiwa’s experience is used by the principal to formulate an accurate set of sample requirements.

The quality system certificate applies to all activities that are involved in the production of a product, process or service. It encompasses the organizational structure, responsibilities, authorities, procedures, processes and facilities establishing quality control within the whole company. Certification is done on the basis of international quality standards from the NEN/ISO 9001 series.

The product certificate indicates proof of product quality. It guarantees to the customers that the product meets agreed upon quality standards. That certainty is supported by the fact that the certificate may only be issued to producers who control their production process in such a way as to have only flawless products leave the factory.

The declaration of water supply technical safety indicates that an installation is certified for water supply technical safety aspects. Installations include all devices that can be connected to the drinking water network.

This certification is meant to uncover possible contamination of the drinking water by dangerous devices. These devices carry with them the risk of putting contaminated installation water back into the water distribution network.

5. The practice of designing

In the previous sections the basic elements of the design process have been explained. In the following, the design process will be further elaborated on using a single concrete project: the construction of a new drinking water production plant in Heel for the Limburg Water Company.
Not only are the design product and the background of the design choices important here, but attention is closelly paid to the process of designing and the growth of the design.

The design process will be dealt with by describing the different design documents, which will be defined according to the NEN/ISO 10628 "Flow diagrams for process plants." The design will be discussed to conform to the phases given previously, accompanied by the documents which were also previously discussed.

The following items will be elucidated:
- preliminary studies
- sketch design and building scheme
- preliminary design
- final design and detailed design
- construction and start-up

5.1 Preliminary studies

Historical developments
The water supply in Limburg fully relied on groundwater. Already in the 1972 "Drinking and industrial water supply structure scheme," it was noticed that for further expansion the use of surface water would be necessary. This scheme included a reservoir from a future gravel extraction site near Heel.
Though the growth in water use that was predicted never really happened, this did lead to a spatial claim on the gravel pit. Of course, many studies have been performed since then concerning this production site and the related specific limitations and opportunities.

In 1980, when dessication became a political issue, a decrease in groundwater abstraction in Limburg was proposed. This was possible if the above project was completed.
Several investigations on decreasing dessication suggested that the best solution would be to reduce all groundwater abstraction sites in central and north Limburg by 50% of the allowed maximum - a maximum which was always used or even surpassed.
In 1993 a specific project organization was instituted, which started the practical implementation.
In 1995, the provincial government of Limburg and the Limburg Water Company agreed upon a covenant to construct the project, in combination with a decrease in groundwater abstraction. The construction started in 1998 and the plant started production in 2002.

Dealing with the decreased capacity
Introducing surface water to decrease production of the existing groundwater plants could be done in a threefold way, in principle:
- all together
- groundwater separated from surface water
- surface water added to groundwater locally

In the first case all the groundwater would be transported to Heel, mixed there with the new plant's production, and afterwards distributed over all north and central Limburg. An advantage of this is a uniform scheme and a constant water quality over the entire province (i.e., no local differences).
In the second case, the groundwater plants would supply the boundary locations of the distribution area, while the centrally located Heel site would supply the immediate surroundings. An advantage of this solution is that ground- and surface water systems would remain separated.
In the third case, the water produced in Heel would be transported to the different groundwater sites and mixed with the locally produced water there.

These alternatives have been thoroughly compared. In order to do this, several studies were undertaken to investigate the consequences for the water quality, distribution infrastructure, possibility for phasing the project, costs, reliability, etc. Of course, this needed several design activities. All three possible solutions would require extensive, extra distribution infrastructures (Figure 11).

Without describing the decision process in detail, the final decision was made to have the surface water added to the groundwater (Figure 12).

Water supply plan

In most cases the production capacity is not reduced drastically. Usually, the increase in the water demand needs to be met by one or more new production plants or by expanding the capacity of current plants.

Figure 13 shows how such a demand coverage can be monitored. The net demand is shown, based on one of the different situations (minimum, maximum and most probable). From those figures and a reserve, a gross demand can be calculated.

