# 4 Earth *(Drs. M.J. Moens)*

Our spatial knowledge spans across the edge of the universe ($10^{25}$ meter) to the inside of an atom ($10^{-16}$ meter). Representative patterns of each spatial scale are depicted per factor of ten in the film "The powers of ten"[a] and the book: "The powers of ten", (P. Morrison, P. Morrison and The office of Charles and Ray Eames (1982), in Dutch P. Morrison, P. Morrison and De studio van Charles and Ray Eames (1985)). From the level of magnification $10^{25}$ to $10^{9}$ meter all we can see is a "speckled" pattern (stars), before the earth comes into view. From powers $10^{8}$ to $10^{-8}$, very distinct forms with relatively little repetition become visible. From $10^{-9}$ to $10^{-16}$ meter thousands of repetitive speckles, spheres, clouds, nebula and fields of force are clearly visible.

The smallest stable abiotic component on earth is the hydrogen molecule ($H_2$), and the biggest is earth itself. By way of comparison: the smallest elementary life form is the virus ($10^{-7}$ meter) while the biggest, according to the Gaia hypothesis (J. Lovelock and B.v. Segeren (1979), J.E. Lovelock (1995)) is earth's surface (10,000 km). The Gaia hypothesis falls outside the scope of this book.
The primary conditions for the creation of life on earth are the presence of solid (abiotic) matter as well as water and energy. The earth's temperature is determined by the distance between the earth and the sun, and is just the right distance to keep water liquid.

Liquid water offers life on earth a chemical panacea and an excellent transportation and regulation system. Water evaporates at temperatures above 100ºC at sea level, and releases heat of condensation at temperatures below 100ºC, in other words it begins to rain or snow. On a global scale, the sun creates winds in the atmosphere that blow from the warm tropics to the cold poles: the large circulation. The differences in temperature above the land and the sea and the earth's rotation make this a very complex process. Differences in temperature between the poles and the equator also create heat transport in the oceans, from the equator to the poles: the warm Gulf Stream.
Apart from the conditions created by light, temperature and water, we can limit our scope to the 15 decimals of earth.

Lovelock, J. and Segeren, B.v. (1979) *Gaia, een nieuwe visie op de Aarde* (Utrecht/Antwerpen) Kosmos (Leerstoelbibliotheek).
Lovelock, J.E. (1995) *Gaia a new look at life on earth* (Oxford) Oxford University Press ISBN 0.19.286030.5.
Morrison, P., Morrison, P. and Eames, D.s.v.C.a.R. (1985) *De machten van tien* (Maastricht/Brussel) Natuur en Techniek ISBN 90-70157-48-9 (Leerstoelbibliotheek).
Morrison, P., Morrison, P. and Eames, T.o.o.C.a.R. (1982) *The powers of ten* (New York) Scientific American Books, Inc. ISBN 0-7167-1409-4 (Leerstoelbibliotheek).

[a] http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/
http://www.powersof10.com/
http://www.eamesoffice.com/

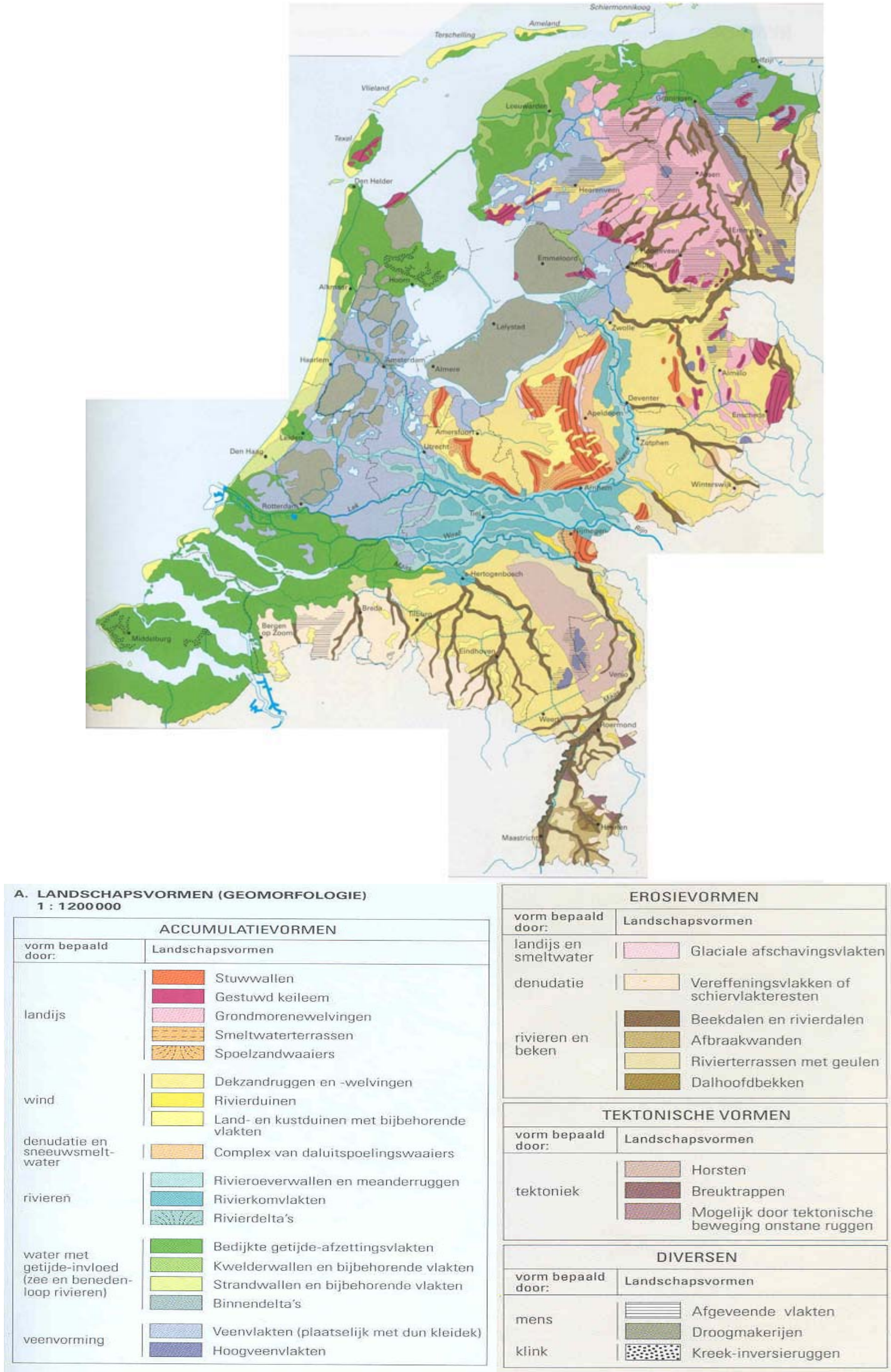
## 4.1 Kilometres: geomorphological landscapes

Geomorphology is concerned with investigating cause and development of all topographic forms. This chapter focuses on the processes that produced the different landforms, and their regional spread of these landforms in the Netherlands.
Geomorphological processes imply all physical and chemical changes affecting the earth's surface.

Geomorphological processes are the result of different agents.
The main geomorphological processes are:

- epigenous or exogenous processes; these processes occur on the earth's surface, such as weathering, erosion, transport and deposition.
- hypogenous or endogenous processes; these processes are influenced by forces in the earth's crust, such as mountain building, rise and subsidence, tectonics, volcanism.
- extraterrestrial processes; processes, where landforms are created by “alien” influences, such as an asteroid collision.

The Netherlands is primarily affected by epigenous processes with corresponding agents.




*Sticht.Wetensch.Atlas_v.Nederland (1985), Sticht.Wetensch.Atlas_v.Nederland, v.d. Berg, Steur and Brus (1987)*

*Fig. 421 Geomorphological landscapes of the Netherlands*

| PROCESS | AGENT |
|---|---|
| Mass wasting / slope processes | |
| Degradation through levelling | Gravity |
| Erosion | 1.flowing water |
| | 2.sea, waves, currents, tides |
| | 3.wind |
| | 4.ice, glaciers |
| | |
| Aggradation through deposition Sedimentation | 1.flowing water |
| | 2.sea, waves, currents, tides |
| | 3.wind |
| | 4.ice, glacier |

*Fig.422 Geomorphological processes and agents*

The following landforms are created by different agents (processes); a description and explanation of their regional spread (pattern) is included:
- landforms created by sea
- landforms created by rivers
- landforms created by ice
- landforms created by wind.

This chapter will focus on landforms specific to the Netherlands. To enable a systematic approach and for the sake of completeness, context is provided in most instances.

### 4.1.1 Landforms created by the sea

To promote a better understanding of the landform patterns created by the sea, the relevant processes should be studied. Water acts as an agent with all the corresponding movements such as waves, currents, tides and tidal currents.

**General information about the sea.**
Over two-thirds of the earth's surface is covered with water. In seas and oceans, sedimentation occurs more often than erosion, whereas on land erosion is more dominant. The greatest part of the sea floor is covered with sedimentary layers. This sediment consists primarily of lime, sand and clay. Over 90% of sediments found on land were originally formed in the sea, and this sedimentary rock was pushed upwards during mountain building and tectonics. Mountain chains such as the Dolomites in Italy, the Jura in Switzerland and France and large parts of the Alps are made up of this sedimentary rock: limestone, marl and sandstone.
Seawater contains practically every chemical element found on the earth's surface, including gas. The salinity of the North Sea is approx. 35 g/l.

Oceans and seas are classified, among other things, according to depth and flora/fauna.
Classification according to depth:
- continental shelf; maximum depth of 200 m; it slopes gradually towards the ocean; the width of the shelf bordering directly on the continents varies.
- continental slope; slope from the continental shelf to the deep sea; considerable relief (slope to 27°); width of 16-32 km.
- deep sea; predominantly horizontal; the deep-sea plains are characterised by trenches (long, narrow, deep depressions up to 10 km) and submarine mountain chains such as the Mid-Atlantic Ridge.

Classification according to flora and fauna:

1. pelagic zone; the living space of swimming organisms or organisms floating in the water
2. benthonic zone; the living space of organisms living on the sea floor. This benthonic zone is subdivided into:
   - littoral zone, (coastal zone)
   - neritic zone, up to a depth of 200 m
   - bathyal zone, depth between 200 and 1000 m
   - abyssal zone, ,the deepest parts of the oceans with the exception of the trench-hadal zone, the trench floor

**Water movements in the sea**

Landforms created by the sea are caused by water movements in the sea, the most important of which are:

- surface waves; wind-generated waves. The energy of the water particles decreases with depth. Sea-floor materials can only be transported in relatively shallow waters, such as in most coastal zones.
- tidal waves; movement caused by the gravitational attraction of the sun and the moon on the turning earth. This is a vertical water movement around the earth, causing regular sea level rise and fall.
- tidal current; this is a horizontal water movement related to tidal rise and fall. This movement has an oscillating character (ebb and flood). In shallow waters, this current can reach considerable speeds and heights.
- non-oscillating currents, such as the warm Gulf Stream generated in the tropics by trade winds blowing over the water.
- tsunami; extremely high waves caused by submarine earthquakes and volcanic eruptions.

In addition to these water movements, there are also gradient currents and convection currents, which will not be dealt with in this chapter.

**Coast**

The coast is an outstanding example of a landform created by the sea. The coastline forms the boundary between land and water. In coastal zones, the floor is clearly influenced by wave movements and high-rising water. This applies both to water and land. Coastlines have a temporary nature. Landward movement (transgression) is usually the result of coastal erosion caused by waves, a rise in sea level or the sinking of land. Seaward movements are caused by sediment supply by rivers, sea currents, waves, wind, a falling sea level and/or rising land. This is called regression. Neutral coasts are coastlines that have remained unchanged for longer periods.

**Coastal forms**

Coasts are classified according to:

1. sea movements in relation to land
2. coastal material.

**1 Sea movements**

a. transgression coasts,(submerged land and submerged river valleys)

- submerged glacial valleys (fjords)
- submerged valleys/sloping coast (ria coastline in Yugoslavia)
- submerged coastal plain with little relief

b. regression coasts

- coastal plain with little relief (slow-ascending)
- coastal plain with terraces (easily identifiable in bedrock)

c. neutral coasts

- coasts composed of river sediments
- delta coasts
- coral coast (tropics)
- volcanic coast

d. fault coasts; coasts influenced by tectonics

**2 Coastal material**

a. rocky coasts
b. coral coasts; coral reef surrounding the actual coast
c. coasts made up of loose material such as gravel, sand or clay. This is the only coastal form prevalent in the Netherlands.

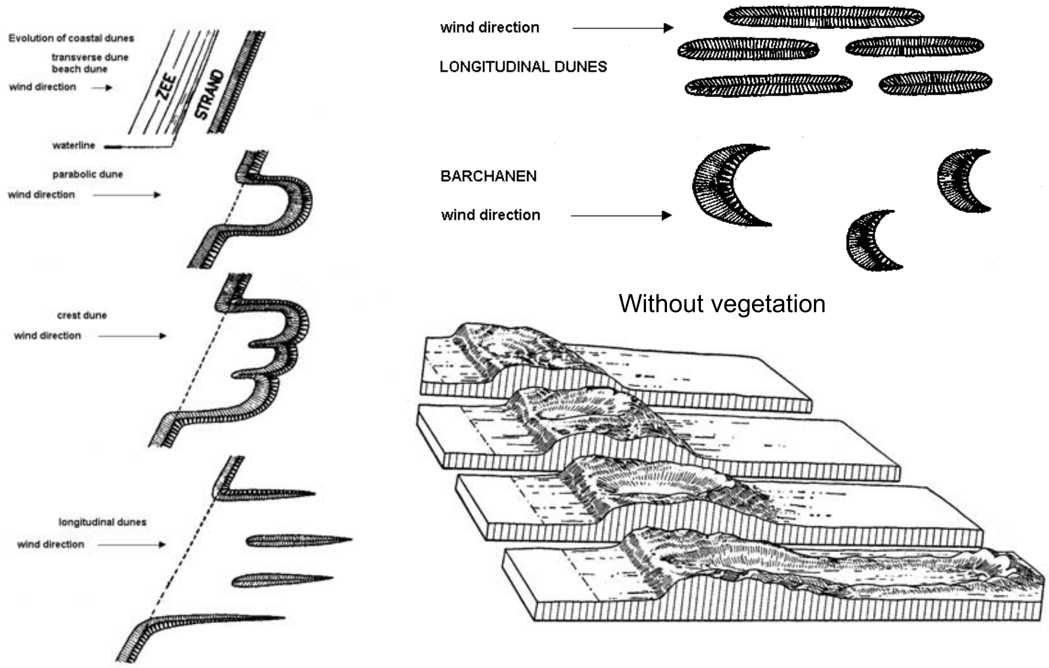
**Coasts made up of loose material**
As mentioned above, this is the only coastal form specific to the Netherlands.
In coastal zones, loose seabed material is transported by currents and waves, and by the wind above the waterline, on land. In itself, sedimentary supply by waves from deeper waters cannot cause the coast to expand seaward. The depth of the seafloor increases as a result of beachward wave movements. This creates an equilibrium, where no further sedimentation takes place. Continuous accretion is usually the result of sedimentary transport parallel to the coast.

**Sediment transport parallel to the coast**
This type of transport can be effected by waves and currents. It is crucial that these two movements work at the same time. Provided that wave movements are strong enough, even the weakest currents can transport material, as the material is mobilised by the waves. Coastal sediment movement is known as beach drift, and as coastal drift when a certain direction dominates. Coastal drift plays an important role in the build-up and erosion of the Dutch coast. This drift must be taken into consideration when choosing coastal locations (such as the Waterman plan), and when carrying out dredging work and raising entire areas such as the Maasvlakte (Meuse deltaic plain). These activities can effect unforeseen coastal changes in the form of erosion on the one hand, and sedimentation on the other.

**Influence of the wind on the coast**
Shores extending along the sediment coast are known as beach plains with barriers. This area extends beyond the reach of the sea, with the wind acting as the most important modeller. Dune formation is related to beach plains, where waves continuously supply new material in the form of sand and clay that are the building materials for dunes. The sand must be good and dry to drift. Clay-like substances retain water and thus prevent drift. The sand of the North Sea coast satisfies these criteria, while the sand along the tidal flat side of the Wadden coast (the Shallows) contains too much silt and mud, which is why hardly any dune formation takes place.

It is universally accepted, that plants play an active role in coastal dune formation. The main flood mark operates along the coastline, where all kinds of material such as weeds, driftwood, plastic and litter are deposited and act as “sand catcher”. This material offers a favourable environment both with regard to food and water management and micro climate, enabling the growth of plants such as sand crouch grass. The deposited sand enables the growth of sand crouch grass (pioneer species) and marram grass (next in the successional series), which retain the sand against further drifting. They can even survive a cover of sand by growing upwards through the sand layer. Provided the circumstances remain favourable with regard to the supply of sand and and plant growth, these series of small dunes with vegetation will turn into a foredune or transverse dune (dune perpendicular to the direction of the prevailing wind).

If a wind hole or blowout is created as a result of disruption of vegetation caused for example by coast erosion, wear and tear or rabit holes, drifting will create another dune form: a parabolic dune. Further deformation through sand drifts will produce ridge dunes and eventually linear dunes. Depressions made by the wind that have reached a certain size are known as “duinpan” [flat bottomed depression amidst dunes] or dell, of which Meijendel is a good example. These layers can be so deep that the ground water is reached and a freshwater lake is formed. Many municipalities in the western part of the Netherlands use this freshwater from the dunes as drinking water. Due to the huge demand for fresh water, the current supply is insufficient. This is why water from the large rivers is used to replenish the original freshwater. This water from outside the area causes a disruption of the vegetation.
N.B. It will be obvious that dunes are not only situated along the coast, but also inland on dry sand plains not covered by vegetation.




With vegetation Diagrams of the evolution of coastal dunes

Escher (1962)

*Fig.423 Dune forms*

**Lagoons, tidal-flat areas and estuaries**

The outer boundary of marine sedimentation is not always formed by a beach and dunes. In certain areas, marine influence stretches to low lying areas bordering the landside of barriers. In most cases, the sea has access to these areas via semi-permanent and permanent tidal inlets.
A distinction is made between lagoons and tidal-flat areas. Lagoons are mostly shallow bodies of water, while tidal-flat areas emerge at low tide and the sea floor is totally submerged at high tide only. A lagoon floor is characterised by little relief, whereas the floor of a tidal-flat area consists of deep channels, as well as plates and banks raised above the low water level. In many lagoons and tidal-flat areas, water salinity differs little from that of the open sea.

Brackish water environments are predominantly found near river mouths such as estuaries and deltas. Estuaries are widened river mouths, where water movement is strongly influenced by the tides as well as the flow of river water. In the seaward parts of the estuary, the water moves seawards during ebb and shorewards during flood. The amount of outflowing water at ebb naturally exceeds the amount flowing in at high tide. Further inland, currents travel permanently seawards, although the current velocity fluctuates under tidal influence, as does the water level. Due to the strong currents, estuary floors are characterised by strong reliefs with deep channels and, at low tide, emerging banks and plates. Estuaries are rather similar to tidal-flat areas as regards their relief forms and sedimentary deposits. They differ in terms of the orientation of the areas. Whereas estuaries run more or less perpendicular to the coast, tidal-flat areas run parallel to the coast. The differences are underlined even further by the absence and presence of barriers on the seaside and the supply of river water.

N.B.Looking at the islands of Zuid Holland and Zeeland - the delta area - , we can conclude that these areas are more akin to estuaries than deltas in terms of their form and position. The islands are characterised by deep channels, planes and banks perpendicular to the coast, all features of an estuary.

**Sedimentation in tidal-flat areas and estuaries**

The processes of sedimentation and erosion are dominated by tidal currents. These currents are strongest in channels, although they prevail in the entire area at high tide, albeit less powerfully than in channels. The floors of those areas are subjected to constant change due to channel diversion as a result of current activity. In addition to channels, the area is also characterised by plates and banks, raised above the high tide level through sedimentation. Plants play an important role as sand and silt catchers. The resultant vegetated terrains are known as “schorren” (salt marshes) in Zuid Holland and Zeeland and as “kwelders” in the Wadden area (tidal-flat areas).

**Deltas**
Deltas are sedimentary deposits created by streams in large basins containing stagnant water, lakes or seas with small tidal difference. Sedimentation is caused by a rapid decline of current velocity, “depositing” particles floating in the water. Sand is deposited first, followed by silt and eventually the finest material, clay due to a decrease in stream velocity. When the sea current is so strong that finer particles cannot be deposited, they will be carried away and deposited elsewhere. The speed of growth of deltas varies considerably: the bigger the sedimentary supply of the river, the smaller the depth of the (sea) floor bordering the river mouth, and the weaker the influence of erosion as a result of wave activity and tidal current, the greater the speed of growth.

The position of the Rhine delta is relatively stable, while the Rhone delta is growing at approximately 20 m per year, and the Volga delta at approximately 170 m per year.

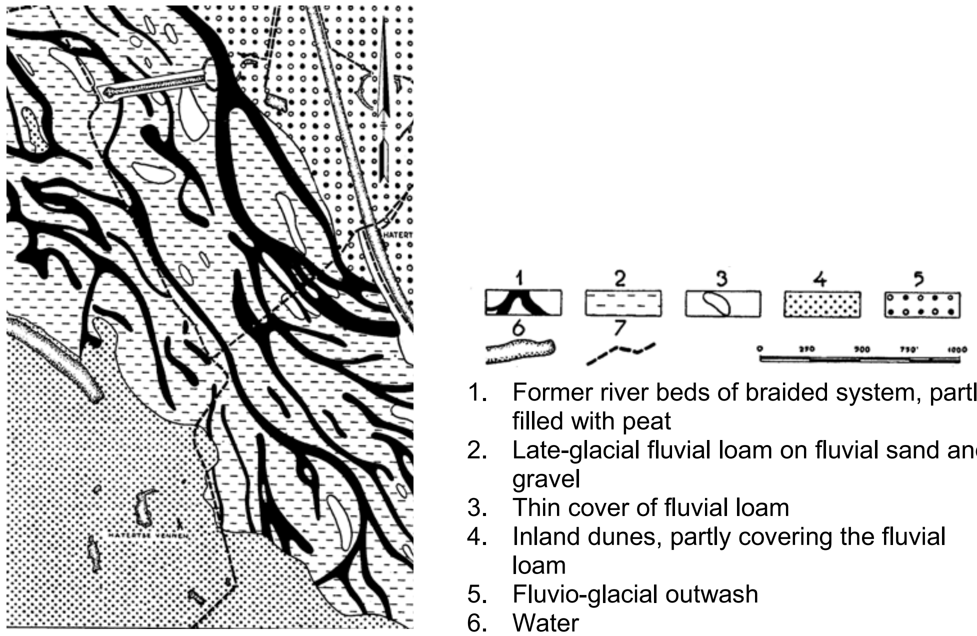
### 4.1.2 Landforms created by rivers

**The landscape of river areas**
A considerable part of the Netherlands is the result of sedimentation of the Rhine and the Meuse, the two largest rivers in the Netherlands. The process of deposition or sedimentation has been going on for millions of years. The Netherlands is located in a so-called area of subsidence.
An excellent example of an area formed by rivers and their sedimentary deposits is the central area of the Netherlands. The pattern of recent river deposits have all the characteristics of a meandering river. Meandering rivers flow slowly in a relatively flat area, creating a multitude of curves - meanders. The river bed is relatively narrow in summer. In winter and spring however, the rivers carry more water and overflow the summer water bed. Normal annual fluctuations, which do not cause the river to overflow excessively. The river deposits coarse material immediately next to the river bed to form a bank: the natural levee, and deposits layers of fine material (clay) in the flood basins or back marshes, further away from the river. Natural levees are used for fields and orchards. In ancient times Man lived on natural levees, and old roads can still be found there. Back marshes form the large open meadows in this area, uninhabited for a long time, with few or no roads. Recent land development plans and/or re-allotment have rendered this old pattern virtually unrecognisable. Since the Middle Ages, river courses in the Netherlands have been fixed by dykes; as a result, all material is deposited on flood plains.

The natural levees in the eastern river area are mostly divided into block-shaped parcels of land, while the flood basin is characterised by strip parcels. The villages in this eastern region have many similarities with *esdorpen*.
Towards the west, land parcels gradually change into strip parcels without habitation. The area where rivers enter the Dutch peat lands is also characterised by strip land division. This area however is inhabited, partly as a result of land reclamation contracts know as “cope ontginning”. Villages in this area have an elongated, linear shape.
Flooding occurs due to extremely high water, and is caused by heavy downpours or the sudden thawing of snow and ice in the catchment area. Flooding is promoted by river canalisation, the discharge velocity of the water will increase. The change in land use causes soil erosion in the catchment area. This changee reduces the buffering capacity for water in the area and sometimes reduces it to nil.

**General information on rivers.**
River classification is based on a number of different criteria, including:
- form and course
- river source
- runoff fluctuation

**Form and course**
A distinction is made between valley-forming rivers, meandering rivers and anastomosing or braided rivers. The Netherlands only has meandering rivers. A meandering river is characterised by more or less regular curves in a flat area and a relatively regular supply of water. Meandering rivers turn into braided rivers with an excessive amount of water. Braided rivers are characterised by a system of many small, medium wide and shallow watercourses, repeatedly dividing and converging.




1. Former river beds of braided system, partly filled with peat
2. Late-glacial fluvial loam on fluvial sand and gravel
3. Thin cover of fluvial loam
4. Inland dunes, partly covering the fluvial loam
5. Fluvio-glacial outwash
6. Water

Roads

A.J. Pannekoek (1956) after Pons, from: C.H. Edelman (1950)

*Fig. 424 Detail of fluvial loam landscape, south-west of Nijmegen.*

The amount of water runoff fluctuates greatly. During the ice ages, both the Rhine and the Meuse were braided rivers, as the amount of water depended primarily on ice melt, while precipitation in the form of rain was virtually non-existent.

**Water supply source**

Depending on the water supply source, rivers can be classified into glacier, rain, source and combined rivers. The water of combined rivers, which encompasses all large rivers, usually consists of all four types. The Rhine is a combined river with snow, glacier and rain as its water supply source, while the Meuse contains no glacial water. As a result, the Meuse is characterised by bigger fluctuations in water supply than the Rhine. Fluctuations depend on the amount of rainfall in the river basin

**Runoff fluctuation**

A distinction is made between intermittent (periodic), permanent and interrupted rivers. Dutch rivers are all permanent rivers.

**Water balance or regime.**

The term water balance or river regime implies the quantity of water (discharge) as it changes during the course of a year or several years, and the influencing factors. Rivers are part of a river system consisting of main streams and tributaries. This system is usually arborescent or dendroid. Because smaller rivers flow together and become a larger river, the discharge increases downstream. The area where precipitation flows into a river is known as the reception basin or drainage basin, while the boundary line between two different drainage basins is known as a watershed. River runoff is determined by

- permeability of the rock floor or the soil
- climate
- vegetation

**Permeability**

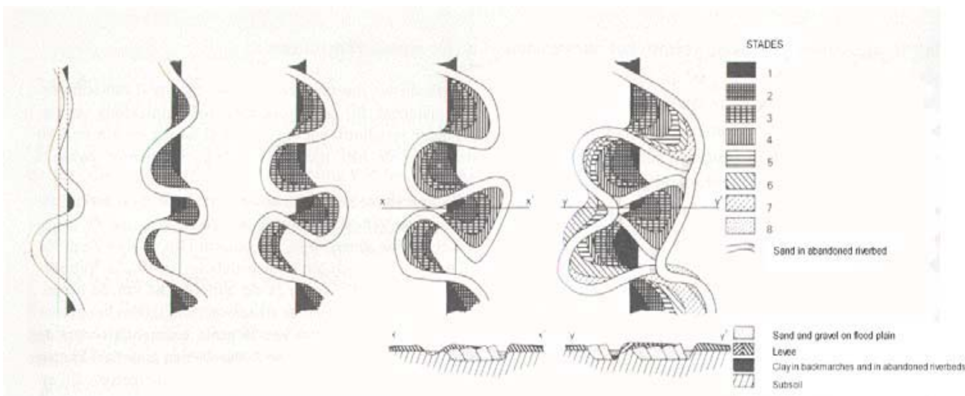
In impermeable soils or rocks, all precipitation flows immediately from the surface to the river, which may produce big fluctuations. This can be compared to an urban area whithout water buffering or absorbing capacity as a result of buildings and paved areas.

Water is stored in permeable rocks and soils and little by little it reaches the river and disappears

**Climate**
Climate is not only influenced by the amount of precipitation, but also by temperature, as this determines what form it takes - snow, ice or rain - and evaporation. The spread of precipitation during a year or several years is of greater importance than the average annual precipitation.

**Vegetation**
Vegetation greatly influences rainwater run-off. If there is vegetation, water will fall on the leaves first before entering the soil and passing through the root canels into the soil. In areas with little or no vegetation, there is a significant chance that water will not penetrate the soil at all, because rain erodes and/or cloggs up the soil.

**Current velocity**
In a straight channel with a symmetric cross section, the highest current velocity is in the centre, on or just beneath the surface. All rivers have curves due to differences in soil and differences rock hardness. In a river bend, the water will attempt to flow in a straight line, creating an accumulation of water on the concave bank and a shortage on the convex bank.





Present riverbed of the Mississippie

Riverbed 200-2000 years old

Riverbed 2000-3000 years old

*A.J. Pannekoek (1973)*

*Fig. 425 Meanders*

Water velocity is greater in concave banks than in convex banks, resulting in bed erosion and deepening. Concave bank erosion means that the river automatically moves the curves downstream. The line that connects the points with the highest current velocity is known as the thread of maximum velocity.

**Longitudinal profile**
The ideal longitudinal profile of a river is characterised by a steep upper part and an increasingly flat bottom part; the curve resembles a parabola. Most rivers have not yet reached this ideal form or have lost it due to tectonics, landslides, lava flows etc.

**Sedimentation**
A distinction is made between material, transport and deposition.

### 4.1.3 Landforms created by ice

The Netherlands was covered with a continental ice sheet at least once in its recent geological history. In addition to this ice period, the country also experienced several cold periods, which have also left their mark on the landscape. During these ice periods, the landscape was shaped and transformed by frost and ice. A flat area that was originally built up by rivers changed to a hilly area. As a result, river deposits were heavily disturbed and partially covered with moraines north of the Haarlem Nijmegen line. On its way through the Netherlands, the continental ice sheet made use of existing river valleys. These valleys were deepened and the valley walls were pushed up by the ice.
Big ice-pushed ridges usually consist of bow-shaped elongated hills with reasonably steep slopes on the inland ice side and slight slopes on the other side. The area north of the Haarlem-Nijmegen line is characterised by bigger and smaller ice-pushed ridges, with altitude variations of 50-100m for the bigger ridges, and 5-10m for the smaller ones.

The material transported by the continental ice sheets, the moraines (boulder clay in the Netherlands), is also found above this line. These moraines form the flat plains such as Drents Plateau. In the (earlier) river valleys, reshaped by the ice, the boulder clay is situated deep beneath the present-day surface.
In the periods following the ice ages, the land was shaped by other agents. As a result, remnants of the ice age have been levelled or disappeared.

**Glaciers and inland ice**
Glaciers are divided into catchment basins of snow and areas of melting ice.
There are different types of glaciers:

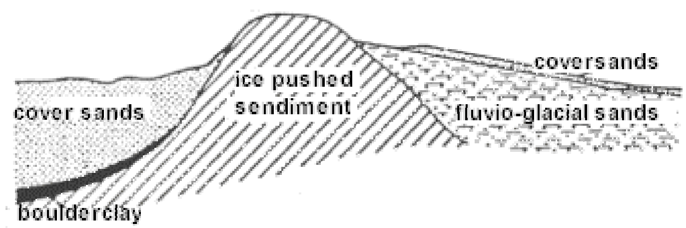
1. continental ice sheet, partly or completely covers the land, irrespective of the form and altitude of the subsoil, examples are Greenland and Antarctica, and, during the ice ages, Scandinavia and the Alps.
2. a catchment basin (firn plateau) with different glacier tongues; the melting area surrounds a communal intake area (continental ice sheets cover a huge area, while this form is modest in size)
3. valley glacier; this type of glacier follows the course of a valley and is fed from different catchment basins; a mountain chain protrudes above the actual area and the glacier, examples are the many glaciers in the Alps.

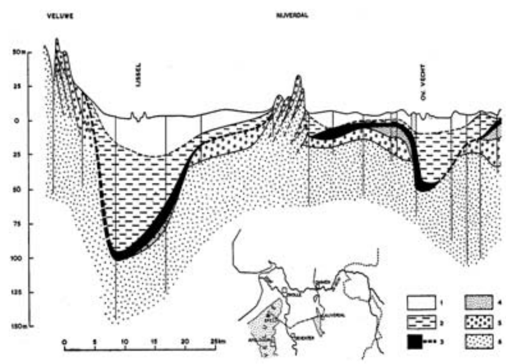
Glaciers are constantly on the move as a result of accumulation of snow and ice and gravitational force. This movement cannot be perceived with the naked eye, but can be measured using reference marks. Alpine glaciers can move at 30-150m a year, while glaciers in Greenland and Alaska can move at 30-50m a day.
The glacier’s journey across the subsoil causes erosion. The ice exercises an abrasive and grinding pressure on the subsoil due to the presence of rocks in the glacier, creating U-shaped valleys or trough-shaped valleys, and depositing moraines on both sides and at the end of the glacier.

**Moraines**
The sediment deposited by glaciers is known as moraine. A distinction is made between lateral moraines, end moraines, recessional moraines and ground moraines.
In principle, the Netherlands contains all moraine types. However, due to later erosion, the majority of this sediment has been cleared. The most prevalent and easily identifiable moraine type is ground moraine. It consists of slightly rounded debris and fine material, eroded and transported by the glacier travelling across the subsoil. This combination of debris and finer material has been blended into a mass, the ground moraines.

Pleistocene ground moraine is known as boulder clay in the Netherlands and can be found in the north and east of the country. The area also contains a variety of big boulders, used by the *Hunnebedbouwers* (megalith builders) to build their graves. Their parcels were surrounded by smaller boulders dug up from the fields. The composition of the boulders indicates that the ice originally came from Scandinavia.

**Ice-pushed ridges**
Glaciers, when moving across loose subsoil, transform this material into a ridge. The cross section of this ridge has an imbricate structure.



1. Eemian and younger
2. Fluvio-glacial younger than ground moraine (Drenthian)
3. Ground moraine (boulder clay) (Drenthian)
4. Fluvio-glacial older than ground moraine (Drenthian)
5. Brown sands with gravel (Needian Drenthian?)
6. White sands with gravel (Taxandrian and older?)

Thin vertical lines: bore holes

A.J. Pannekoek (1956)

*Fig. 426 Ice-pushed ridge*

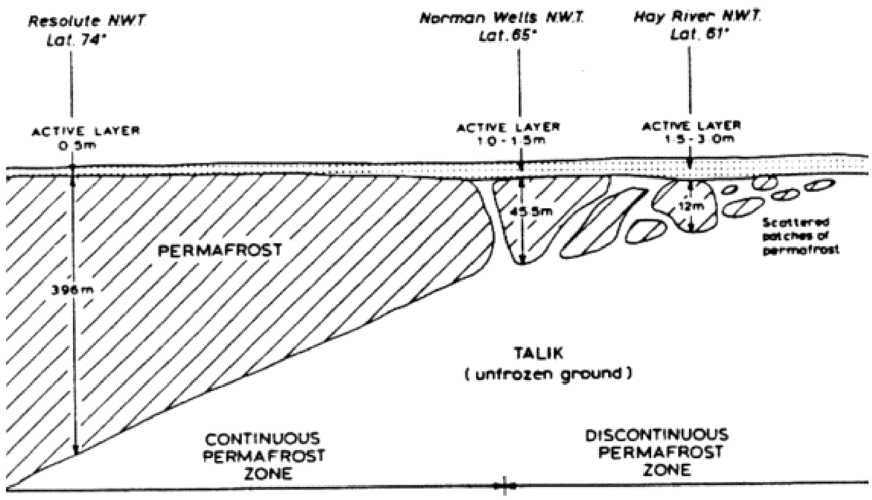
With their imbricate structure of older river deposits, ice-pushed ridges differ from end moraines which are an unsorted sediment, ranging from clay to boulders.
There is a variety of intermediate forms of end moraines and ice-pushed ridges.

**Fluvioglacial deposits**
In addition to sediments deposited directly by ice, we can also distinguish sediments deposited by ice and water (rivers). These are known as fluvioglacial deposits. We can distinguish the following forms:
1. extremely flat debris/sand till (sandr) deposited by the ice front
2. elongated winding ridges of relatively uniform width (esker). These were formed in glacial river tunnels situated in or beneath the glacier. They can be hundreds of kilometres long and dozens of metres high.
3. fluvioglacial deposits in the form of terraces between the glacier and the valley wall or the ice-pushed ridge, deposited by glacial meltwater streams on and along the surface of the glacier. No sedimentation takes place where blocks of ice (deadice) occur in a kame terrace or sandr. When ice melts it leaves behind depressions that become lakes, for example Uddelermeer and Zuidlaardermeer.

**Periglacial phenomena**
The continental ice sheet did not reach the Netherlands during all ice ages. Nevertheless, the temperatures in our country were low enough to cause the soil to freeze and produce periglacial forms. Conditions that define these structures are sub-zero temperatures for long periods during a year, the presence of soil moisture and little or no vegetation. The forms that can be categorized under periglacial phenomena are permafrost, frost mounds or pingos and frost cracks.

**Permafrost**
Permafrost is a thick subsurface layer of soil that remains below freezing point throughout the year, occurring chiefly underneath the tundra in the polar regions. In general, the top layer thaws in the warm season and freezes in the cold season. This alternating process of freezing and thawing

produces special forms and causes strong deformation of non-frozen layers. This phenomenon is known as cryoturbation, and is commonly found in many places in the subsoil of the Netherlands. The permafrost layer can be several hundred metres deep in the coldest areas, decreasing to 10-20 metres towards the edge. The frozen layers disintegrate into blocks in a variatey of sizes

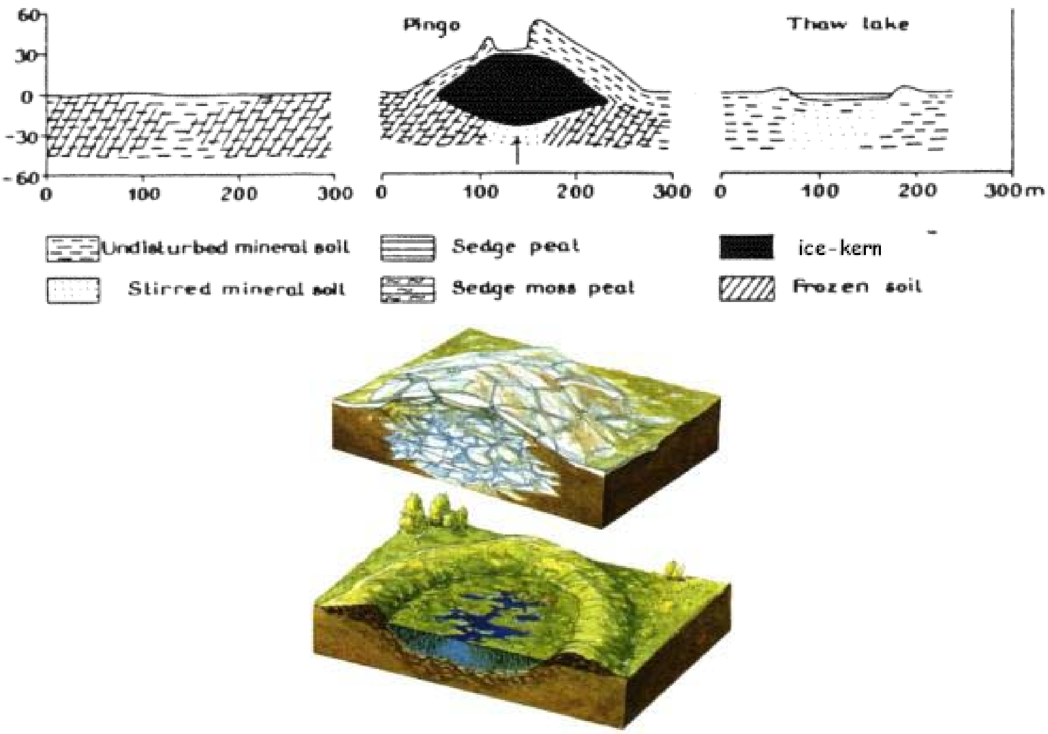


Cooke and Doornkamp (1974) p.22

*Fig. 427 Permafrost*

We are all familiar with the process of frost and thaw during a frosty winter, when roads are damaged by "surface thaw".
It is important that wires and buildings in permafrost areas are insulated to eliminate heat transfer to the sub soil, thus preventing subsidence by melting ice.

**Frost mounds or pingos**
Pingos are dome-shaped mounds with a core of ice which presses the mound upwards. They occur exclusively in permafrost areas. When the ice core grows the surrounding layer of soil breaks and the mound "caves in".




Hails (1977) p. 26, Standaardgidsen (?)