New capacity will be realized stepwise, causing a repeating spare capacity to be available. In a water supply plan, the calculations are based on

Figure 12 - Surface water treatment in Heel supplies drinking water to the province of Limburg in addition to the existing groundwater plants

Figure 11 - For all alternatives, a considerable pipeline infrastructure was needed

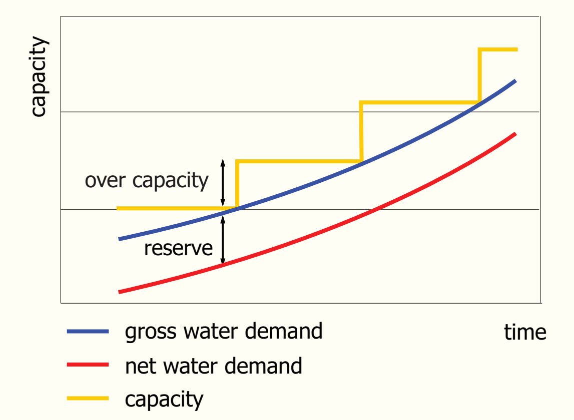


Figure 13 - Growth and coverage of water demand

yearly capacities. Based on the expected maximum peak factor, the maximum daily production can be determined.

In the water supply plan, a description is provided regarding which production plants need to be functional and when to increase a plant's production capacity. The uncertainty in the predictions is mainly dealt with by shifting the moment at which the additional capacity will be realized.

To estimate the time when an extra facility to handle additional capacity will be required, one can calculate backwards to determine the last possible moment to start preparations for building the new plant.

5.2 Sketch design and building scheme

Treatment process
Besides the required capacity, the treatment process needs to be decided upon as well. The following research methods are used to come to this decision:
- evaluation of current experience
- investigation of new treatment techniques
- pilot research (semi-technical scale)
- full-scale research (temporary production plant)

Time and means do not always allow the use of all those methods. This increases the uncertainty of the process design and of the entire operation.

In the plant this can be compensated for by increasing flexibility and safety in the design (larger buildings or increased possibilities for expansion) and in the operation (increased control options, increased doses). Either of these will increase the investment costs and complicate the operation. The start-up will take longer as well, because operators might not be familiar, or are less familiar, with the chosen treatment process.
In the Heel case, all investigation methods named above have been employed. Important research inquiries included, among others:
- the necessity of either a disinfection (UV) after the active carbon filtration or of an additional disinfectant (ozone)
- the effect of a combined abstraction of both aerobic recharge water and anaerobic groundwater
- the backwash water treatment with vertical ultra filtration and air flushing

Block diagram (treatment scheme)
The design in this phase will represent the treatment process as a block diagram (ISO 10628).
A block diagram represents a treatment process, or a treatment plant or other units by rectangular blocks, which are named and connected to each

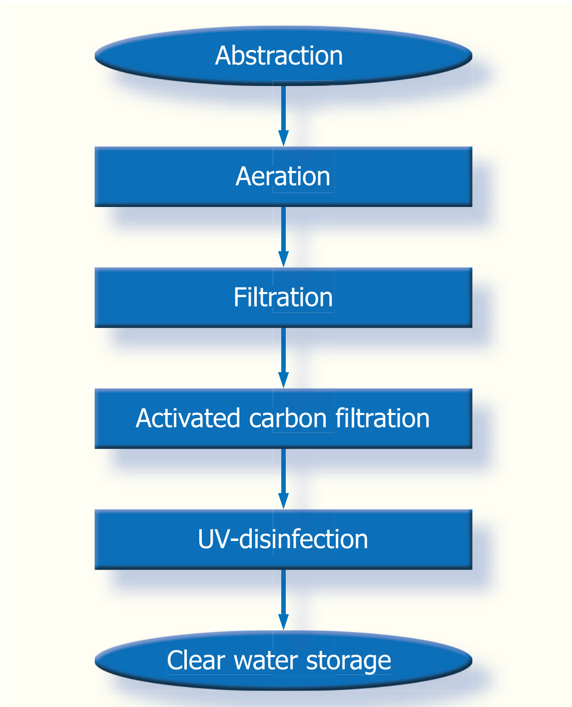


Figure 14 - Global setup of the treatment scheme

other by way of streamlines. A block diagram, at the very least, consists of the following parts:
- names of the blocks
- names of in- and out-flowing mass and energy flows (for the block diagram as a whole)
- directions of the main streams between the blocks

Also, a block diagram may contain additional information, like the names of the flows between the blocks, the amounts of in- and out-flowing mass and energy flows, the amounts of the most important flows between the blocks, and the typical process conditions. A limited block diagram is shown in Figure 14.

As an addition to the block diagram, a more visual representation of the treatment process can be drawn. Mostly, this is a rough section of the process, including the most important pumping phases. Figure 15 shows an example.

Site layout plan

When the capacity and the treatment processes are roughly known, a provisional site layout plan can be drawn. This plan is especially aimed at the zoning of the plant area and at the related orientation of the buildings. Site layout plans are usually drawn at a scale of either 1:500 or 1:1000.

Typical zones within a site layout plan are:
- clean water reservoirs with high pressure pumping station
- treatment plant
- sludge and backwash water treatment units
- energy supply (including emergency power)
- additional services (e.g., workshops)
- main roads and transport routes
- space for future expansion

When formulating the site layout plan, the building boundaries are either not important or not yet known. Generally, the spatial demand per process part can be determined. In this determination, it holds that the spatial demand of most processes (i.e., filtration, flocculation, sedimentation, etc.) is about 2 to 3 times as much as the actual area necessary for the process. This is because of necessary pipe galleries and control rooms. Besides, one needs to keep in mind that during construction a large space around the building is required.
Finally, it is desirable to calculate for future developments and for future replacements. For a replacement, the new construction should be finished before an old construction is demolished, to maintain continuity in the supply of drinking water. Figure 16 gives an artistic impression of the Heel production site.

Sketch design

In addition to the documents named above, formulating some very rough design drawings to present the intended construction to third parties may be desirable. Usually, a single floor plan and one or two sections will suffice.

Building scheme

The sketch design names the projected structures and gives their projected dimensions. The building scheme is formulated based on this design, including plans for the construction work (Figure 17). One should keep in mind that this kind of plan-

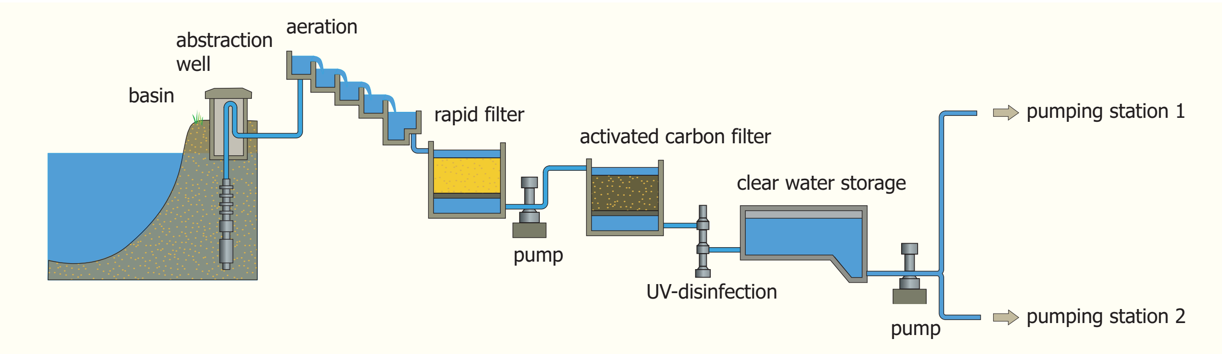


Figure 15 - Visual presentation of the treatment process

Figure 16 - Artistic impression of the Heel production site

ning tends to fail, for example, because of lagging permit procedures.