*Fig. 428 Pingo*

The same occurs when the ice core melts, leaving a more or less circular lake surrounded by an embankment. The size of these lakes varies from several metres to several hundreds of metres. There are many such lakes, often filled with peat, in the Netherlands. They are called *dobben.*

**Frost cracks**
A sudden drop in temperature of 20º C or more can create cracks in the ground due to water changing to ice. These cracks can be filled with other material from the surrounding area. Frost cracks occur throughout the Netherlands.

**The ice ages**
Many phenomena that are found in areas nearer or further away from present-day glaciers and continental ice sheets can only be explained by assuming that these areas were covered with glaciers and continental ice sheets in recent geological history. These phenomena show traces of glacial erosion, glacial and fluvioglacial sedimentation, periglacial circumstances, plant and animal migration, sea level fluctuations etc.
These cold periods are localised stratigraphically in the Pleistocene.
Significant processes of glaciation are referred to as an ice age or glacial age. Intermittent warm periods in a succession of glacials are known as interglacial periods. Warmer periods (of shorter duration) during an ice age are referred to as interstadial periods.
In the Netherlands and the surrounding regions glacial periods are identified and characterised by arctic or subarctic vegetation. This can be determined through a pollen analysis (palynology).

| *Time scale* | *Geological periods* | *Sediment* | *Archeological periods* |
|---|---|---|---|
| | SUBATLANTICUM | Younger young sea clay | |
| + 1200 | | | dikes around old kerns<br>Carolingian settlements |
| | | Young dunes<br>Older young sea clay | |
| + 300 | | | |
| + 100 | | | Roman settlements |
| ± 0 | | First young sea clay deposits | |
| - 700 | | | Iron Age<br>Bronze Age |
| | SUBBOREAAL | Bog/peat | |
| - 300 | | | Neolithicum / Young Stone Age |
| | ATLANTICUM | Old dune landscape<br>Old sea clay | |
| - 5500 | | | |
| | BOREAAL | Bog at large depths | |
| - 7500 | | | Mesolithicum (homo sapiens) |
| | PRE-BOREAAL | idem | |
| - 8000 | | | |
| | LATE GLACIAL (Young-pleistocene) | Cover sand and loess | |
| - 20 000 | | | |
| | WÜRM ICE AGE | Cover sand and loess | Paleolithicum (Neanderthal) |
| -200 000 | RISS ICE AGE | Ice-pushed ridges, boulder clay, boulders, fluvio glacial sand | |
| | OLD PLEISTOCENE | Gravel. sand and loan deposited by the old rivers (pre-glacial sand etc.) | |
| - 1.000.000 | | | |

S.F. Kuipers (1972)

*Fig. 429 Geological time scale*

### 4.1.4 Landforms created by the wind – aeolian processes

The Netherlands has two distinct landscapes formed primarily by the wind, i.e. the coastal dunes and the inland cover sand and loess areas in the eastern and southern provinces. Apart from these regions, dunes are found in all other sand areas of the Netherlands, including river areas.
In other words, dunes are created in all areas where sand drifts occur because there is no vegetation to retain sand.
The processes of erosion, transport and deposition are all influenced by the wind.

**Wind erosion**

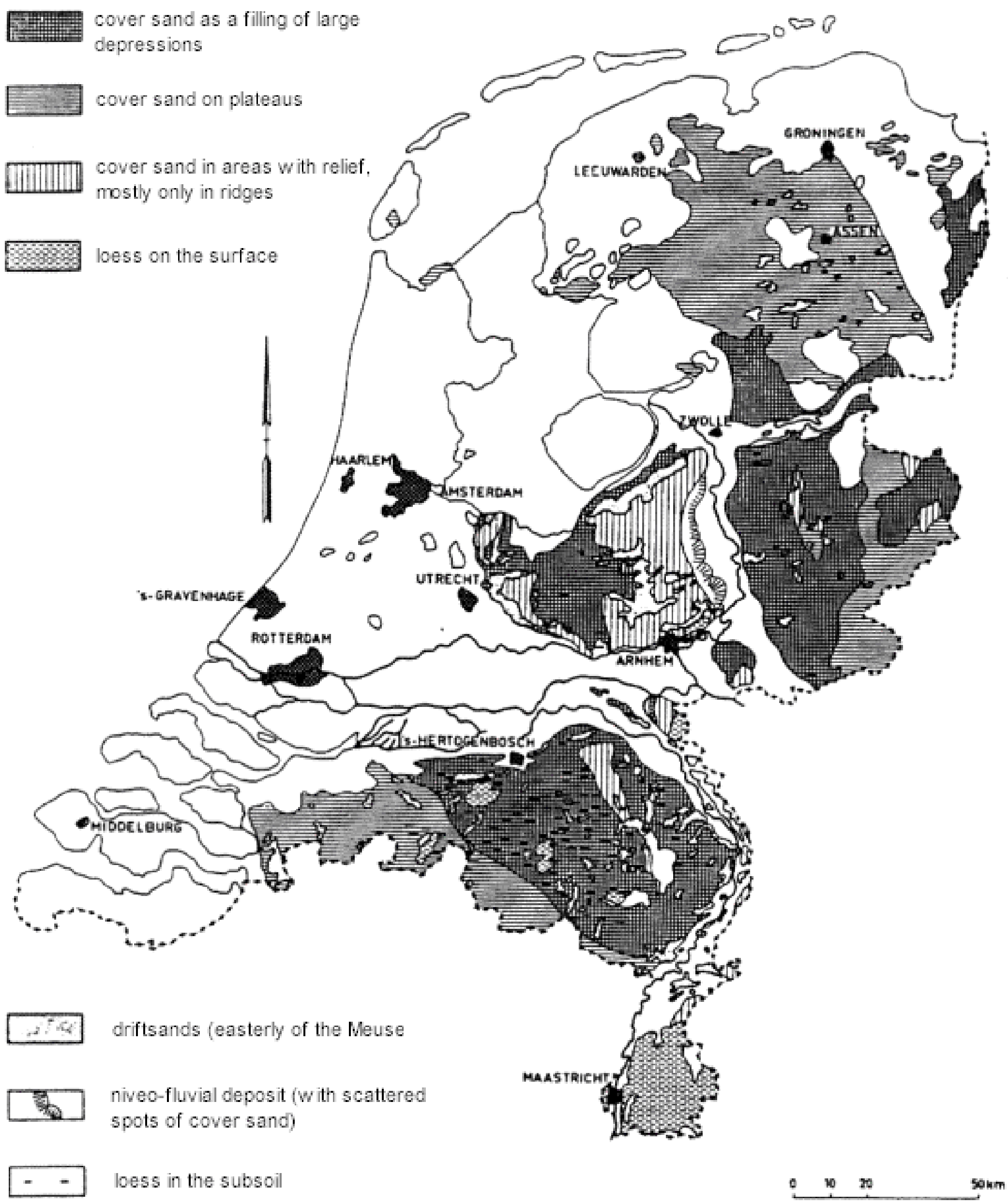
In wind erosion, a distinction is made between the lifting and removal (deflation) of material by the wind and material abrasion or damage caused by sand drifts (compare the sandblasting of buildings, metals, glass etc.) Both aspects usually occur at the same time. Limiting factors for deflation or drift are:

1. shortage of material
2. high ground water levels (wet sand does not drift)
3. gravel bars (gravel layers with ventifacts)
4. podzol soil profile, containing hardened B horizon.

**Wind transport or Aeolian transport**
Aeolian transport is comparable with transport in flowing water. The speed of fall of a material particle is far greater in the air than in water, which means that wind can transport small particles only. A particle with the same diameter requires greater stream velocity in the air than in water.

**Aeolian accumulation or deposition**
Wind-borne material is deposited in a random location. Transport can be high up in the air by turbulent currents or close to the surface. Aeolian deposits have a relatively wide spread across the earth's surface. Depending on particle size, they can be categorised into two main groups: sand and loess.

**Sand deposits**
Wind-borne sand particles can be deposited in several ways, for example in front of or behind an obstacle, or on an open plane like a blanket. It can also be "caught" and retained by vegetation.
This creates dune forms, including river dunes, free dunes and phytogenic dunes, cover sand and drift sand.
Phytogenic dunes predominantly occur along the coastline, where sand is retained by vegetation.
Free dunes are created on an open sand plane; they migrate and change form. Examples include crescentic dunes or barchan, transverse dunes and longitudinal dunes.
River dunes are situated along rivers; the sand comes from dried-up riverbeds. Many dunes were created in the Netherlands alongside the rivers during the ice ages. A river dune surrounded by river deposits from a later era is known as a *donk*.
Cover sand covers large surfaces like a blanket, covering all original forms. These cover sands were deposited in the Netherlands during the ice ages.
Aeolian sand is created by local drifting in a sand area after disruption of vegetation. Bear in mind that any disruption of vegetation in a sand area causes sand drifting of wind-deposited material.




STIBOKA (1962) p. 189

*Fig. 430 Aeolian deposits*

**Loess deposits**

Particle size analyses of loess have revealed a domination of the soil fraction of 16-50 micron.
A distinction is made between desert loess (continental loess) and loess originating from earlier periglacial areas: glacial loess. Continental loess was deposited on the leeward side of deserts (compare loess found in China on the leeward side of the Gobi desert). Glacial loess originates from areas without of vegetation during the ice age, with sufficient fine and loose material exposed to deflation.
It is generally accepted that there is a correlation between the northern boundary of Pleistocene loess deposits and the vegetation boundary of the last cold period, i.e. the northern boundary of the cold grass steppe.

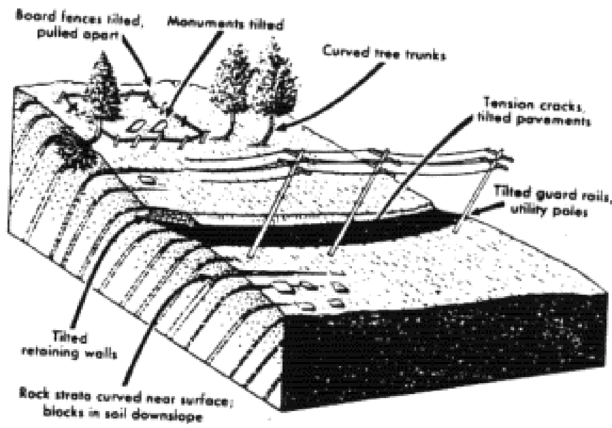
### 4.1.5 Landforms created by slope processes

Slope material loosened through weathering is prone to movement under the influence of gravity, provided that the material overcomes abrasive effects exercised on it. Abrasion is dependent on a range of factors including sloping, form and roughness of the terrain, and form and roughness of the loosened material. The greater the slope angle of a terrain and the steeper the slope, the easier rock will move. Critical slope angles depend on the roundedness and the weight of the material. In practice, this means that the critical slope angle must be taken into consideration when constructing banks for roads and railway lines, dykes, debris hills, and embankments of rivers, streams, channels and ditches, lakes and ponds. Another point to be taken into consideration is that space for the slope must be reserved. When these conditions are satisfied, there is no risk of movement along the slope
Water plays a vital role in mass movement. Flow processes are created as the quantity of water in the groundmass of the slope increases. The water acts as a lubricant for the groundmass.
Slope vegetation encourages slope stability, as plants are able to retain soil through their root system. In addition, precipitation does not fall on the soil directly, but falls on the plant first and makes it grow. The surplus of rainwater in the soil is added to the groundwater

The following slope processes have been identified:
1. falling and rolling of stones under the influence of gravity; limited to steep slopes - rock fall, stone avalanches.
2. sliding or slipping; the downward slipping or sliding of rock debris or ground mass sliding retains its original form; landslides
3. creeping (soil creep); slow movement of ground mass downslope due to the alternating process of expanding and shrinking (wet-dry; frost-thaw). This is the most common process in the Netherlands.
4. flow; as a result of saturation of slope material with water, mass obtains a plastic consistency and begins to flow; the internal cohesion is lost. This process takes place in the Netherlands.
5. surface wash; in this process, loose material is transported downslope through rainwater; when this water accumulates in streams and rivers, it is a fluvial process. This process takes place in the Netherlands.
6. soil creep; (extremely) slow downslope movement (creeping) under the influence of gravity; mass cohesion is maintained. This process takes place in the Netherlands.
7. solifluction; see creep. In this process, water and/or ice act as lubricant.

When the amount of water increases and begins to dominate, we are no longer dealing with slope processes but with fluvial processes; i.e. processes influenced by flowing water in the form of rivers, streams etc

The stability of both natural and manmade slopes can be influenced by providing for soil/slope vegetation. This explains why road banks in the Netherlands are often grass-covered. In areas with natural slopes such as mountainous areas, all steep slopes have been forested as much as possible. Planted slopes could have prevented the disastrous floods in northern Italy in the spring of 1994. This natural disaster is additionally attributable to the construction of an increasing number of ski runs, some of which were built in wholly unsuitable areas. Such activities cause significant disruption to and subsequent absence of vegetation, which makes water regulation extremely difficult. Other natural disasters, such as landslides, can be prevented by not building on steep slopes. Almost every year, landslides occur in countries where the poor build their huts on slopes unsuitable for building. These slopes are the 'left-overs' of open space in a city area. You can find these nearly everywhere in South America, for example Rio de Janeiro and Sao Paulo in Brasil, and Caracas in Venezuela, but also in the United States in the hills around the city of Los Angeles




Cooke and Doornkamp (1974) p. 146

*Fig. 431 Slope processes*

| Nature and rate of movement | | | With increasing ice content | Rock or Soil | With increasing water content | |
|---|---|---|---|---|---|---|
| | Impercep-tible | | SOLIFLUCTION | CREEP | SOLIFLUCTION | |
| FLOW | slow to rapid | GLACIAL TRANSPORT | debris avalanche | | earth flow mud flow debris avalanche | FLUVIAL TRANSPORT |
| SLIDE | slow to rapid | | | slump debris-slide debris-fall rock-slide rock fall | | |

Bloom (1973) p.42

*Fig. 432 Classification of slope movements*

#### 4.1.6 References to kilometres: geomorphological landscapes

Bloom (1973) *The service of the earth* (London) Prentice Hall International.
Cooke and Doornkamp (1974) *Geomorphology in environmental management* (Oxford) Clarendon press.
Edelman, C.H. (1950) *Soils of the Netherlands* (Amsterdam) North-Holland Publ. Co.
Escher (1962) *Geologie van Nederland [Geology of the Netherlands].*
z *Applied geomorphology* (Amsterdam) Elsevier.
Kuipers, S.F. (1972) *Bodemkunde* (Culemborg) Tjeenk Willink ISBN 90-11-54410-2 (Bibliotheek Moens).
Pannekoek, A.J., Ed. (1956) *Geological History of the Netherlands* ('s-Gravenhage) Staatdrukkerij- en Uitgeverijbedrijf (Bibliotheek Moens).
Pannekoek, A.J., Ed. (1973) *Algemene Geologie* (Groningen) Tjeenk Willink ISBN 90 01 68975-2 (Bibliotheek Moens).
Standaardgidsen (?) *Brussel en Wallonië* (Antwerpen) Standaard Uitgeverij (Leerstoelbibliotheek).

STIBOKA (1962) *Bodem van Nederland* (Wageningen).
Sticht.Wetensch.Atlas_v.Nederland (1985) *Atlas van Nederland. Deel 13. Geologie* (Den Haag) SDU ISBN 90-12-05013-8 (Leerstoelbibliotheek).
Sticht.Wetensch.Atlas_v.Nederland, Berg, v.d., Steur and Brus (1987) *Atlas van Nederland. Deel 14. Bodem* (Den Haag) SDU ISBN 90-12-05014-6 (Leerstoelbibliotheek).

## 4.2 Metres: soil units

### 4.2.1 Soil unit

Soil with almost identical profile characteristics is known as a soil unit. These soil units are determined spatially and classified through soil drilling and landscape features and then mapped. First this work was carried out by the Stichting Bodemkartering (STIBOKA – Netherlands Soil Survey Institute). Now it is done by Alterra. The disadvantage of soil maps is that they only provide information on the top 1.20m of the earth's crust, which is insufficient for urban development purposes.
For soils deeper than 1.20 m, consult the geological maps and soil drillings, the results of which are housed at the Rijks Geologische Dienst (Geological Survey of the Netherlands) in Haarlem. A complete set of 1:50,000 soil maps of the Netherlands is available, but a set of geological and geomorphological maps covering the whole country still has to be completed. These maps will also be issued as 1:50,000 scale maps. More detailed information is available from some municipalities, or from special surveys and driliings.

### 4.2.2 Soil group

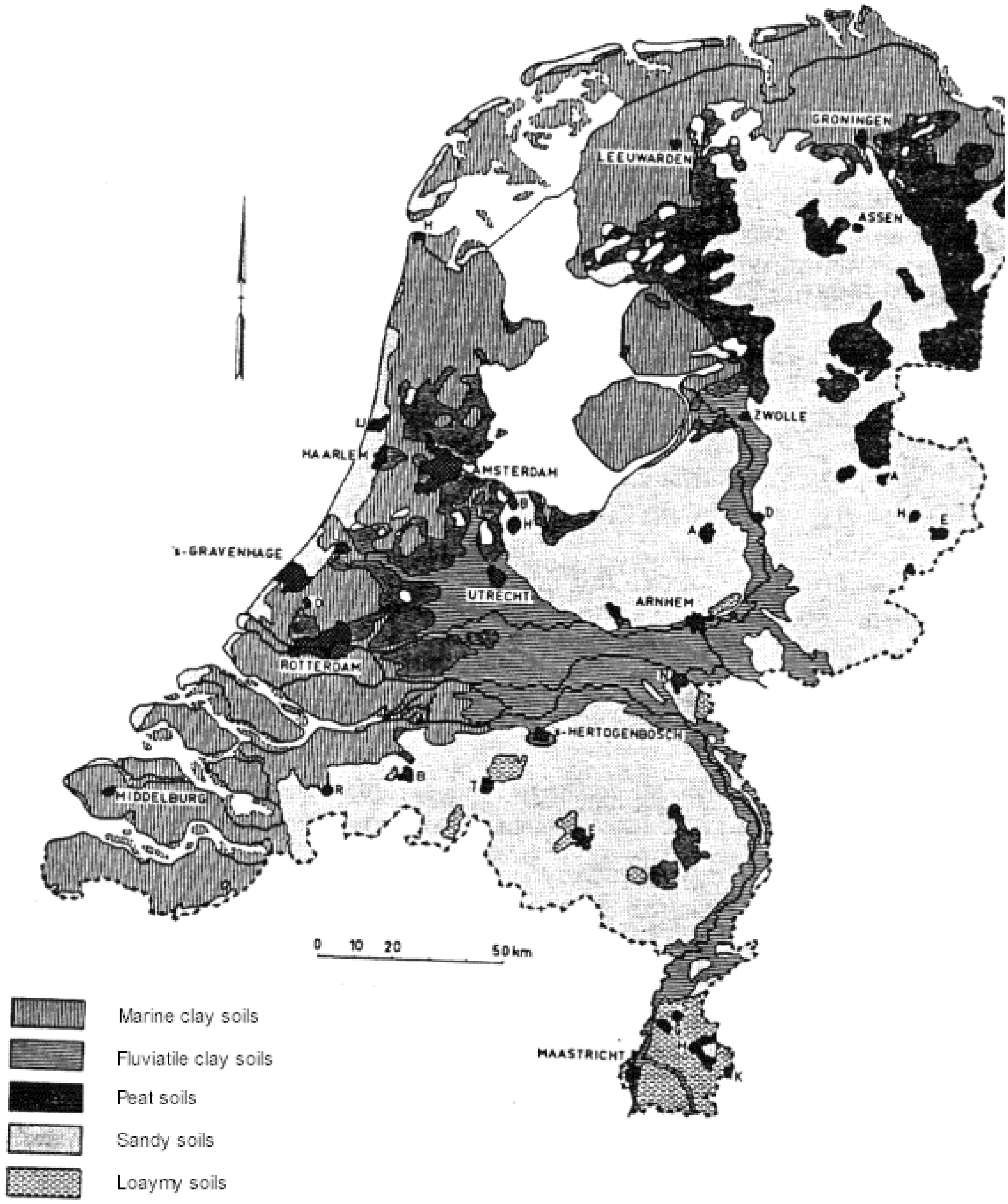
Soil groups can be divided into different types:

- clay soils
- loamy soils
- sand soils
- bog soils or peat soils

Basically, each of these soils have the same composition in terms of particle size. For further information on particle size and naming, please turn to page 244. Peat soil must contain 22.5% or more organic matter. Peat is formed locally from decomposed plants, unlike clay, loam and sand.