During preparation for the Heel production plant, it became clear that the gravel suppliers needed an extra year to develop the gravel pit and the adjacent shores. Partly because of this extra preparation time, it was possible to raise the operational level of the reservoir, which increased the groundwater level in the area and, thereby, reduced the environmental impact. The environmental impact was quantified as a part of the Environmental Impact Assessment procedure (EIA).

5.3 Preliminary design

The most important design documents in the preliminary design phase are the

- hydraulic line scheme
- process flow diagram
- design drawings

These documents will be explained below.

Hydraulic line scheme

The hydraulic line scheme is a design document that is typical for water treatment plants. Because of using open tanks, canals, processes with a free water surface (i.e., cascades), the water level in the processes becomes quite important, especially when an energy and cost-saving design is desired. There are no national standards for the hydraulic line scheme.

Basically, the hydraulic line scheme is a vertical section of the building, presenting the building elements schematically, but presenting relevant heights on an exact scale (Figure 18). In addition, other relevant data, like ground level, roof height, passage height, are indicated.

During the design process, this scheme will be further refined and other levels (e.g., emergency overflow) will be indicated.

Hydraulics plays a very important role in the design of a drinking water production plant. One reason for this is that the water will be divided over several parallel units more than once. Basically, a hydraulic division is used here, because of the robustness of hydraulic control compared to mechanical or electrical control systems (Figure 19). A hydraulic control system is often used to compensate for the increased filter resistance during the process.

Process flow diagram (PFD)

A further elaboration of the treatment process can be represented as a process flow diagram (PFD) (ISO 10628).

A PFD indicates installations, by means of standardized symbols, and the flow of mass and energy between them. At a minimum, it consists of the following blocks:

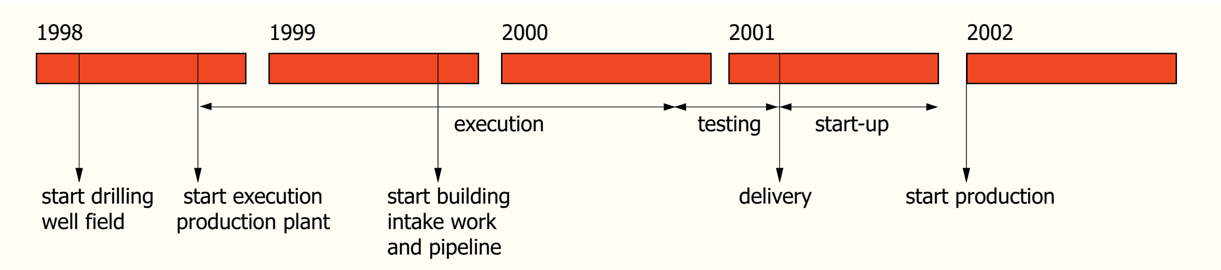


Figure 17 - Actual timeframe for construction of Heel production plant

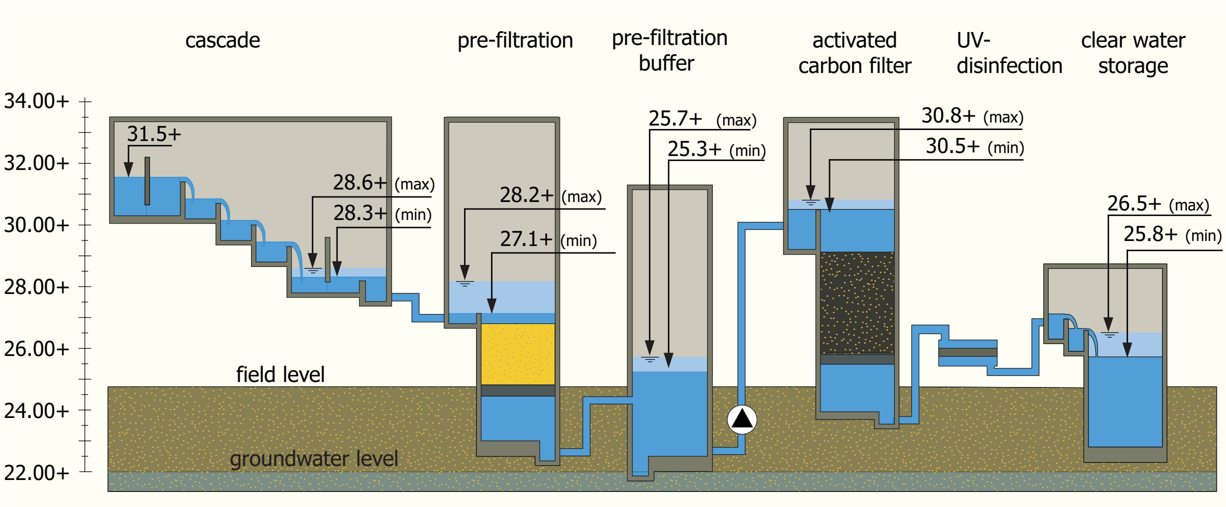


Figure 18 - Hydraulic line scheme

- type of equipment necessary for the process
- coding of the installation
- direction and route of in- and out flowing mass and energy
- labeling and quantifying of in- and out flowing masses
- labeling and quantifying of in- and out flowing energy flows
- typical process conditions

A process flow diagram may contain additional information, like the magnitudes of flows and amounts between process steps, major valves, functional indication of instrument and control systems in a specified position, additional process conditions, names of characteristic installation data, names and characteristic data of propulsion systems, and the elevation levels of terraces and installations.

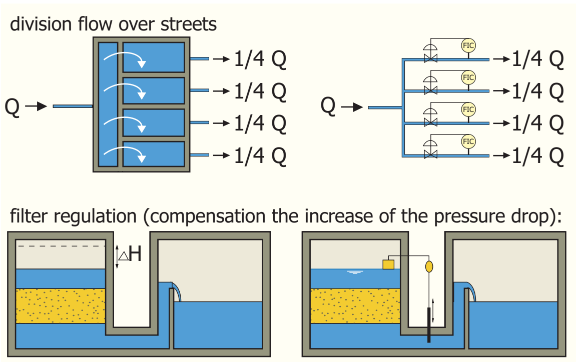


Figure 19 - Hydraulic solutions are easier and more robust

For the design of a drinking water production plant, it is only useful to formulate a PFD in addition to the hydraulic line scheme when all parallel process parts are presented separately. This makes the diagram correspond to the much used main water flow diagram (Figure 20).
This specification is desirable so that the PFD can be used to determine the different hydraulic loads of units and piping, both in normal and in special circumstances. For normal conditions one can describe the different process conditions with the diagram (e.g., filter during backwash, etc.). The extraordinary conditions determine the dimensions of the parts. In this way, the PFD is the basis for the detailed hydraulic calculations and the functional description of the control and operating system.

Design drawings

Design drawings represent the physical reality.
During the preliminary design phase, especially the dimensions of the process units and the different rooms will be decided.
More and more, these drawings are made by 3D design systems. In these designs the designer indicates the 3D elements, after which the system generates the different drawings (floor plans and sections) and some 3D representations (Figures 21 and 22). These later drawings are especially useful during the preliminary design phase, and they are comprehensible to the general public, who will benefit the design process through their feedback.