### 4.2.3 Pedological landscapes

In addition to classification according to particle size, pedological landscapes are categorised according to sedimentation (clay, loam and sand) and/or origins (peat). This classification overlaps with geomorphology. Geomorphology is primarily concerned with interpreting topographic forms and their history.




STIBOKA (1962) p. 3

*Fig. 433 Pedological landscapes*

### 4.2.4 Clay soils

Clay soils are sea and river deposits, formed in calm water. The lighter soils (sandy clay) border a stream or river, while heavier soils (clay) can be found further away from the river.
We can distinguish the following types of sediments:

1) Water deposits in tidal areas (ebb and flood);
2) Washover deposits overlying peat;
3) Coastal deposits;
4) Subaquatic deposits;
5) River deposits.

These different types of deposition have created different types of clay landscapes.

**Water deposits in tidal areas.**
We can distinguish three stages in this type of vertical accretion:
- sand flat or tidal-flat sand,
- ooze or mud flat, without vegetation
- kwelder (term used in North Holland for salt marsh] or schor [term used in province of Zeeland for salt marsh), with vegetation.

Vertical accretion in free water initially creates a sand flat or tidal flat sand. Except at extremely low tides, this sand is usually below mean-tide level, and is barren of vegetation. Gradually, the area will rise above mean-tide level and produce vegetation, for example glasswart, which decelerates the flow of sea water. This encourages the settlement of finer muddy material as well as sand. The terrain usually rises above the mean-tide level at ebb. This is known as an ooze or tidal flat area. Gradually, this ooze is raised due to further vertical accretion, producing more vegetation such as glasswart, cord-grass and finally salt marsh grassses. Areas with brackish water, for example the Biesbosch, a wetland area in the province of Brabant, are characterised by cane and wicker. The terrain is submerged only at high tide. This is known as a kwelder (salt marsh), a gors or a schor. The vegetation helps calm the water at high tide. During this stage both clay and fine sand are deposited.

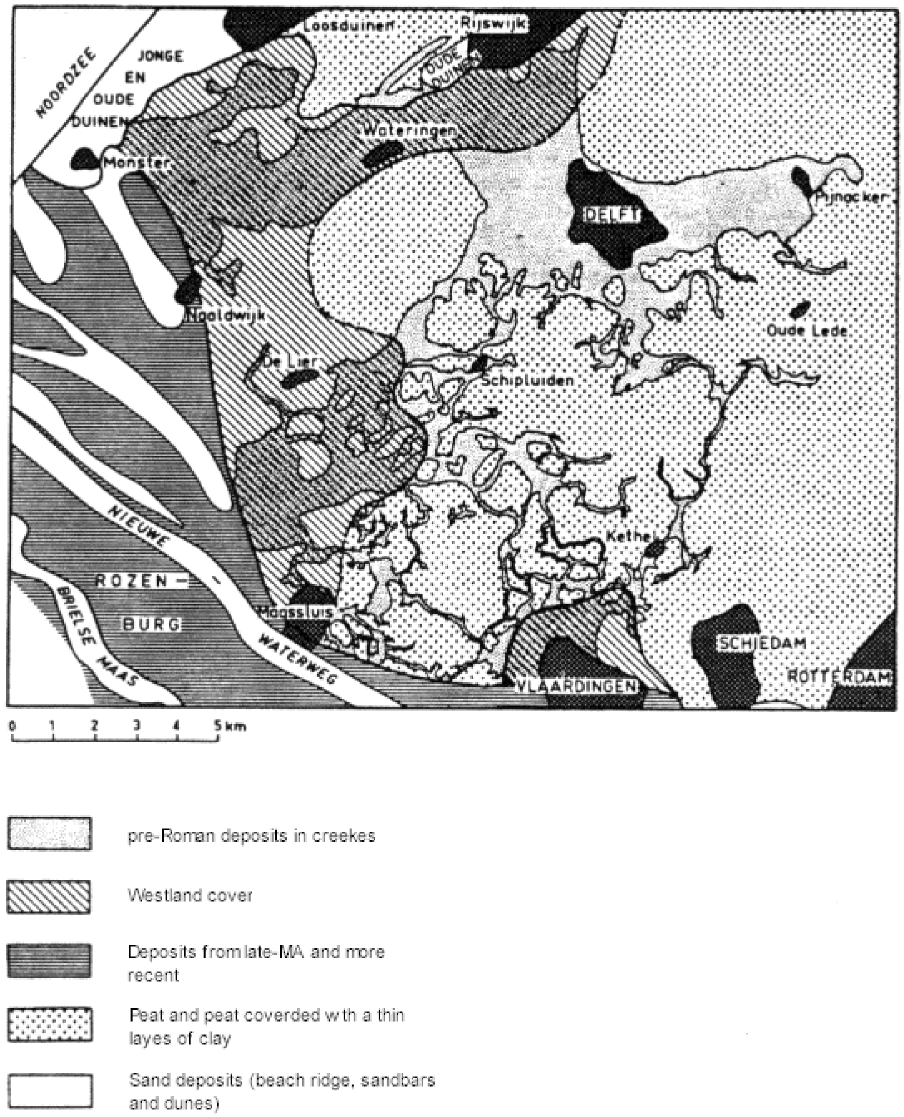
In this type of vertical accretion, we can also identify accretion and aggradation.
Accretion is characterised by silting up against the existing land, usually dyked land. Following dyking of this new accretion, heavier soils border the old dyke, and lighter soils the new dyke.
Aggradation takes place in free water. The centre consists of a sand flat surrounded by streams. The heaviest soils are located in the aggradation core, while the lighter soils are found along the borders.
These free water deposits have produced creating the flat polder landscapes, such as in:

| SOUTH-WEST NETHERLANDS | NORTH NETHERLANDS | OLD POLDERS |
|---|---|---|
| marsh soils | gors soils (salt marsh)<br>young *kwelder* soils (high salt marsh) | *Kwelder* soils (high marsh)<br>Shallow soils |
| shallow soils | young sea bosom soils | tidal flat soils (‘wad’) |
| stream bed soils | | Moddergronden (mud soil)] |

*Fig. 434 Deposits in free water*

All the above listed soil types are clay soils with more or less good properties; sand is found underneath the clay layer.

**Washover deposits overlying peat**
When the sea or a river penetrates a peatland area, the peat is carried away through the breach channels. The remaining peat between the streams is situated higher than the stream level, and is subject to flooding from the streams at extreme high tide. This occurs directly on the salt marsh, creating reasonably heavy clay blankets on the peat.



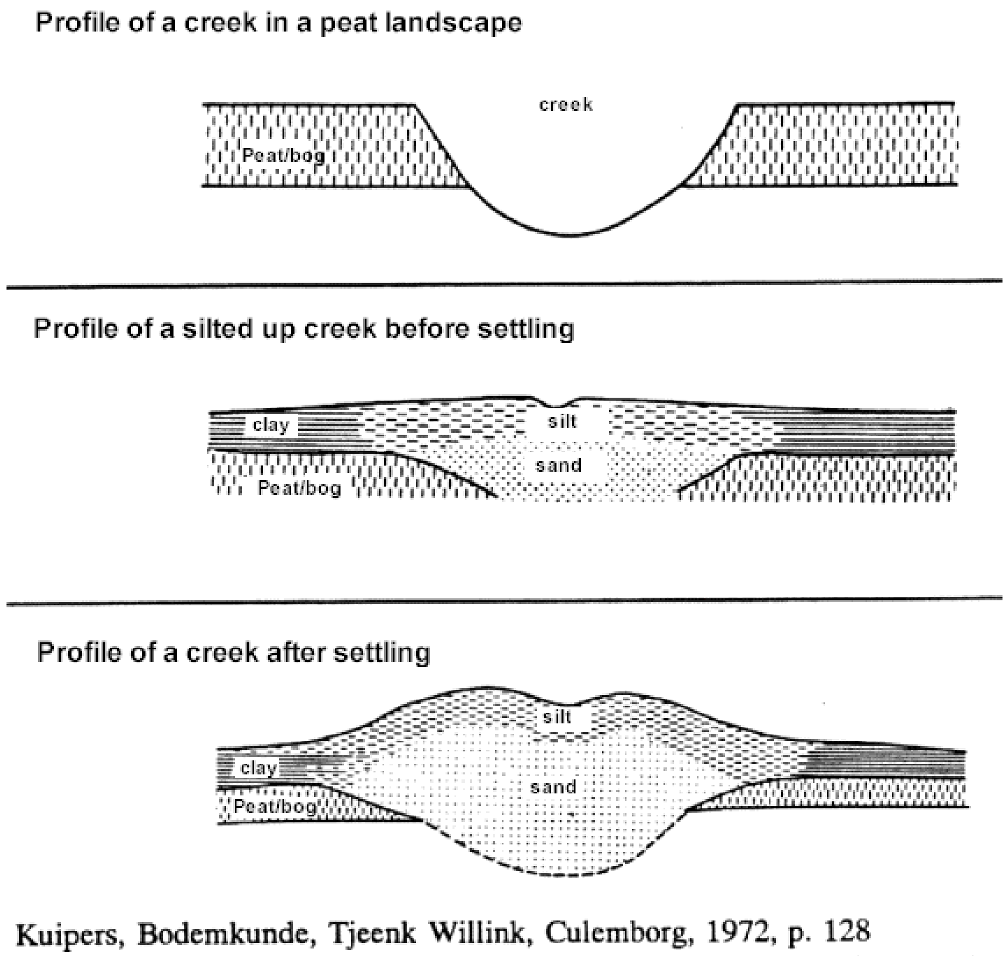

STIBOKA (1962) p. 41

*Fig. 435 Streams in the peat landscape of the Westland*

The creeks themselves gradually silt up over time. Once the area is drained, the peat settles very quickly.

As earlier creeks contain little to no peat, this area is subjected to significantly less settlement than the terrain beyond the streams. As a result, the earlier, silted-up creeks create a ridge formation in the landscape, while the intermediate clay-on-peat soils form the low areas.

This phenomenon is known as inversion of the landscape.




S.F. Kuipers (1972)

*Fig. 436 Development of transverse profiles of a creek*

In the north of the Netherlands, seawater entered peatland areas less forcefully, with the shallow (the Dutch shallows = W*addeneilanden)* and the coastal marsh bars acting as a protective barrier. As a result, the area is characterised by clay-covered peat and an absence of large creek ridges. There are however slight altitude variations as a result of inversion.

**Landscapes and soil series**

The following soil series can be distinguished in the inversion landscape of south west Netherlands:

- creek ridge soils,
- clay-on-peat soils,
- clay shallow/shoal soils.

Old creek ridge soils: these are elevated non-calcareous loam soils containing calcareous silted sand in the subsoil.

Old clay-on-peat soils: these are non-calcareous, moderately heavy, low-lying clay soils with peat subsoil.

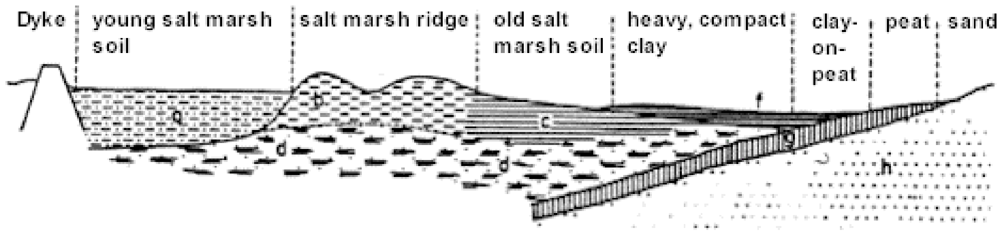
Clay shoal soils: these are non-calcareous loam soils with an anomalous, extremely dense clay bank with a poor structure in the subsoil.

The following soil series prevail in the north of the Netherlands:

- clay-on-peat soils,
- *roodoorn* soils,
- woodland soils,
- heavy, compact clay soils (clay-on-peat soil, *knipklei* in Dutch).

*Roodoorn* soils: red-brown coloured, reasonably drained clay-on-peat soils, dusty and sandy in dry state.

Wood soils: clay soils with a higher organic dust content.




Cross section of north marine clay soils

a. calcareous clay or silt
b. silt deficient in lime
c. clay deficient in lime
d. stratified calcareous shallow soils (sand containing silt and silt
f. heavy, compact clay
g. peat/bog
h. sand plating from the Pleistocene

S.F. Kuipers (1972) p. 160

*Fig. 437 Profile of the northern sea clay area*

**Coastal deposits**
The daily ebb and flood movements create seaward and landward currents moving in a perpendicular direction to the coastline. The transition from ebb to flood is characterised by calm water, creating the right conditions for sand and silt deposits. This process explains the offshore bars that run parallel to the Dutch coastline, as well as the beach ridges with intermediate beach plains. Sand drifting encouraged dune formation from and on these beach ridges.
The process outlined above also explains the creation of marsh bars with intermediate kwelder (salt marsh) running parallel to the old Friesland-Groningen coast line. Here, however, the material is silt/clay instead of sand. Sedimentation occurred behind the shallows in a calmer environment, creating the marsh bars (made of light loam soils) and kwelder (salt marsh) basins (made of heavier soil).

**Subaquatic deposits**
In the Noordoostpolder (North-East Polder) and in Flevoland, most soils were created by silt sinking to the floor of the former Zuiderzee and the later IJsselmeer as a result of extremely calm conditions. The heaviest soils are found nearest to the "oudeland" (old land), with the soils becoming gradually lighter towards the north, the sea. These deposits are characterised by a significant uniformity in a horizontal direction.
In vertical direction, i.e. in the soil profile, several layers can be identified. Humus rich material makes up the bottom layer, created at the same time as the Zuiderzee as a result of a large peat bog being affected by the sea (peat and detritus). The following layers contain deposits from the Zuiderzee period, with sometimes a thin depositary layer from the IJsselmeer period on top.

**River deposits**
We can distinguish the following sedimentary processes:
- meandering rivers,
- braided rivers (no longer occur in the Netherlands).
- tidal rivers,

The soil series in the region of meandering rivers and tidal rivers are:
- Natural levee soils: elevated soils with a heavier topsoil, gradually transformed into a lighter subsoil.
- Backmarsh /swamp soils: heavy to extremely heavy clay soils with occasional peat formation.
- Flood plain soils: formed next to river after dyking.
- Flood soils: caused by dyke breaches.

**New classification and naming of clay soils.**
Brik soils: these occur in some (of: a number of ) older river deposits in Limburg and the Achterhoek (so-called river loams). These soils contain a heavier layer, an illuvial horizon of clay in the subsoil. This layer is known as clay plan or textural B horizon.

*Eerd* soils: these occur locally in the clay areas of West-Friesland and the Old Polders. These soils have a thick, clearly dark, humus-rich topsoil.

Vague soils: all soils without a clear profile development, i.e. with no clear horizons and no typically clear topsoil. The majority of sea and river clay soils belong to this order.

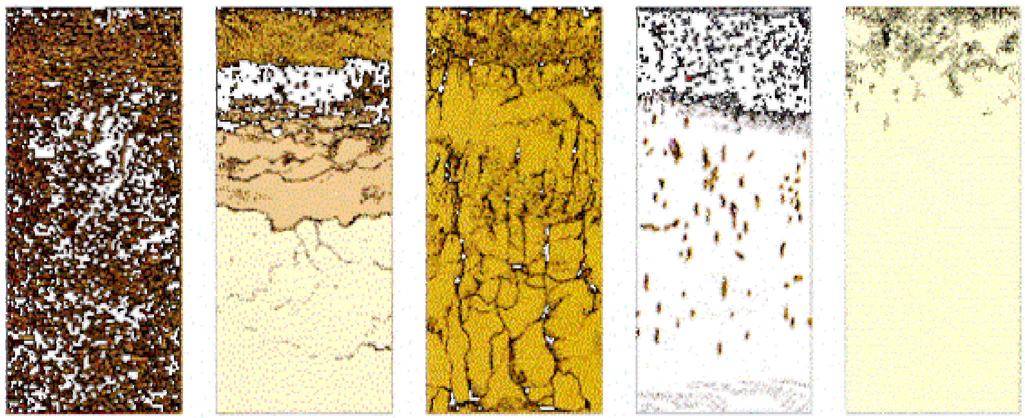
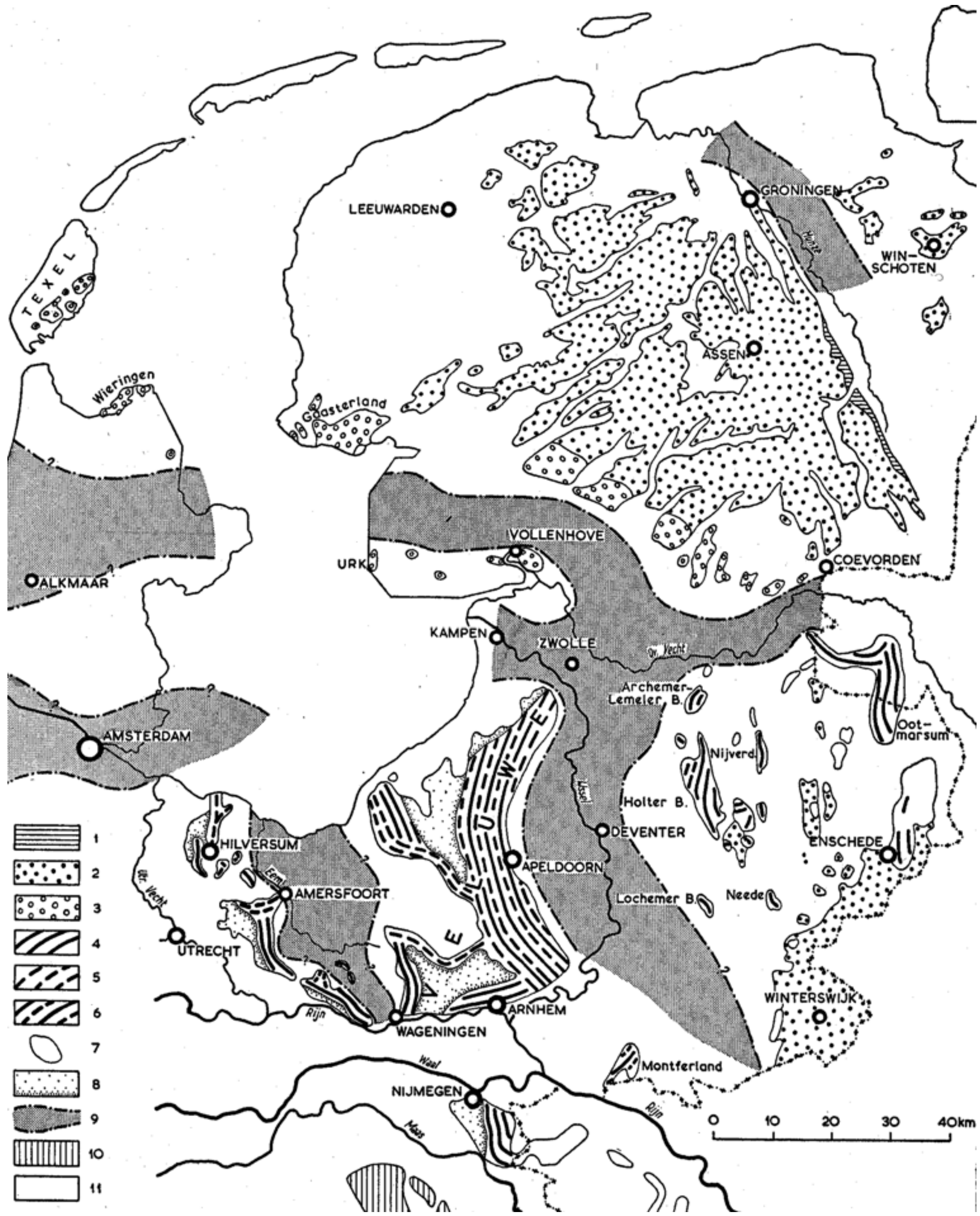

moorland soil podzol soil illuviated clay soil eerd soil vague soil
Sticht.Wetensch.Atlas_v.Nederland, v.d. Berg, Steur and Brus (1987) p.11

*Fig. 438 Prototypes of soil classification*

### 4.2.5 Sand soils
While part of the Dutch sand soils is deposited by the sea and rivers, much sand is also borne by the wind.
Due to the different geneses, we can identify several typical sand landscapes:
1. coarse-grained sand, river terraces and ice-pushed ridge landscapes;
2. cover sand landscape;
3. drift sand landscape ;
   a. inland dune landscape or drift sand landscape
   b. holocene dune and sea landscape.




1. Fluvio-glacial older than ground-moraine
2. Ground-moraine (boulder clay) at the surface or under thin coverzand
3. Ground-moraine of great thickness (terminal moraine according to A. Brouwer)
4. Ice-pushed ridges, phase A (after Maarleveld)
5. Ice-pushed ridges, phases B + C (after Maarleveld)
6. Ice-pushed ridges, consorted in phases A and B + C
7. Ice-pushed ridges, strike not indicated
8. Main fluvio-glacial deposits (after Maarleveld)
9. Buried valleys with deep boulder clay
10. Uncontorted fluvial Needian-Drenthian
11. Deposits younger than Drenthian

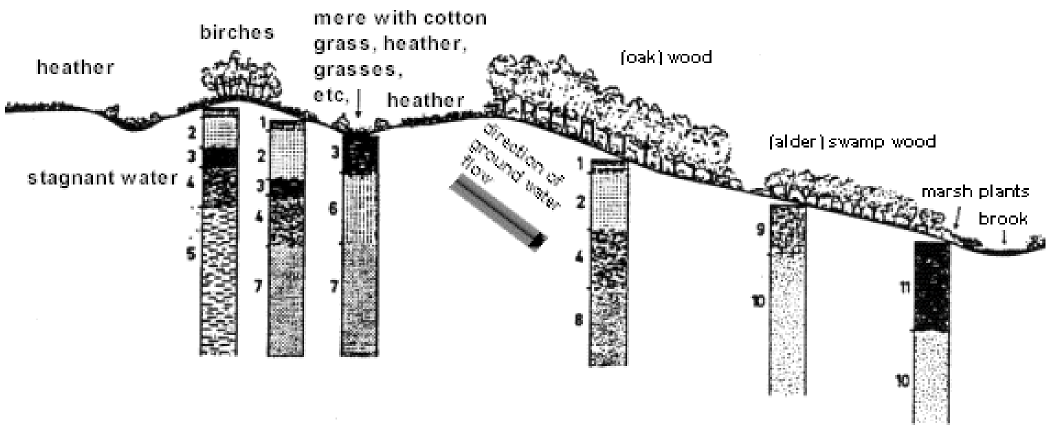
STIBOKA (1962) p. 184

*Fig. 439 Ice-pushed ridge landscape Stiboka, Bodem van Nederland, p.184*

**Coarse-grained sand, river terraces and ice-pushed ridge landscape.**
The flat river terraces landscape is characteristic of several places in central Brabant and the Peelhorst in eastern Brabant. The ice-pushed ridge landscape was created in regions where coarse-grained and loamy deposits of pre-glacial rivers were pushed up by glacial mass during the third ice age or Riss. Examples of such landscapes are: the Utrechtse Heuvelrug and de Veluwe, Montferland,

Overijssel, Rijk van Nijmegen, het Gooi). These soils, originally river sands and loams, are generally chemically richer than cover sands.
However, from an agricultural point of view their quality is poor, due to their susceptibility to drought. As a result, they tend to be characterised by woodland and heathland.

**Cover sand landscape**
Cover sand landscape embraces the majority of our Pleistocene sand soils. A pure cover sand landscape is neither entirely flat nor characterised by significant altitude variations. It is slightly undulating. Sand composition is generally uniform; it was deposited by the wind on older deposits of divergent character. It is finer than sand found in ice-pushed ridge landscape. There is however a slight variation in soil texture (the largest soil fraction lies between 105 and 150 mu).
Through the cover sand landscape run relatively wide valleys; these were created in earlier times, when large water masses had to be discharged. The width does not correspond with the size of present-day rivers. The area is additionally characterised by many (elongated) depressions between the cover sand ridges.




1 heather sods
2 bleached layer
3 iron pan
4 iron pan
5 yellow-brown sand with brown fibres
6 brown sand
7 yellow sand
8 red or yellow sand
9 humus-rich sand
10 grey sand
11 peat/bog.

(...)

*Fig. 440 Profile of plateau brook valley with vegetation*

**Original vegetation and habitation.**
Originally brook valleys have had a marshy character. The lowest places in the valley provided ideal growing conditions for peat, while the more elevated terrains saw the growth of extremely dense almost impenetrable marshy woodland. Plant growth was encouraged by the relatively nutritious ground water flowing down from the higher plains and water from the brooks. Higher up the stream, tall forests flourished along the borders of the valley. The forested character of the area is characterised by the regional place names, such as the Friesche Wouden, Westerwolde in Groningen, Paterswolde, Ruinerwolde in Drenthe, Woudenberg, Renswoude in the Gelderse Vallei, and Sliebengewald in northern Limburg (woud, wolde, woude and wald are different words for wood). All these places are situated on moist sand soils. The terrain beyond the valleys is reasonably flat. There is poor water runoff and the water is poor in nutrients, which is reflected in the plant species. The moist low areas were covered with bell heather, cotton grass, tubular straw, etc; while dryer and higher-lying areas saw the growth of ling, birch and pine.

Man settled in the fertile areas that were not too moist, i.e. along the embankments of the rivers or on the ridges in cover sand soil areas. Here they cleared the forest, built settlements and reclaimed farmland (known as es, eng or enk). In the course of the centuries, these fields were considerably elevated as a result of regular supply of heather sods and sand, used as litter in sheep folds. Lower-level strips of land were reclaimed and used as grassland. The terrain bordering the stream was too moist and inaccessible, so that the ‘forests’ remained in tact for some time. This terrain was later turned into grassland.

Sheep were set to graze on the poorer soils. Because sheep graze bare all the shoots of young trees, these areas were converted into heather land. As soon as the sheep disappeared, a poor forest of pine and birch developed. There was a strict correlation between the surface area of the field and the quantity of manure and therefore the number of sheep and the area of heathland the farmers had at their disposal. They were therefore unable to reclaim heathland into arable land or grassland at random.
Since the introduction of artificial fertilisers, from approximately 1900 onwards, these soils have been turned into large-scale farming land (reclamation soils).

**Drift sand landscapes.**

a. Drift sand landscape is spread across cover sand areas and can also be identified in the ice-pushed ridge landscape, for example along the banks of the river Maas and the Overijsselse Vecht, in the Land van Maas en Waal, Drunense Duinen, on the Hoge Veluwe (for example near Kootwijk), and along the Hondsrug (Drouwenerzand), etc. These drift sands are much younger than cover sands. They were formed in the Holocene epoch, when the wind blew away the soil, which had become bare due to man-made damage to natural vegetation (deforestation, forest fires, intensive heather grazing by sheep). Other causes included drought or sand drifts in dry river beds. The wind-borne sand was deposited a little further, on lower and moist plains with substantial vegetation, creating dunes from drift sand. The original, humus-rich soil profile can often still be found underneath the drift sand profiles. The once elevated, dry regions from where the sand had originated, now became the lowest sections of the terrain. In terms of pedology, drift sand soils are relatively young, and are characterised by little profile formation.

b. The Holocene dune and sea landscape soils are even younger than the sand soils mentioned above. They are found along the North Sea coast.

Dune landscapes can be categorised into:

- young dune landscapes
- old dune landscapes.

Young dune landscapes to the south of Egmond consist of calcareous sand, and to the north of non-calcareous sand. The average particle size of the sand is 200 mu. Hardly any soil formation has taken place.

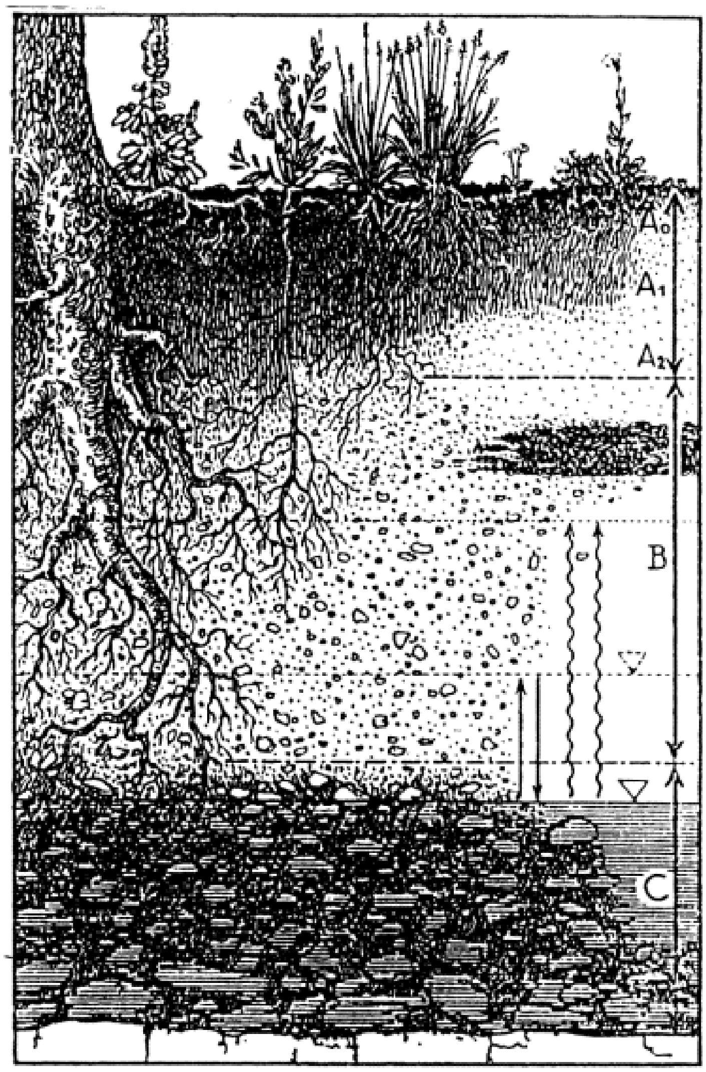
Old dune landscapes consist of non-calcareous (decalcified) flat beach ridges ('geest' - sandy soil between the dunes and the polder) with the intermediate low beach plains. This landscape dates from 2300 years BC. The beach ridges are often levelled to obtain flat plots for bulb cultivation and sand for the cement industry.
Century-old forest vegetation has created a forest profile in the soil, especially in moist sections of this area.
There is a strong correlation between the quality of beach ridge soils and the ground-water table. This soil is ideal for bulb cultivation when the ground-water table is situated at 50 - 60 cm below ground level, and there are no disturbing layers (for example silt- or humus layers). Fruit culture is also possible, although this requires good groundwater management (no strong fluctuations). This has been achieved in the province of Zuid-Holland by controlling the polder level. In the province of Noord-Holland the water is discharged in a natural way. The dune water piping system draws from the groundwater reservoir in the dunes. In order to access groundwater, partial sand excavation was commenced in several dune sand areas. These are known as ‘zanderij’.
Beach plains are usually characterised by clay deposits or peat formation. They are predominantly used as grassland. Marine sand soils have been discussed in the section on shallow soils of sea clay.

**Soil-forming processes in sand soils.**
As can be deduced from the above, the most highly developed soils were created by sand deposits, as these were longest exposed to soil-forming processes. For sand soils, the most important processes are:

1. illuviation and eluviation;
2. accumulation of soil-organic matter.

**Illuviation and eluviation**
Sand soils can be subject to eluviation and illuviation of iron, aluminium and organic matter. This produces podzol soils. These soils contain A2-horizon, which is bereft of iron, aluminium and soil-

organic matter, and are found directly under the humus-rich topsoil A1, the surface horizon (see *Figure 21*). The layer below A2 is known as the B-horizon, which contains extra organic matter and occasionally iron and aluminium.




A.v. Kruedener (1951)

*Fig. 441 Soil profile*

A1 darker coloured horizon, with organic matter accumulation
A2 horizon, subjected to eluviation; usually lighter in colour than A1 to ash grey (podzol), eluviation consists of organic matter and/or minerals, such as calcium carbonate, iron, aluminium and silt
B illuviation horizon; dark to black in colour, illuviation of matter mentioned under A2, can be cemented to a pan
C horizon of unconsolidated material, also known as parent material
G reduction horizon.

The G horizon contains ground water; it can be the initial layer in every horizon. In A2G and BG for example, the reduced horizon can be identified by its blue-grey colour, caused by a reduction in iron (FeO); the transition is known as the ground-water table. Above the ground-water, the profile first shows alternating rust and grey spots and above that a uniform rust colour caused by oxidation rust $Fe0_2$. (NB these colours only occur in iron-rich soils).

Podzol soils are submitted to the processes of eluviation and illuviation during a long period. The result is a mature soil profile with all the discernable soil horizons. The B-horizon of illuviation horizon is often hardened by illuviated organic matter and iron. The hardened layer is called hardpan or duricrust ('oerbank' in Dutch).
The most complete soil profile in sand soils is the podzol soil profile

In principle, each soil profile contains all soil horizons. However, due to too short a period of soil formation, they are not yet identifiable as such. This is especially applicable to the situation in the Netherlands.

We can distinguish two types of podzol soils:

- moder podzol soils;
- humus podzol soils,

Moder podzol soils were formed on relatively mineral-rich sand soils, for example on the submerged pre-glacial Veluwe (originally river sands) and loamy sand soils. Due to the slightly higher pH value of these soils, they were not subject to extreme forms of illuviation and eluviation.
There are no clearly identifiable separate A, B and C-horizons, i.e. there are no bleached layers and iron pans. The A-horizon still contains traces of iron. The removal of organic matter from this layer through calcination produces a less red-brown colour than in the underlying, clearly reddish-brown B-horizon. The organic matter in this B-layer is made up of moder.
These soils were once referred to as humus-iron podzol soils or brown forest soils. Ground water did not influence the formation of these soils.
These are good conditions for a natural development of a richer vegetation, such as deciduous forests. Consequently, this produced a thicker humus-rich top layer than is the case in heathland.

In humus podzol soils, iron and soil-organic matter is heavily subject to eluviation. This process was possible on mineral-poor, acidic sand soil, and was enhanced by "acidic" vegetation such as heathland. These profiles are therefore more prominent on heathland reclamations of cover sands. Humus podzol soils can be found both high above and near groundwater level. In humus podzol soils, the A-horizon is yellow deferrized; part of this layer is usually humus-poor (bleached layer). The B-horizon is largely or completely deferrized and usually consists of a typical humus or humus iron bar. This humus is highly liquefied (amorphous humus), and sand particles are often bonded together. Deferrizing is easy to determine through calcination.

**Accumulation of soil-organic matter**
A significant percentage of sand soils have a distinctly dark top soil or A1 horizon. This is either the result of supply of soil-organic matter by lush plant growth or medium decay of this soil-organic matter (too wet, too acidic) or the supply of humus-rich soil by man (accumulation). In the new Dutch classification system, these soils are called eerd soils. A1 layers thicker than 50 are referred to as thick *eerd* soils, which include enkeerd soils (old farmland or ash soils). The humus-rich topsoil was formed by layers of sod mixed with manure. This addition of new layers raised the surface of the fields (enk or es). This humus-rich layer covers podzol soils (with bleached layer and orterde). Provided the humus content is not too low and the humus-rich layer is substantially thick, these soils make good arable land. The pH is frequently too low. We can distinguish black and brown enkeerd soils.
Black enkeerd soils were formed in regions where only heather sods were available. Brown soils indicate a nutritious soil and higher quality humus; they are elevated with forest litter or grass sods.

<table>
<tr><td rowspan="7">PODZOL SOILS</td><td colspan="3">Moder podzol soils Moder podzol soils - B</td><td>Woody podzol soil thin A1 (brown forest soil</td></tr>
<tr><td rowspan="6">Humus podzol soils humus podzol - B</td><td rowspan="4">Hydro podzol soils (wet)</td><td rowspan="2">Peaty podzol soils with peaty topsoil</td><td>Peaty podzol soil A1 (layers in low cultivated soils)</td></tr>
<tr><td>Dam podzol soil with humus sand cover (worn valley soil)</td></tr>
<tr><td rowspan="2">Ordinary hydro podzol soils</td><td>Field podzol soil thin A1 (low reclamation soil)</td></tr>
<tr><td>Laarpodzol soil thicker A1 (older reclamation soil)</td></tr>
<tr><td colspan="2" rowspan="2">Xeropodzol soil dry</td><td>Hair podzol soil thin A1 (high heathland reclamation soil)</td></tr>
<tr><td>Camp podzol soil thick A1 (older reclamation soils)</td></tr>
</table>

Fig. 442 *Podzol soils*

<table>
<tr><td rowspan="6">EERD SOILS</td><td colspan="2" rowspan="2">Thick eerd soils thick A1</td><td rowspan="2">Enkeerd soils</td><td>Brown enkeerd soils brown A1</td></tr>
<tr><td>Black enkeerd soils black A1</td></tr>
<tr><td rowspan="4">Thin eerd soils</td><td rowspan="3">Hydro-eerd soils no iron cutans or reduction within 80 cm</td><td>Peaty eerd soils (peaty eerd layer)</td><td>Bog eerd soil (lowest sections of brook valleys)</td></tr>
<tr><td rowspan="2">Ordinary hydro-eerd soil no peaty topsoil</td><td>Brown brook eerd soil brown A1 and rust spots<br>(gley soils from brook valleys)</td></tr>
<tr><td>Black brook eerd soil black A1 further ditto</td></tr>
<tr><td colspan="2">Xero-eerd soils iron cutans</td><td>Kant eerd soil thin A1</td></tr>
</table>

*Fig. 443 Eerd soils*

**Loamy soils**
Loamy soils are divided into loess soils and weathering soils. Loess soils are primarily confined to Zuid-Limburg and also occur in pockets in Noord-Brabant and Gelderland (including the Postbank). Loess is an aeolian deposit characterised by uniform grain-size frequency distribution and a high percentage of loam. These soils have a clay-retaining horizon caused by illuviation. Loess soils are the oldest arable soils in our country. The landscape is highly uneven and prone to water erosion.
Old weathering soils are confined to pockets in Zuid-Limburg. They occur on geological formations such as chalk. These soils contain clear traces of different soil-forming processes.

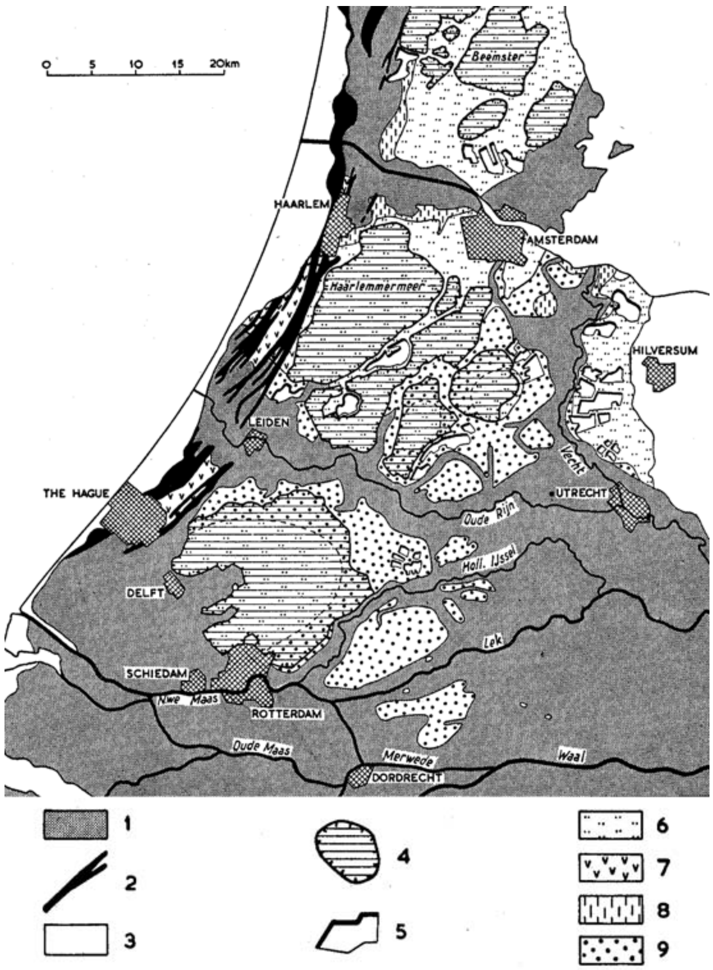
### 4.2.6 Bog soils and peat reclamation soils

**Genesis of bog**
Unlike clay and sand, most of the bog types in the Netherlands were not borne and deposited. They were formed in situ from partially decomposed plants. This vegetation had hardly decomposed or not at all due to extremely wet conditions (lack of aeration) and, sporadically, low pH values. This produced an accumulation of organic matter, sometimes into extremely thick layers.
Most peat layers have been temporarily subjected to decay, as they remained above the water surface for some time, allowing oxygen to penetrate. This explains the presence of a groundmass, containing remains of plants and clearly identifiable remains of roots, twigs, seeds, etc.

**Bog types**
The bog types we know have been formed by various plant communities. Bog can be divided into the following important groups:
- eutrophic bog: formed in water with a high nutrient content;
- mesotrophic bog : formed in water with a moderate nutrient content;
- oligotrophic bog: formed in water with a low nutrient content.

The most important peat types are:
- young sphagnum bog;
- old sphagnum bog;
- wood bog;
- sedge bog;
- reed bog.