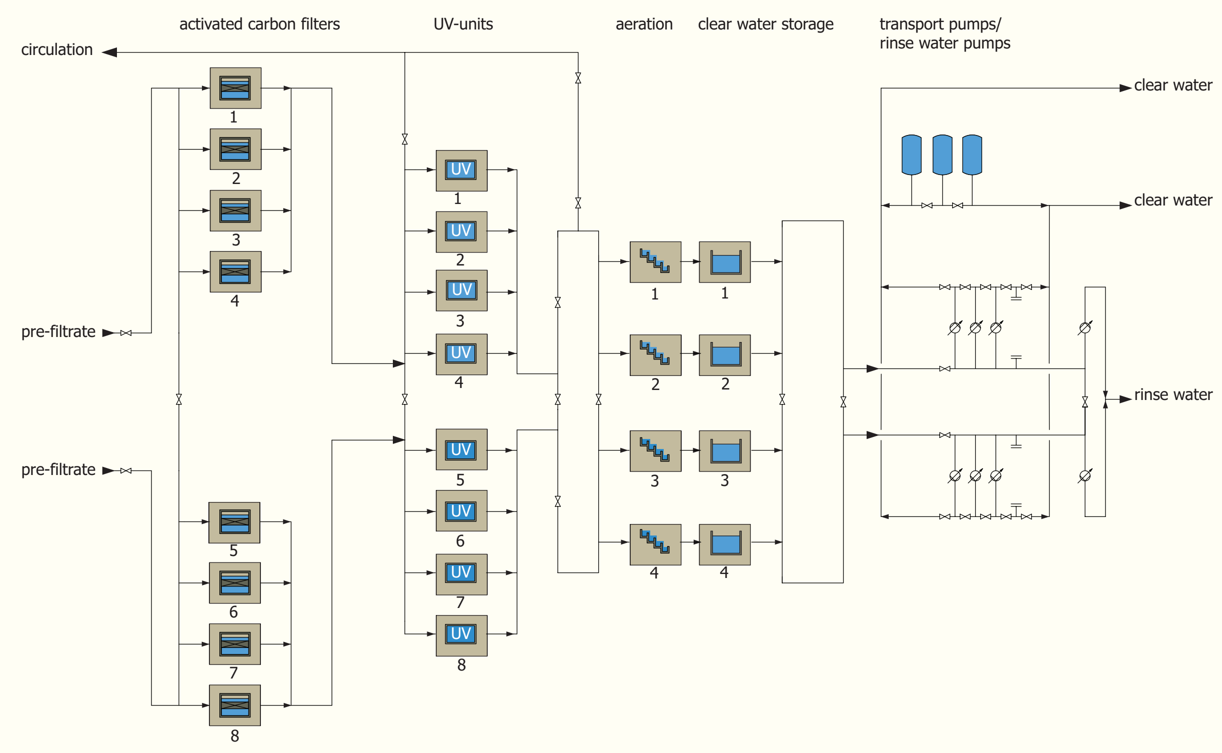


Figure 20 - A part of the process flow diagram (Main water flow diagram)

Structural aspects

During the preliminary design phase, the dimensions of the structural elements cannot be determined accurately yet. This is because the loads are only approximated. Nevertheless, it has proven feasible to make some realistic assumptions instead. For concrete constructions, the floor and wall sizes are mostly estimated at 0.4-0.6 m. When, in a later phase, these dimensions need to be changed, typically only the inside dimensions are adjusted while the outside building size remains the same.
During the preliminary design phase it is important to examine both the foundation and the division of the building using dilatation seams in closer detail.

Architecture

In the rough design drawings, technical choices with regard to the design have been decided. Adjustment of the design because of architectural considerations may be desirable. Therefore, it is useful to indicate the functional relationships between the different components. This will give a better indication to the architect of the degrees of freedom and of the consequences of breaking them (Figures 23 and 24).