**Young sphagnum bog.**
This type of peat is light brown in colour. Its components, peat mosses, are clearly identifiable. Peat moss grows in a moist environment with a low nutrient content, i.e. in areas with a lot of rain water and an absence of ground, river and sea water. Young sphagnum bog is not suitable for turf reclamation. It is sold as mull for the garden.




1 Young marine and fluvial deposits, mostly lying on top of peat
2 Bars with Old dunes
3 Young dunes and Pleistocene
4 Peat removed by digging or erosion (reclaimed lakes)
5 Present lakes
6 Aphagnum peat
7 Carex- and Carex-Alnus peat
8 Phragmites-Scirpus peat
9 Wood peat

STIBOKA (1962) p. 146

*Fig. 444 Botanical peat types*

**Old sphagnum bog**
Old sphagnum bog has a dark colour, and is strongly decomposed peat, hence its popular name of black peat. Bog mosses are difficult to identify in the black groundmass, although we can still distinguish heather twigs and stalks, as well as fibrous cotton grass. Bog moss is found beneath young sphagnum bog and is ideal for making turf in the form of bricks. The genesis of old sphagnum bog is

identical to that of young sphagnum bog. It is however much older: the growth of bog moss was repeatedly interrupted by occasional dry spells, which made the formed bog moss weather and darken in colour. In addition, the bog moss was subsituted by slightly different types of plant, such as heather, cotton grass, etc., during these dryer periods.

**Wood bog**
Wood bog is a highly decomposed bog type. Its components, twigs and tree roots, are clearly identifiable in the darkly coloured groundmass. In the ground water zone, it is reddish-brown in colour. Wood bog is usually mixed with a percentage of silt and clay as it is primarily formed in areas that are flooded by river water from time to time. This water provides the nutrients needed for tree growth, while water runoff aerates the soil sufficiently to enable root growth. This bog is not suitable for turf reclamation. This explains why wood bog has remained unexcavated in the West of the Netherlands, as opposed to sphagnum bog.

**Sedge bog**
Sedge bog is also a darkly coloured, shapeless bog type. We can however identify numerous small, grey roots in the groundmass, and occasionally birch and gale twigs, and reed. It was formed in a medium-nutrient moist environment, i.e. in areas with a high groundwater level.

**Reed bog**
Reed bog is a lightly coloured, somewhat layered bog type. It is easily identifiable by the many coarse, flattened roots of the reed. It usually contains a relatively high percentage of silt; reed bog is formed in moist areas with a medium to high nutrient content, usually brackish water. These conditions are perfect for reed growth, and also explain the presence of silt. It is often acidic, with yellow acid sulphate spots. Reed bog is most prevalent in the transition from bog to clay.

**Peat mud and peat dust**
Peat mud and peat dust are subaquatic deposits of organic matter in ponds, lakes, and occasionally old ditches. They were formed in water with a high nutrient content from the remains of lower plants and animals, such as marine algae, shellfish and diatoms. It is usually mixed with clay or peat, which was deposited in the water as a result of erosion. Gyttja in water with a high nutrient content, deposited peat mud or peat dust. Dy in acidic water, deposited peat mud or peat dust.

**Bog or peat landscapes**
These can be divided as follows:
1. lowland bog
2. upland bog
3. brookland bog

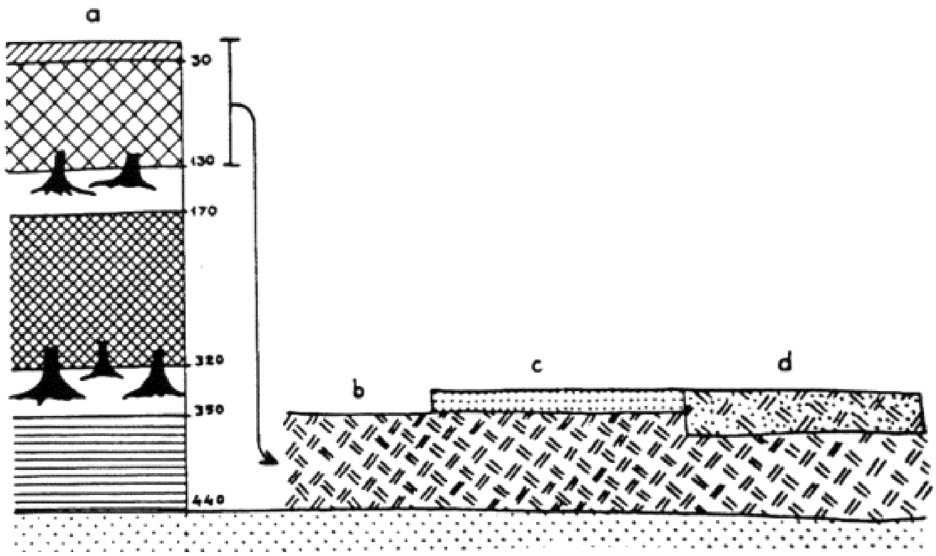
The division is based on the area where bog is found, not on the composition of plants

**1. Lowland bog**
This category principally incorporates low and wet bog soils, composed of different bog types. Along rivers and brook valleys, these are usually wood bog and peat bog with wood remains. At some distance from the river, these soils turn into reed and sedge bog, and a little further into sphagnum bog. These bog types are often found on top of each other in sometimes quite thick layers, which also contain clay particles. Insofar as lowland bog comprises sphagnum bog with a low clay content, it will largely have been dredged or dug for peat reclamation. This process formed elongated lakes in the west of the Netherlands and in north Overijssel, the majority of which have been reclaimed or impoldered since the sixteenth century. Several of these lakes, such as the Haarlemmermeer, were already bog lakes before peat excavation activities began.

Surrounding the remaining peat lakes, such as the Westeinderplassen, Loosdrechtse Plassen, and in north western Overijssel and the Zaanstreek region, are large areas with pet gaten or trekgaten (a kind of channel). These are the remnants of the time of peat reclamation. They are comparable to the broads in East Anglia. These channels are separated by strips of unexcavated peat, the ‘ribben’ (strips of land) or embankments, onto which the peat was dried. Over the years, the channels gradually fill up with remnants of reed and other water plants and turn into land. Various stages of this process can be found in peat areas. In some cases, poor grassland is reclaimed from this newly formed land. The unreclaimed section of the low-level bog consists of non-calcareous clay soils with a peaty top layer or peat soils with a thin clay cover.
They were formed as a result of the gradual wedging out of sea and river clay across the peat, and are usually the transitional strips between sea or river clay soils and lowland peat soils with

a low clay content.

**2. Upland bog – and dalgrond**
Upland bog is elevated in comparison with the sand soils of the surrounding area. It mainly comprises sphagnum bog. Unreclaimed and partially dug upland bog only occurs in small pockets near Emmen, Vriezenveen and in the Peel. They are the last remnants of the vast upland moors of the nortnear st and south of the Netherlands.




STIBOKA (1962) p. 152

*Fig. 445 Peat and dalgrond*

After draining, the peat in these areas was cut, and the rest of the bog was mixed with the sandy subsoil. This soil mixture is called dalgrond. Turf was usually transported by ship via channels, which doubled as a drainage system and for opening up the area. Peat areas can be subdivided into old and young reclamations. The younger peat areas were reclaimed systematically by removing the peat. Peat that remained was mixed with with the topmost layer of soil (the bolster layer), which wass very important for later plant growth in the fields. It is often missing in the older reclamation areas.

A typical profile of low-lying bog soil in the west of the Netherlands comprises the following:

| | |
|---|---|
| 0 - 30 cm | young sea clay, |
| 30 - 45 cm | reed bog, |
| 45 - 80 cm | sedge bog, |
| 80 - 250 cm | young sphagnum bog, |
| 250 - 280 cm | spalter bog, |
| 280 - 400 cm | old sphagnum bog, |
| 400 - 450 cm | sedge bog, |
| 450 - 500 cm | reed bog, |
| 500 - | old sea clay. |

This profile is the result of the gradual closing off of the western old sea clay area from the sea. Salt water gradually turned first into brackish and finally fresh water; this explains the growth of reed followed by sedge The area was beginning to turn into land. First there was groundwater bog, followed by rainwater bog, i.e. sphagnum bog.
Spalter bog was formed during temporary dry spells, and was the surface layer for some time.
A typical feature of the bog types in the west of the Netherlands is that, unlike the high-lying bog in the east, they are "submerged". The sea became an increasingly influential factor, causing the groundwater table of this area to rise, encouraging new growth of groundwater bog on top of the rainwater bog, in other words, a layer of sedge bog developed on top of sphagnum bog. In some areas, seawater would submerge this bog, creating silted reed bog. This process continued: eventually, large sections of bog were covered with a small layer of young sea clay, or acquired a muddy topsoil.

**Bog peat in brookvalleys**
Bog peat was formed in marshy areas, characterised by limited tree growth. It can be found for example in the centre of brook valleys in sand areas.

| | | | |
|---|---|---|---|
| PEAT SOILS | Eerd peat soils mouldered topsoil | Clay-like eerd peat soils clay-like A1 | Aarveen soil thick A1 (peat soil from the wood peat area of Zuid Holland, horticulture) |
| | | | Koopveen soil thin A1 (peat soil from the wood peat area of Zuid Holland, grass land) |
| | | Eerdveen soils with a low clay content A1 | Bosveen soil thick A1 (unreclaimed upland peat with a layer of cultivated land) |
| | | | Madeveen soil thin A1 (bog peat in lowest sections of brook valleys) |
| | Raw peat soils, topsoil scarcely mouldered | Initial raw peat soils unripened | Vlietveen soil (weak low-land peat soil) |
| | | Podzol raw peat soils peaty B (glide) ripened | Mondveengrond with sand cover and glide (reclaimed peat soil) |
| | | Ordinary raw peat soil Ripened | Weideveen and waardeveen soil with clay cover (clay-on-peat soil) |
| | | | Meerveen soil with sand cover (Veenkoloniën) |

*Fig. 446 Peat soils*

N.B.: Mouldering: after drainage soil life was possible. Plants that were still recognisable at this point disappeared and a darkly coloured humus-type peat was formed.

### 4.2.7 References to metres: soil units

Kruedener, A.v. (1951) *Ingenieurbiologie* (Basel) Reinhardt.
Kuipers, S.F. (1972) *Bodemkunde* (Culemborg) Tjeenk Willink ISBN 90-11-54410-2 (Bibliotheek Moens).
STIBOKA (1962) *Bodem van Nederland* (Wageningen).
Sticht.Wetensch.Atlas_v.Nederland, Berg, Steur and Brus (1987) *Atlas van Nederland. Deel 14. Bodem* (Den Haag) SDU ISBN 90-12-05014-6 (Leerstoelbibliotheek).

## 4.3 Millimetres: soil structure

### 4.3.1 Soil structure

Soil structure is determined by the spatial arrangement and bond of soil particles. The mutual arrangement of soil particles, the bond of the particals and the resultant voids form the composition or structure of the soil. It is a network of soil particles.
The significance of soil structure lies in the presence of pores and voids, which can hold air, water, roots and pollution. Coarser pores discharge excess water.

### 4.3.2 Structure types

A distinction is made between the structure types, which must be taken into account when preparing a site for development. We can identify the following structures

- crumb
- clod
- prismatic structure
- platy structure
- grain structure
- (pumiceous structure / concrete structure)

Crumb and clay structures play a particularly important role in agriculture. Prismatic and platy structures are compact and prevent water to penetrate the soil. The topsoil is soon saturated with water that cannot be drained quickly enough. These layers are found on the earth's surface as well as deeper down in the ground. Grain structures are found mainly in sand soils; they can easily become wind-borne when they are located on the surface and are bereft of vegetation, which has implications for the surrounding area (dust storms). In addition, small particles will percolate downwards and form a compact layer in the subsoil. These soils soak or silt up during heavy rainfall, leaving large pools of water on the surface.
Poorer structures are often caused by frequent traffic and by on-site materials storage, which occurs regularly during construction work.
As mentioned above, soil structure affects water behaviour. Platy structures can hardly discharge water, or not at all, while other structures are characterised by more stable water drainage.

**Soil profile**

Individual soil particles present in the soil are influenced by water and vegetation. Various processes contribute to soil formation and the formation of a soil profile. These processes occur under the downward influence of gravity. The following processes can be identified:

- water inflow and drainage (illuviation and eluviation); heterogenisation
- inflow and conversion of organic material
- homogenisation by man, plant and animal
- oxidation ($Fe^{4+}$, $FeO_2$) and reduction ($Fe^{2+}$, FeO) (primarily conversion of iron)
- maturing (withdrawal of water from newly raised ground)

These processes produce stratification in the soil profile, which was originally lacking. The layers, known as soil horizons, differ in terms of composition and properties, and together form the soil profile. Soil scientists classify profile horizons using the letters indicated in *Fig. 441* on page 230.
Weathering of soil particles and solid parent material continues during soil genesis or soil formation, slowly releasing fertilizing substances and minerals.

**Ground water**

The ground is made up of solid constituents (mineral or organic), soil particles with interjacent pores. These pores can be saturated with air, air and water, and water. Depending on the state of the water in the ground we speak of groundwater zone (pores saturated with water), capillary fringe(pores saturated with air and water) and zones primarily filled with air (hangwaterzone) but semi-permanently filled with water after a rainfall. This is the pedological classification of ground water.
In geology, subterranean water is divided into two groups; water in the unsaturated upper zone – soil water - and water in the underlying saturated zone – groundwater

Ground water only partially fills the voids between the (soil) particles with water, while the other voids are saturated with air. Soil water corresponds with the capillary fringe and capillary water zone. The

interface between groundwater and the capillary zone is known as the phreatic level or ground-water table.
In general, the term groundwater refers to fresh water, which is important for all manner of biotic processes. The majority of subterranean water, however, is sea water. In the Netherlands in particular, this subterranean sea water plays an important role in coastal areas. It occurs virtually everywhere in the provinces of Holland and Zeeland, covered by a layer of fresh ground water[a]. The deep polders of these provinces (4 to 6m below sea level) contain salt seepage water[b] due to the absence of fresh groundwater or too thin a layer as a result of drainage/surface drainage.
The following table shows an estimated quantity of water on earth. A distinction is made between fresh water and salt water.

| | Volume (in $km^3$ x $10^3$) | Percentage of total volume |
|---|---|---|
| *Surface Water* | | |
| – Fresh water lakes | 125 | 0,009 |
| – Salt and brackish lakes and in land seas | 104 | 0,008 |
| – Main quantity of rivers and canals | 1,25 | 0,0001 |
| *Subsoil water* | | |
| – Water in un saturated zone of the soil | 67 | 0,005 |
| – Undeep groundwater (till depth of 800 m.) | 4 168 | 0,31 |
| – Deep groundwater (till depth of 5000 m.) | 4 168* | 0,31 |
| *Remaining occurrences of water* | | |
| – Ice caps and glaciers | 29 200 | 2,15 |
| – Atmosphere (on sea level) | 13 | 0,001 |
| – Seas and oceans | 1 320 000 | 97,2 |
| Totals (in round figures) | 1 359 000 | 100 |

U.S.-Geological-Survey (1969)

*Fig. 447 Water on earth*

The water in the upper soil layer - ground water - can be categorised according to increasing moisture content. Even without the supply of (rain) water, soil particles are surrounded by hygroscopically-bound water molecules; an atmospheric humidity of 0 never occurs in nature. An increase in atmospheric humidity leads to an increase in the number of molecules, bound hygroscopically to the soil particles.

Soil particles are surrounded by a layer under the influence of adhesive forces, even after little rainfall. As the films of water surrounding the soil particles thicken, the particles begin to bond, while open air-filled pores remain. This zone is known as the capillary fringe.

Initially, these air-filled pores form a network. However, the increased supply of water eventually causes all pores to fill up with water, allowing water to flow freely between the soil particles. This last zone is known as the groundwater zone. This zone is easily identifiable in the soil. When digging or drilling a hole, water is accessed at a certain depth, which, after a while, will be at a constant distance in relation to the ground level. This plane is known as the ground-water table or the phreatic level. The distance to the ground level is known as the groundwater level and is expressed in cms below ground level. The groundwater beneath the ground-water table moves freely.

The ‘hangwaterzone’ is found in the upper layers of the profile. This zone is also saturated with water by capillary or adhesive forces, but does not have ground water as its source, nor does it have a

[a] Freshwater has a lower specific gravity than salt water, and “floats “ on the salt water as it were.
[b] Seepage is a vertical groundwater flow; water moves from the underground to the surface under the influence of water pressure.

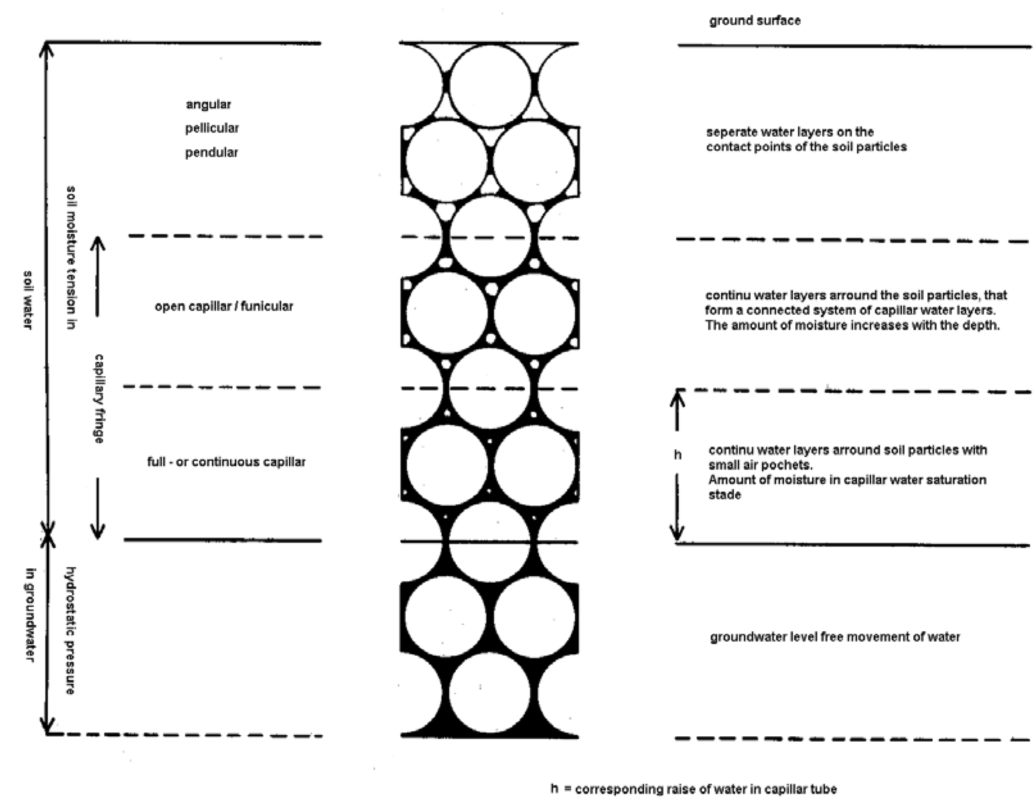
connection with ground water. It remains as gravitational water of the downward seeping water following rainfall.

**Capillary action of the ground.**
Water is primarily retained in the ground by capillary forces. The capillary action is caused by the attraction between the water molecules (cohesive force) and the attraction of soil particles on the adjoining water molecules (adhesive forces), which can be illustrated as follows: Water that is placed in a thin tube in a reservoir with water will rise due to capillary forces. The level of water rise is determined by the thickness of the tube. When the water rises, the adhesive force between the tube and water is greater than the cohesive force among the water molecules. This phenomenon also occurs in the ground. The smaller the particles, the more water is retained. The same applies to the pores; the smaller the pores, the more the water level rises. In other words, clay ground consisting of minute particles with intermediate narrow pores is characterised by a high capillary rise compared with sand, which has large particles and pores. This also implies that clay soils will be less easy to drain than sand soils, as clay retains water better than sand.

Based on laboratory tests and field observations using dipsticks, the following values for capillary heights above the ground-water table have been determined in accordance with Bogomolov (1958):

- Coarse sand 12 - 15 cm
- Intermediate coarse sand 40 - 50 cm
- Fine sand 90 - 110 cm
- Sandy loam 175 - 200 cm
- Loam 225 – 250 cm

Due to the capillary action of the soil, the groundwater is pulled into a spherical shape between two ditches; the water level in the ditch acts as the lowest point.