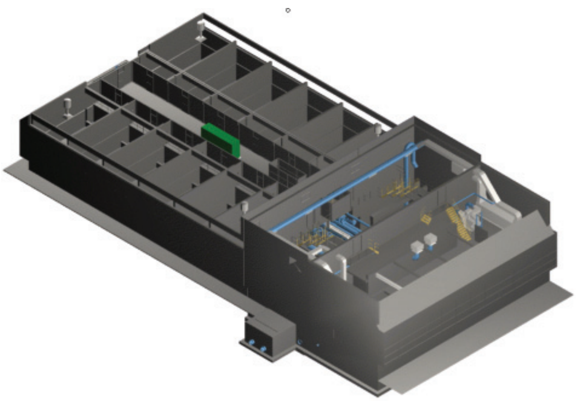


Figure 21 - Design of building

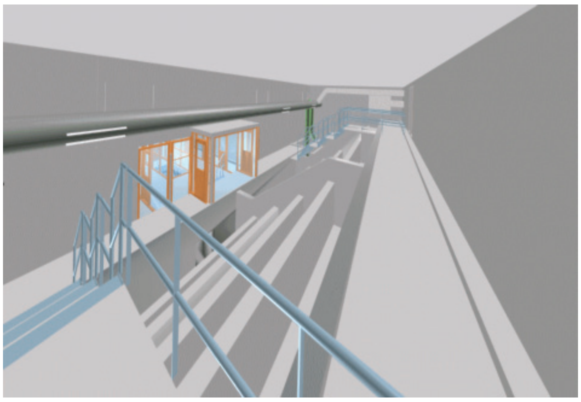


Figure 22 - Design cascade aeration

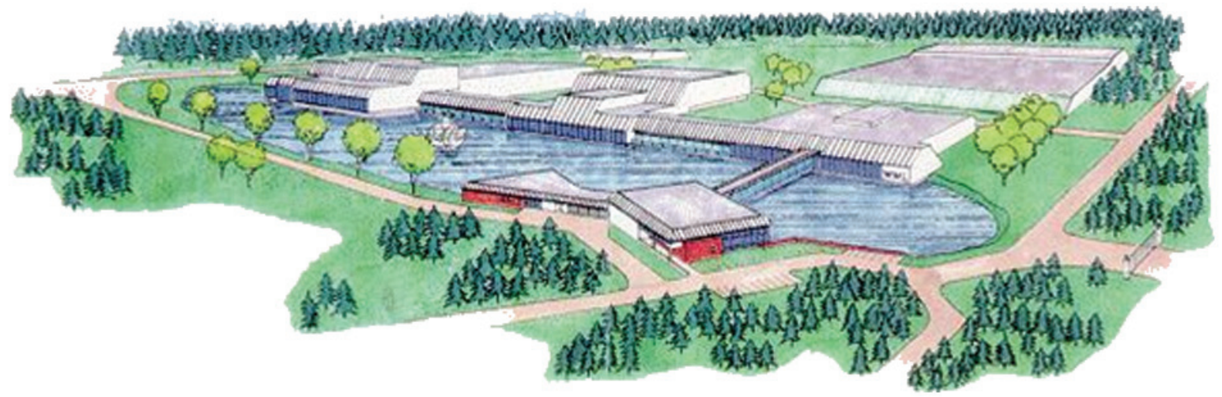


Figure 23 - Architectural design drawings

Architectural drawings from the preliminary design phase are necessary in order to apply for a building permit.

5.4 Final design and detailed design

During the final design and detailed design phases, many more design documents are still formulated. This section will only deal with the piping and instrument diagram.

Piping and instrument diagram (P&ID)

The piping and instrument diagram (P&ID) (ISO 10628) indicates the technical construction of a process by means of standardized symbols for installations, pipes, instruments and control systems.

The minimum information in a piping and instrument diagram includes the following:

- function or type of apparatus, including drives and installed spare parts
- identification number of apparatus including drives and installed spare parts

Figure 24 - An architect's scale model

Figure 25 - Heel production plant and reservoir

- characteristic data of apparatus (on a separate list)
- identification of nominal diameter, pressure class, piping material and classification
- details of installations, pipes, gauges and junctions
- process measurement installations and control systems with identification
- characteristic data of drivers

A piping and instrument diagram may also contain several additional details. The piping and instrument diagram is the central document for detailed engineering, for the mechanical parts (pumps, pipes, installations, gauges), the electrical parts (power supply), and for the control parts (measurement and control systems, operating systems).

5.5 Construction and start-up

Even during the construction phase, several design activities are performed. These may include a further detailed elaboration of the design (i.e., form and reinforcement drawings) or temporary constructions (dam walls, concrete molds).

After the construction phase, and during the start-up phase, the designer's efforts will either be proven succesfull or not (Figures 25, 26, 27).

Figure 26 - Heel reservoir

Figure 27 - Production plant at Heel

Literature and websites

Construction process
- 'Organisatie van het bouwen', Lecture notes CT2110 (Civil Engineering), TUDelft (2001)

Laws and standards
- Stroomschema's voor de procestechniek – Algemene regels (NEN/ISO 10628), NEN Rijswijk (2000)
- Aanbevelingen voor het bedrijfsbeleid in technisch-hygiënisch opzicht, VEWIN Rijswijk (maart 1985)
- Beschermingsplan waterleidingbedrijven, VROM (maart 1991)

Heel production plant
- Waterproductiebedrijf Heel, Themanummer H2O, H2O 10+11 (2002)

- www.overheid.nl/wetten
- www.nni.nl
- www.cenorm.be
- www.iso.org
- www.vewin.nl
- www.kiwa.nl
- www.awwa.com

Questions and applications

Planning process for public water supply

1. Indicate the different plans that deal with public water supply, the plan period and the organization formulating the plan.

2. The national policy plan has two functions. What are they?

3. The Association of Dutch Water Companies' ten-year plan has become less significant during the past few years. What is the most important reason for its declining importance?

Design activities in the infrastructure's life cycle

1. Roughly indicate the phases and sub-phases during a construction project.

2. Which components make up a project definition?

3. Why are special measures necessary during the construction of a drinking water supply plant?

Laws, permits and standards

1. Indicate some characteristic permits necessary for a typical construction project.

2. Indicate a reason for using a system of standards.

Designing in practice

1. What is "formulating a site layout," and what does this mean to a water supply production plant?

Answers

Planning process for public water supply

1.

Name	Timeframe (years)	Organization
Policy plan for drinking and industrial water supply	20 - 30	Ministry VROM
Ten-year plan	5 - 10	VEWIN
Provincial policy plans	5 - 10	Province
Provincial management plans	5 - 10	Province
Regional plans	5 - 10	Province
Land use plans	5 - 10	Municipality
Water supply plan	10 - 30	Company
Multi-year investment plan	5 - 10	Company
Business plan	5	Company

2. First, it indicates the concerns for water management that need to be considered in spatial planning decisions on the national, provincial and municipal levels. Second, the policy plan is indicative for the public water supply section; only in emergencies are the water companies allowed to diverge from the plan.

3. More and more the water companies operate on a provincial or super-provincial level. This requires less mutual adjustment between the different water companies. Part of the purpose of the ten-year plan is now covered by the water companies' plans.

Design activities in the infrastructure's life cycle

1. The different phases are:
   - Initiative: identification, definition
   - Construction: design, contracting, construction
   - Operation: start-up, operation
   - Demolitionl: demolition and removal

2. A project definition consists of a:
   - requirements program
   - sketch design
   - building scheme

3. Because of the hygienic nature of the public water supply, special measures are necessary in order to prevent contamination. Besides, during construction clean work is necessary, because a dirty construction site will contaminate new plant units. At the start-up such contamination can be highly problematic, because it will be difficult or even impossible to achieve the required microbiological quality of the drinking water.

Laws, permits, standards

1. Some characteristic permits include:
   - tree cutting permit (making the area construction ready)
   - building permit (for construction)
   - environmental permit (for operation)
   - draining permit (for discharge of waste water)

2. For several permit procedures, the design is required to comply with specific standards. Standards are a complex system of mainly technical directives and prescriptions. Also, standards play an important role in the reproducibility and the responsibility of the design. Because standards uniquely define concepts, they are helpful in the communication between the different parties involved in a construction project.

Designing in practice

1. A site layout plan is mainly aimed at the zoning of the plant area and the related orientation of the buildings. Site layout plans are usually drawn at a scale of 1:500 or 1:1000.
   Typical zones within a site layout plan include:
   - clear water reservoirs and high pressure pumping station
   - treatment plant
   - sludge and backwash water treatment
   - energy supply, including emergency power
   - additional services (workshops, etc.)
   - main roads and transport routes
   - space for future expansions