A.J. Pannekoek (1973) Table p.316

*Fig. 448 Capillary action of the soil*

**Water-table classes.**
Groundwater tables are divided into water-table classes, in which the highest groundwater level

(HMGL) and the lowest mean groundwater level (LMGL) has been calculated. The groundwater level is determined in relation to the ground level; the depth of the groundwater is representative. The annual natural fluctuation of the groundwater in the Netherlands is tens of centimetres. This movement is characterised by rust stains in the otherwise grey to grey-blue groundmass. This staining is caused by the presence of iron in the soil. Soil that is always saturated with water has a grey to grey-blue colour, and soil containing no water at all has a rust colour. The colours are produced by oxidation in iron ($Fe^{4+}$) in layers without water, and by reduction in iron ($Fe^{2+}$) in water saturated zones. Both colours are found in the transition zone (the capillary zone). The zone that forms the difference between HMGL and LMGL is also speckled with rust and grey-blue colours.

| Gt | I | II | III | IV | V | VI | VII |
|---|---|---|---|---|---|---|---|
| LMGL | - | - | ≤40 | ≥40 | ≤40 | 40-80 | ≥80 |
| HMGL | ≤50 | 50-80 | 80-120 | 80-120 | ≥120 | ≥120 | ≥120 |

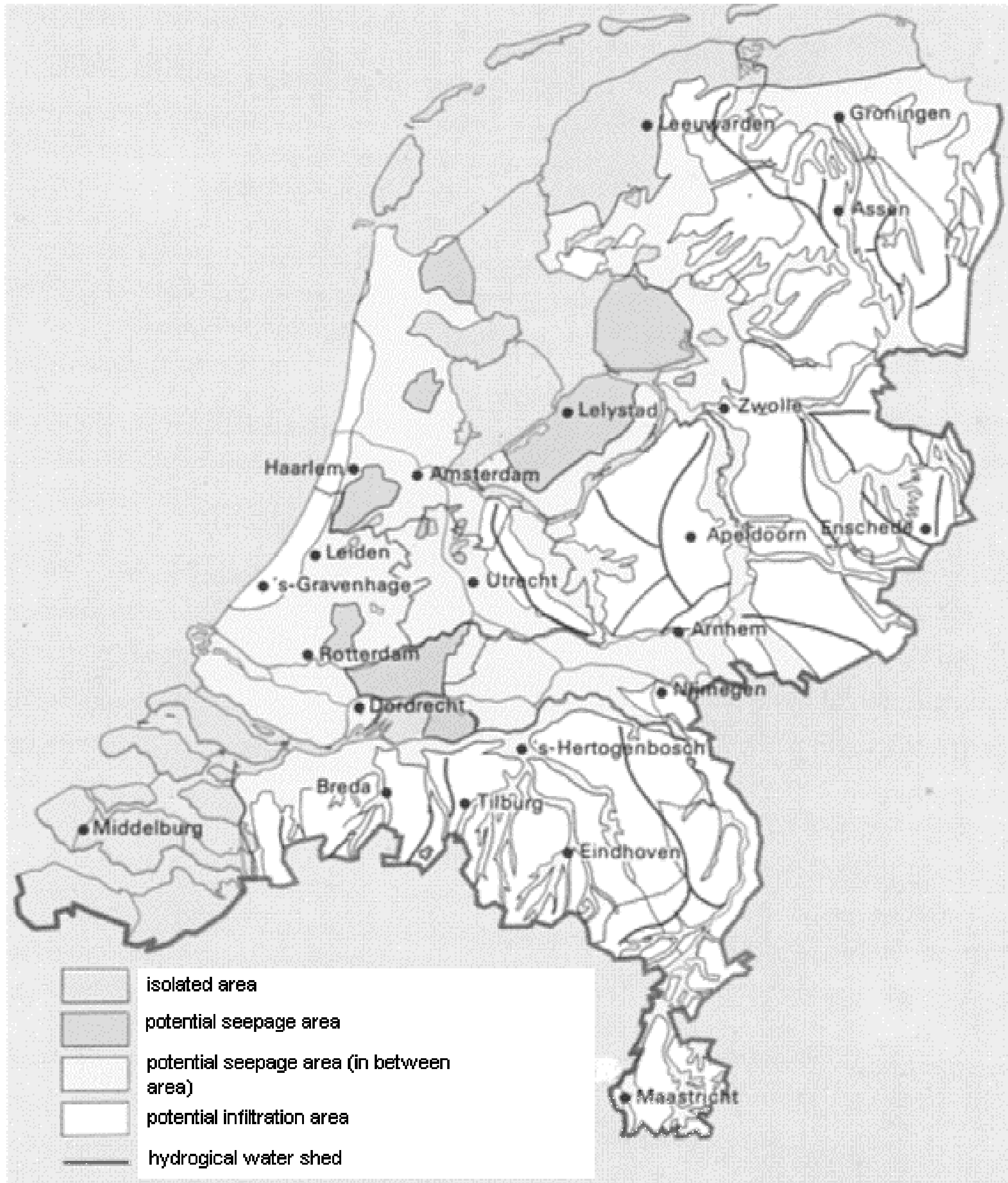
*Fig. 449 Main subdivision of water-table classes (groundwater level in cms below ground level)*

**Groundwater flow.**

Groundwater flows are the result of differences in groundwater levels in an area. Although the general direction of the groundwater flow is known, it will need to be determined for local situations. Flow is dependent on pore volume and the size of the pores and, indirectly, particle size. In addition, soil is not an homogenous entity due to stratification in sedimentation, causing big fluctuations in permeability across relatively short distances.
In addition to natural groundwater tables, the Netherlands also has artificial groundwater tables, which are kept at a predetermined level through pumping. These artificial groudwater levels are found in the polders. Pumping also creates groundwater flows towards the pumping plant.

In addition to horizontal groundwater flow, there is also a vertical movement of water in the soil. This is known as seepage (kwel), where the water ‘surfaces' from the ground-water, and infiltration, characterised by ‘downward movement’ of water. The latter process is a natural phenomenon that occurs under the influence of gravity. This movement takes place in the profile zone above the ground-water table. Technically, this is also the profile zone, where water is temporarily stored.

Seepage is caused by water pressure from an elevated area to a low-lying area.
Seepage can occur along hill ridges, when the groundwater level on the hill ridge is higher than the adjoining areas. This causes a subterranean flow in the direction of the lower-lying area. Springs arise in areas where the water issues to the earth’s surface.

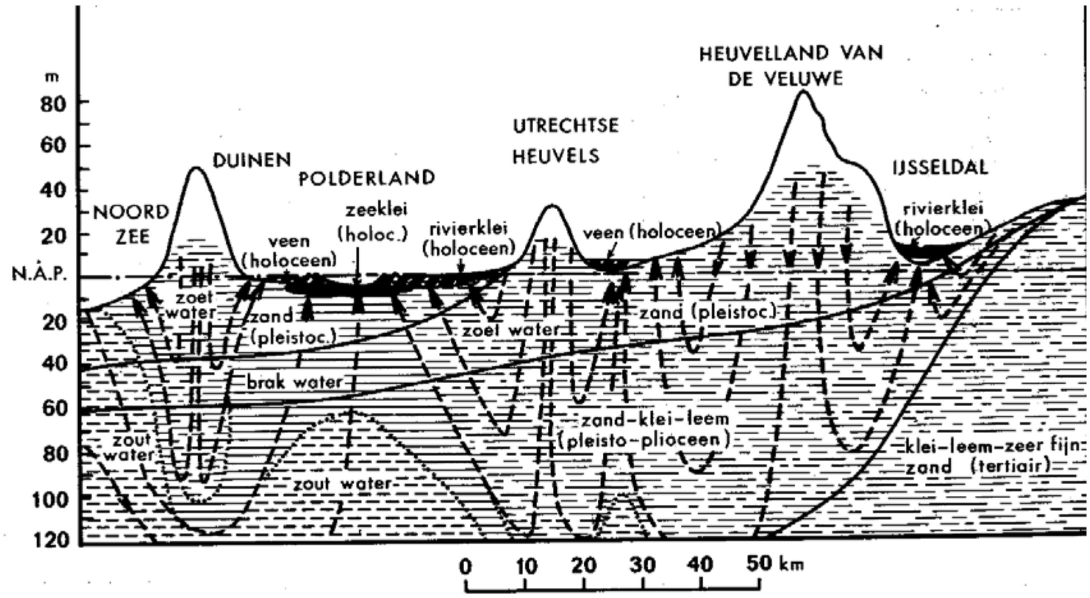


Sticht.Wetensch.Atlas_v.Nederland, v.d. Berg, Steur and Brus (1987)

*Fig. 450 Potential seepage areas*

A similar phenomenon occurs in areas bordering big rivers, whenever the level of the river water is higher than the neighbouring polders. Water rises to the earth's surface on the polder side of the dykes, when the water level of the rivers is higher than that of the land behind the dykes. The pressure of the elevated water produces water movement underneath the (porous) dykes. The seepage water rises to the surface along the dyke. This is why ditches are constructed alongside dykes to collect and discharge seepage water.

This situation can also occur in the west of the Netherlands because polders are drained at a greater depth than storage basins, the big rivers and the sea. The surface of the deepest polders lie at approximately 6 metres below sea level. Seepage in this area can be saltwater, freshwater or brackish water, depending on whether the water comes from: a storage basin or salt groundwater. Seepage water from the storage basin rises to the earth's surface near the dyke. Brackish and salt seepage water originating from the brackish/saltwater bell in the subsoil of the west of the Netherlands rises to the earth's surface in the lowest sections of the polder, when the freshwater layer has thinned as a result of drainage activities that salt water rises to the surface though pressure in the saltwater bell.




A.J. Pannekoek (1973) p. 323

*Fig. 451 Water in the dunes*

Schematic hydrogeological cross-section of the Netherlands (from: Commissie-Drinkwatervoorziening-Westen-des-lands (1940))
Supplemeted with a schematic not quantitave image of the pattern of groundwater flowlines for the deeper groundwater flow. The precipitation the deeper groundwater infiltrates in Overijssel, the Veluwe, the Utrechtse Heuvelrug and the coastal dunes. This causes seepage in the IJsselvallei, the Gelderse vallei and the polder area of West Netherland.
The exagerated heights (x 350) in the cross-section causes a strongly deformed pattern of flowlines. In reality the horizontal component of the pattern is more pronounced than the vertical component.

Soil pollution can be spread through the soil by the flow of ground water. If this is to be cleaned up, it is essential to have an insight into the speed and direction of the spread. For further information on this topic, see chapter 2.

**Soil horizon differentiation**

The potential outcome of all these soil forming processes is that soils that originally "looked the same", will start to differ from each other in the course of the centuries (soil horizon differentiation). Soil profile development depends on the following:

- climate (temperature and precipitation)
- parent material
- slope of the terrain
- groundwater level
- period of weathering.

### 4.3.3 References to Millimetres: soil structure


Commissie-Drinkwatervoorziening-Westen-des-lands (1940) *Rapport van de Commissie Drinkwatervoorziening Westen des lands*.

Pannekoek, A.J., Ed. (1973) *Algemene Geologie* (Groningen) Tjeenk Willink ISBN 90 01 68975-2 (Bibliotheek Moens).

Sticht.Wetensch.Atlas_v.Nederland, Berg, v.d., Steur and Brus (1987) *Atlas van Nederland. Deel 14. Bodem* (Den Haag) SDU ISBN 90-12-05014-6 (Leerstoelbibliotheek).

U.S.-Geological-Survey (1969) *Water of the World*.

## 4.4 Micrometres: physical-chemical composition

### 4.4.1 Chemical composition of the earth's crust

Crystallisation in cooling magma is followed by a change in the composition of residual liquids. The first minerals contain a relatively high number of $AlO_4$-tetrahedrons. Continuous cooling produces minerals with proportionally more $SiO_4$- tetrahedrons.It is clear that the crystallising minerals will prevent each other from adopting their own form. This explains the complete absence of beautiful, big crystals in plutonic rock. Rock composition is analysed with the aid of a microscope.
From the known minerals, only a minority are formed as igneous rock in the depth of the mantle. Igneous rock primarily contains the following minerals:

| | |
|---|---|
| feldspar | 59.5% |
| amphibole / pyroxene | 16.8% |
| quartz | 12.0% |
| mica | 3.8% |
| other minerals | 7.9% |

Feldspars include orthoclase, plagioclase, oligoclase; they consist of the elements $SiO_2$, $Al_2O_3$, Ca, Na, K, CaO, $Na_2O$, $K_2O$.
Amphiboles include hornblende, olivine, peridotite; they consist of the elements Mg, Fe, Ca, $AlO_4$, $SiO_4$, OH
Pyroxenes include augite, hyperstone, diopsite; they consist of the same elements as amphiboles, with the exception of OH.
Micas include biotite and muscovite; they form sheets, which consist primarily of $SiO_4$-, $AlO_4$- and $FeO_4$ tetrahedrons.
To a significant extent, this composition also determines the chemical composition of the soil.

### 4.4.2 Weathering

Weathering occurs when rock on the surface is eroded by water and oxygen. Under the influence of gravitational force and, primarily, water, this material is transported from elevated planes to lower-lying basins, where it is deposited as layers that can be kilometres thick. The Netherlands lies in such a sedimentation basin.
We can distinguish three types of weathering:

- physical weathering
- chemical weathering
- biogenic weathering

Physical weathering mechanically reduces solid rock lying at the earth's surface. No change in chemical composition occurs! The resultant loose material is layered across the original rock. Physical weathering takes place under the influence of temperature, water and/or wind. Concomittant processes are expanding and contracting, dissolving, swelling and contracting, and abrasion.
Once the rock has shattered into smaller fragments - causing the overall surface to expand - chemical weathering starts to play a major part. Under the influence of water, oxygen and acids such as carbon and organic soil acids, many minerals are affected and converted into new minerals.
Biogenic weathering can be of a physical or a chemical nature. Rock is split as a result of root growth. Under the influence of fungi and bacteria, organic material releases substances such as acids and $CO_2$, which cause various reactions in the soil.

### 4.4.3 Sediments

As mentioned previously, weathered material is transported from elevated areas to lower-lying areas by ice, flowing water or air (wind).
In the Netherlands, loose material is deposited in different ways and in different periods.

- by rivers from surrounding countries
- by coastal currents
- wind-borne from areas with a lot of loose material such as the dried up North Sea and the vast river plains during dry periods of the Ice Age when there was virtually no vegetation
- by ice from Scandinavia during the penultimate Ice Age.

In general, sediments are characterised by stratification and material sorting due to the manner of deposition.

Water deposits are generally stratified, while the layers themselves have a relatively homogenous particle size composition.
Wind-borne deposits have a uniform composition, provided material is transported across a large distance. Loess has a particle size of 0.05-0.075 mm and cover sand of 0.075-0.15 mm. These deposits do not form any stratification within the profile. However, material transported across a relatively short distance, as in dune areas and in sand drift areas, bring about a criss-cross stratification and relatively little uniformity in particle size uniformity due to fluctuations in wind velocity.
Ice deposits, such as boulder clay or till in the north and east of the Netherlands show no signs of stratification and are not sorted (large boulders in loam)
Two processes work simultaneously on the earth's surface. In addition to the upwards weathering processes, soil formation processes occur in weathered loose material. It is a top-down process under the influence of water and plant growth.

### 4.4.4 Soil

In the first instance, soil types are classified according to particle size:

| | |
|---|---|
| (large rock block | |
| small rock block | |
| large stone | |
| small stone) | |
| coarse gravel | |
| fine gravel | |
| coarse sand | 2000 - 210 |
| fine sand | 210 - 50 |
| loam / silt | 50 - 2 |
| clay | < 2 |

*Fig. 452 Particle sizes*

The smaller soil fractions can be determined by assessing their settling velocity in water. The smaller the soil fraction, the slower they settle in water, as their specific surface is bigger. Sand fractions take approx. 1 minute to settle in a normal glass of water, while silt fractions takes approx. 12 hours, and clay fractions even longer.
The surface of the particles per kg of dry matter is 10 m2 for sand, 100 m2 for silt and 1000 m2 for clay. The size of the surface is relevant for the absorbing capacity of soil particles of nutrients on the one hand, and pollution on the other.

Sand fractions retain hardly any water or nutrients. Silt fractions retain water reasonably well but hardly any nutrients. Clay fractions retain both water and nutrients well, but pollution too.

### 4.4.5 Identifying soil fractions in the field

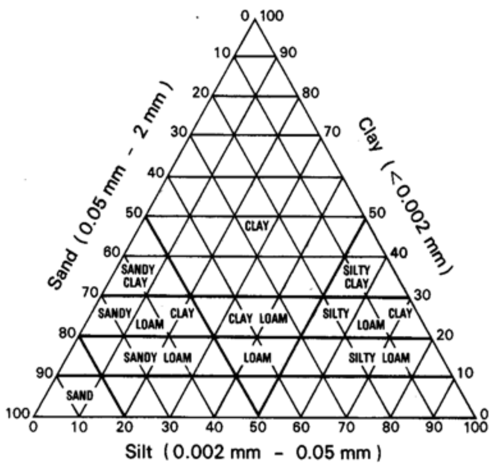
Soil fraction identification is carried out on the basis of vegetation. Coltsfoot for example indicates a high content of soil consisting of particles smaller than 0.016 mm. By rubbing a quantity of fine grained soil in our palms, we are left with remnants of that soil in the lines of our hands. Loess in a dry state has a similar consistency to flour;. Sand is easily identifiable. And so on.

### 4.4.6 Naming of soil types

Naming soil types is one of the most complicated processes in pedology. A distinction is made between clay soils and sand soils. These names alone encompass a broad range of particle sizes. It is this distinction between particle sizes or fractions that determine the names of soil types. Based on the present classification, clay soils comprise a minimum of 8% of clay or clay fraction and over 10% of soil containing particles smaller than 0.016 mm (=clay + loam/silt); the rest of the clay soil is made up of sand. Note the difference between clay and clay soil! Clay can be the soil fraction or a mineral, while clay soil is a soil type. Sand soil is mostly made up of particles bigger than 50 mu and consists of different minerals or a mixture of minerals.

| Subdivision of clay soils | | | Subdivision of sand soils | |
|---|---|---|---|---|
| % clay | % particles smaller than 0.016 mm | name | % loam | name |
| 0-5 | 0-6,5 | sand with a negligible clay content | 0-10 | sand with a negligible loam content |
| 5-8 | 6,5-10 | clay-like sand | 10-17.5 | sand with a medium loam content |
| 8-12 | 10-16 | extremely light sandy clay | 17,5-32,5 | sand with a high loam content |
| 12-17,5 | 16-23 | moderately light sandy clay | 32,5-50 | sand with an extremely high loam content |
| 17,5-25 | 23-33 | heavy sandy clay | 50-85 | sandy loam |
| 25-35 | 33-45 | light clay | 85-100 | silty loam |
| >35 | >45 | heavy clay | | |

*Fig. 453 Subdivision of clay and sand soils*




| Class | % sand | % silt | % clay |
|---|---|---|---|
| sand | 80 - 100 | 0 - 20 | 0 - 20 |
| sandy loam | 50 - 80 | 0 - 50 | 0 - 20 |
| loam | 30 - 50 | 30 - 50 | 0 - 20 |
| silty loam | 0 - 50 | 50 - 100 | 0 - 20 |
| sandy clay loam | 50 - 80 | 0 - 30 | 20 - 30 |
| clay loam | 20 - 50 | 20 - 50 | 20 - 30 |
| silty clay loam | 0 - 30 | 50 - 80 | 20 - 30 |
| sandy clay | 50 - 70 | 0 - 20 | 30 - 50 |
| clay | 0 - 50 | 0 - 50 | 30 - 100 |
| silty clay | 0 - 20 | 50 - 70 | 30 - 50 |

( ... )

*Fig. 454 Soil fraction diagram*

### 4.4.7 References to micrometers: physical-chemical composition

P.M.

## 4.5 Soil pollution

The choice of location for a building, a complex or a new neighbourhood depends on position, orientation, land shortage and potential soil pollution. This will influence the price of the location and the as well as determining the choice of location, this topic of potential soil pollution is also of interest to urban planners and architects. After all, most contracts depend on the starting date of building activities, allowing sufficient time to obtain the relevant permits and to plan activities. A lack of knowledge concerning soil pollution – including the relevant permits – will delay activities see J.G.M. Koolenbrander (1995).

This chapter offers guidelines for carrying out research in the context of the decontamination clauses of the Wet Bodembescherming (Soil Protection Act), with the emphasis placed on "terrestrial soils". Detailed information will be given on a range of pedologic properties and concepts. Examples of potential areas affected by soil pollution are also included, as is a brief summary of remediation techniques.

This paragraph, coupled with a concluding report, will enable architects to carry out preliminary or historic survey into soil pollution to initially obtain a “clean soil statement”.

Until comparatively recently, planning permission applications needed to include a so-called "clean soil statement". This has been replaced by a suitability certificate, indicating intended purpose. As a result, the soil no longer needs to be completely "clean", provided it is xxx suitable for its designated use. Building work cannot commence until this declaration has been issued. This certificate is not only concerned with the topic of soil pollution, but also with “cleaning”, soil remediation, if pollution has been detected.
To encourage greater understanding of the underlying problems, this chapter shall focus on the protocols involved in the investigation procedure into (likely) soil pollution and resulting reports, and highlight a number of pedologic concepts.
This chapter is concerned with outlining the different types of pollution, coupled to industry activities, their prevention and location in the townscape and landscape. Current and developed remediation methods or technics have been included for the sake of completeness. The underlying idea is that cleaning decontaminating and preparing a terrain for development follow naturally from one another, or could even be carried out in unison, thereby influencing the overall design.

### 4.5.1 Soil pollution

The term ‘soil pollution’ denotes a negative impact on soil quality, which affects the soil to such an extent, that it is rendered unsuitable or less suitable for its intended purpose.
The soil must be protected in such a way, that future generations can make use of it. This means that the soil must not be damaged, or become irreversibly damaged, in accordance with the concept of sustainability.
When analysing mans exposure to substances in the soil, we can identify different types of damage/exposure. In the case of soil pollution, this exposure includes inhaling VOCs (volatile organic compounds), consuming soil particles, drinking water, etc.
The consumption of dangerous substances that put our health at risk will complicate considerably the situation. The level of exposure is expressed in ADI (acceptable daily intake). Please note that ADI differs from person to person. As such, an average figure applies.

With regard to soil pollution, it is advisable to consider the different functions of the soil, and the relevant quality assessments to be adopted.

- supportive function for buildings, roads and other constructions
- productive function: growth medium for natural vegetation and agricultural crops to feed people and animals.
- filter function for water
- ecosystem function; life in the soil makes a major contribution to the cycle of C, N and S.

To acquire a better understanding of these functions see E.v.d. Maarel and P.L.s. Dauvellier (1978), it is essential that we have a general understanding of the concept of soil.

### 4.5.2 General soil knowledge

**Soil**

What is the difference between soil and ground?
The term ‘ground’ refers to all the loose natural materials found at the earth’s surface. In terms of composition, it is an undefined material. The material consists of mineral and organic components. The term ‘soil’ refers to the arrangement of the individual soil particles, their size and how they occur in nature. Chemical, physical and biogenic processes play an important part in soil formation.

The Dutch language fails to differentiate the terms ‘soil’ and ‘ground’. This problem can be solved by including a definition.
Soil and ground are made up of solid, liquid and gassy constituents. Solid constituents are divided into mineral and organic constituents.
The naming of ground types is based on particle-size distribution of the mineral particles. Please note that most grounds do not have a homogenous particle size. In other words: the designation ’sandy ground’ or in english sandy soil implies that the majority of particles fall under the particle size fraction of sand.

We can distinguish the following particle size fractions:

to 2µ: clay fraction or clay
2µ to 50µ: silt fraction or loam fraction
50µ to 2000µ: sand fraction (2000µ= 2 mm)
2 mm to 64 mm: gravel fraction

The organic matter in ground is made up of decomposed plant remains. If these remains form a thin layer on the soil surface, we refer to them as humus, which is brown-black in colour. Thicker layers of organic material (up to several metres thick) are known as peat or bog. Due to excess water, the plant material has not been converted into humus. Peat is primarily converted into humus following drainage of moist peatland, under influence of oxygen.

**Groundwater**

Water contained in the ground can be found in different forms. A distinction is made between

- groundwater: this water fills all pores between the particles, both big and small, and flows freely. The upper limit of the groundwater is known as the ground-water table or phreatic level. The depth (or height) of the ground water is always measured in relation to the ground level
- capillary water: this water saturates the fine pores and fissures of the ground, and is unable to move freely.
- swell water and adhesion water: water in and around the solid soil particles.

Capillary water, swell water and adhesion water are also known as soil water.

Groundwater level of a terrain can easily be established through soil drilling. In the Netherlands, the ground beneath the ground-water table – fully saturated by water – is grey in colour due to iron having the bivalent oxide FeO. In dry soil above the phreatic level, iron only occurs as $Fe_2O_3$, which is rusty in colour. The transition zone is spechled with rusty and spots. This method is not 100% foolproof however, as numerous grounds in the Netherlands contain little or no iron.

Groundwater tables are divided into water-table classes, where the highest mean groundwater level (HMGL (Dutch GHG)) and lowest mean groundwater level (LMGL (DutchGLG)) groundwater level is processed. The groundwater level is determined in relation to the ground level; the depth of the groundwater is representative. The annual natural fluctuation of the groundwater in the Netherlands amounts to several centimetres (10 or more). This movement is characterised by rust stains in the grey-blue groundmass.

| Gt | I | II | III | IV | V | VI | VII |
|---|---|---|---|---|---|---|---|
| HMGL | - | - | <40 | >40 | <40 | 40-80 | >80 |
| LMGL | <50 | 50-80 | 80-120 | 80-120 | >120 | >120 | >120 |
| N.B. groundwater level in cm's below ground level. | | | | | | | |

*Fig. 455 Main subdivision of the water-table classes*

Downward groundwater flows are the result of differences in groundwater levels in an area. Although the general direction of the groundwater flow is known, it will need to be determined for local situations.

In addition to horizontal groundwater flow, we can also identify a vertical movement of water in the ground. This is known as effluent seepage [kwel], where the water ‘surfaces' from the ground-water, and infiltration, characterised by ‘downward movement’ of water.
Soil pollution can spread through the soil through groundwater flow. An insight into the degree, velocity and direction of spread is therefore essential.

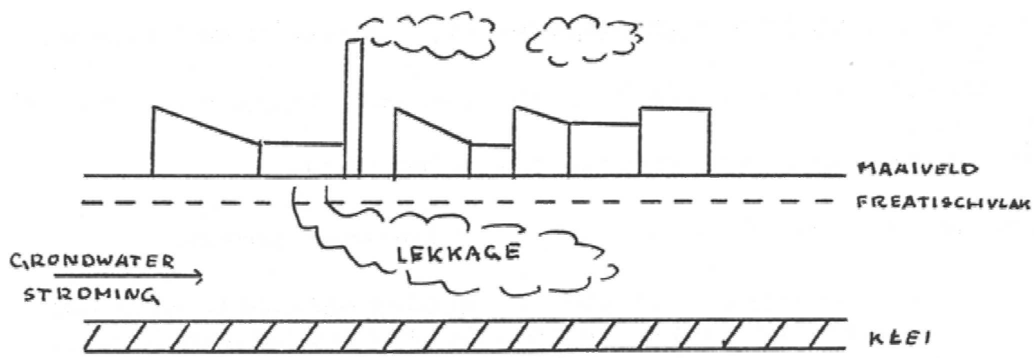



*Fig. 456 Horizontal groundwater flow*

**Soil vapour**
Soil vapour occurs in all areas where the pores of the soil are not saturated by water. This air plays a part in all biogenic activities in the ground, but can also be relevant for the different chemical processes in the soil.
The composition of this soil vapour can vary strongly. The air is usually more or less identical to the atmosphere. However, because of the chemical pedological processes and soil pollution, the composition can differ significantly from the atmosphere, and even be toxic.

**Soil types**
On the basis soil types of the solid constituents of the ground, it can be classified into sand, clay and peat.
- sandy soil; this soil primarily consists of mineral soil particles with a particle size of 50 to 2000 mu, while the clay content (particles) is less than 8% of the overall weight per unit of soil; soil permeability is good
- clay; this soil contains at least 25% clay fraction; soil with a clay content of 8-25% is known as sandy clay; ground permeability is poor or non-existent.
- peat soil; this soil is primarily made up of decomposed plant remains other than humus. The organic dust content must be at least 22.5% of the weight. The other constituents are mineral and can contain particle sizes of clay and sand.

### 4.5.3 Soil pollution and building activities

**Application (previous) "clean soil statement"**
Until comparatively recently, planning permission applications were needed to include a so-called "clean soil statement". This has been replaced by a suitability certificate, indicating intended purpose. A soil survey report needs to be submitted during the application stage. The investigation must be carried out in accordance with the "Soil Protection Guidelines". If the exploratory survey (historic survey) reveals signs of soil pollution, a follow-up investigation will be required.

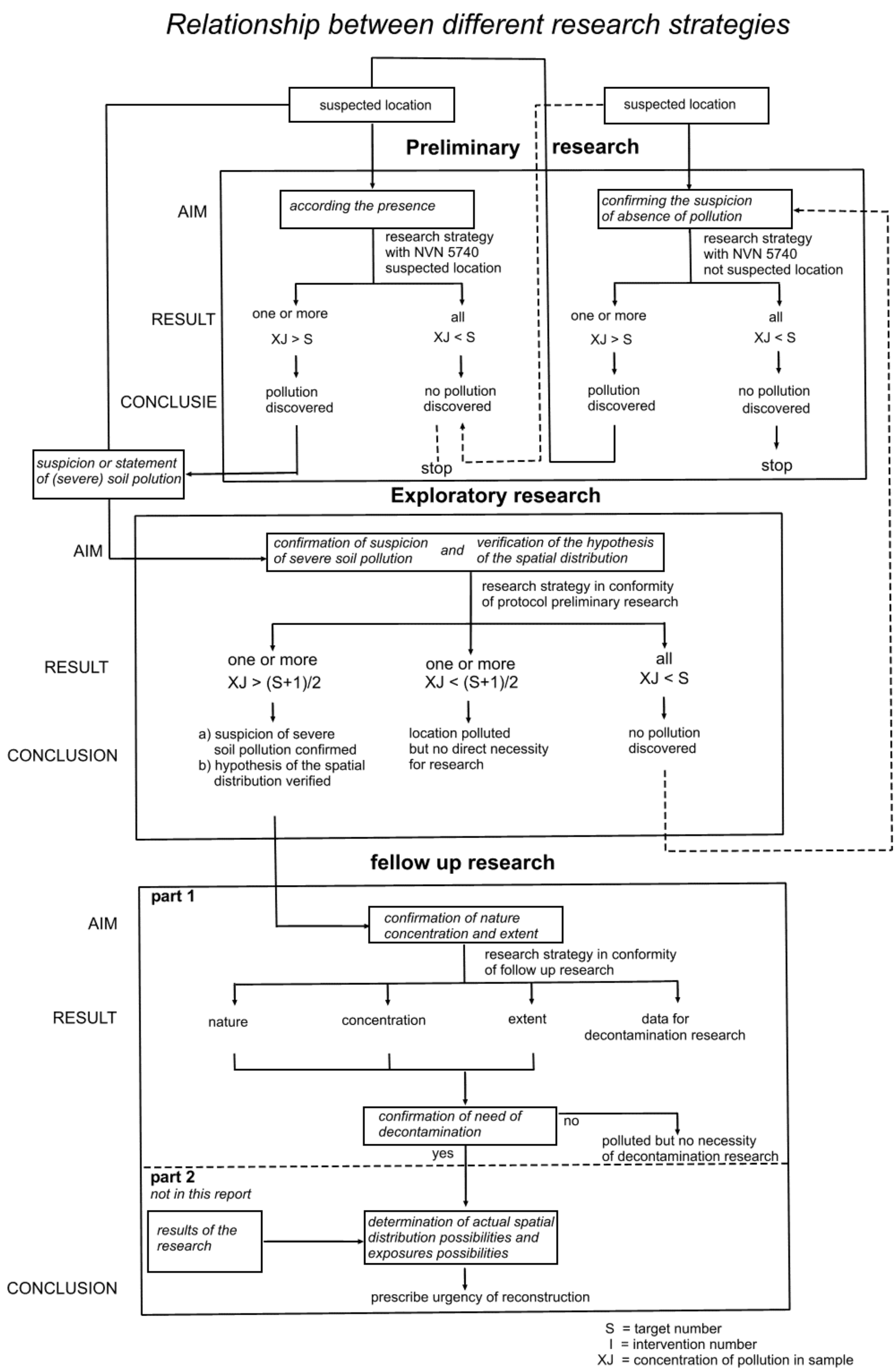
When drawing up his historic survey report, the investigator makes use of standardised survey setups, as well as municipal information and assessments. In many cases, the relevant council can provide information on behalf of the "historic survey". Based on the outcome of the survey, an exploratory investigation is instigated if contamination is suspected. The sole purpose of this investigation is to indicate the incidence of soil pollution.

The setup and criteria which the investigation must satisfy are laid down in two protocols:

- "Exploratory survey protocol" into the nature and concentration of contaminating substances, and the location of soil pollution[a];
- "Follow-up investigation protocol" (into the nature and concentration of contaminating substances, and the scope of soil pollution)[b].

On the basis of both protocols, an overview is included of the survey methods to be deployed, including information relevant for building contractors. If you wish to carry out this survey yourself, you will be required to comply with these protocols.

[a] Lame and Bosman (1994): "Protocol voor het oriënterend onderzoek" naar de aard en concentratie van verontreinigende stoffen en de plaats van voorkomen van bodemverontreiniging.
[b] Lame and Bosman (1993): "Protocol voor het nader onderzoek" naar de aard en de concentratie van verontreinigende stoffen en de omvang van bodemverontreiniging.

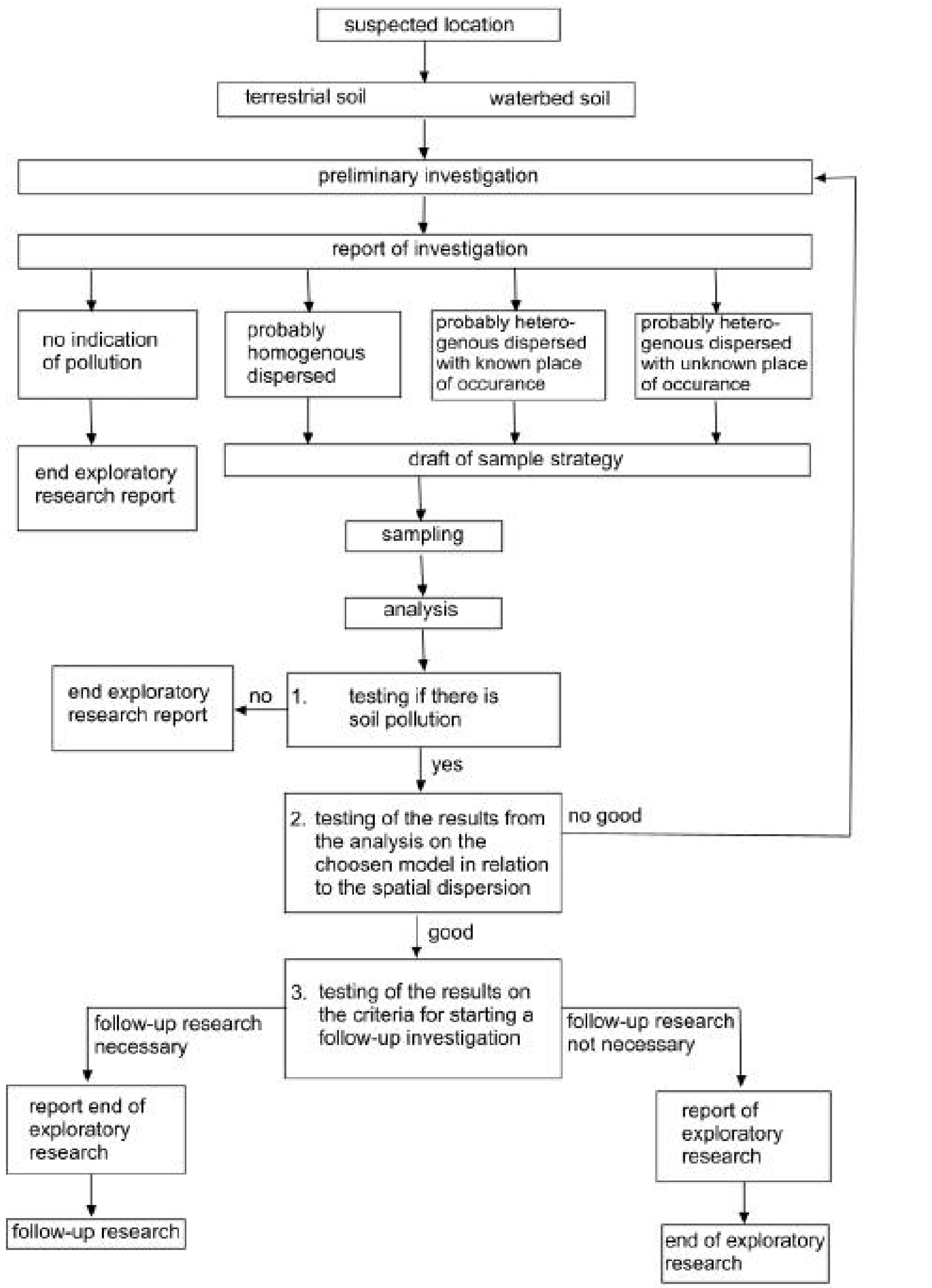



The exploratory research in confirmity of NVN 5740 refer only to the research of a land soil.

F.P.J. Lame and R. Bosman (1994)

*Fig. 457 Research strategies in protocols*

### 4.5.4 Exploratory survey




The structure of the exploratory research is the same for terrestrial soils as for waterbed soils; the strategy for sampling can differ on certain parts.. The soheme should be executed seperately for both soil's.

F.P.J. Lame and R. Bosman (1993)

*Fig. 458 Exploratory survey protocol*[a]

As demonstrated by the above diagram, the exploratory survey is divided into terrestrial soils and waterbed soils, while the survey itself is divided into an exploratory investigation with a concluding report, and a more detailed investigation in the event of soil pollution. This investigation is also concluded with a report.

[a] Lamé and Bosman, Protocol voor het oriënterend onderzoek, SDU, Den Haag 1994

**Preliminary survey**
An exploratory survey must be carried out at all times to obtain a suitability certificate to commence building work. This process involves collecting information and data on past and present use of the site, as well as the soil conditions, soil composition and the (geo)hydrologic setting. This might also involve the pollution crossing terrain boundaries, from the location "outwards", and "outwards" towards the location. Pollution might also concern the ground beneath the buildings, in particular if we are dealing with a permeable soil such as sandy ground.
The investigation includes an on-site visit. During this visit, soil drillings can be carried out to gain an impression of the soil composition and the likely contamination detected through sensory perceptions (colour and odour).

Please take your own safety into consideration; be careful when inhaling and touching substances. If you need to smell and/or touch something, please do so in small quantities at a time.

The sampling strategy of the continuation investigation is based on information obtained from this "field visit" – such as location and structural condition of the buildings. So the results should be reported
With regard to construction work, we will confine our research to terrestrial soils.

**Information required for preliminary survey**
As previously mentioned, this information needs to include details on:
1. past and present use of the site
2. the soil composition and geo-hydrologic settings of the site.

As a minimum, information on past and present use of the site must contain the following details:
- past use of the location and immediate surroundings;
- location of occurrence of possible pollution sources; for example legal or illegal dumping and discharging, leaking (underground) pipes and tanks. Council registrations of pipes and storage tanks are a useful tool in detecting the source of contamination, but do not rely too much on this registration. It is not always used on private owned plots.
- information on potentially contaminating activities, such as production processes, storage and transfer locations. Remember also to draw up an inventory of the relevant substances. An indication of the location of these activities, if possible, will simplify inventory activities and the investigation.
- methods and materials used in the past for preparing a site for building, including opening up the site.
- details of in-situ cables, pipes, debris, consolidations.
- past and present activities on adjoining terrains.
- investigations into soil pollution on neighbouring or adjacent terrains
- inventory of past users of the terrain, with their activities from approx. 1900.

**Information on soil composition and geo-hydrologic settings of the site**
As a minimum, this information must encompass the following:
- on-site soil composition, both shallow and deep (over 10m); information obtained from soil drilling tests and drilling;
- depth of the ground water
- horizontal and vertical movements of the ground water (effluent seepage, seepage and groundwater flows)
- position of water channels and other surface water (also drained)
- presence of groundwater sources and groundwater drawoff
- prevention of brackish and/ or salty ground water
- results of earlier soil surveys on-site or in the immediate surroundings; also include past surveys into soil pollution.

It is advisable to incorporate into the survey research of the properties of contaminating substances and microbiological activities. Although it is not compulsory to include this information, it can provide a valuable insight into the problems, and assist in selecting an investigation strategy and, if need be, determining the remediation method.

The information on past and present use of the site, as well as the information on soil composition and geo-hydrologic settings of the site, needs to be incorporated into the exploratory survey report, including relevant sources.

**Implementation of preliminary survey**
How can we obtain the relevant information?[9]

- use recent maps: topographical, from the land registry and maps of pipelines and mains, as well as soil and geological maps including legends. The local council office can usually provide historic data.
- use of old and recent aerial photographs, which can be obtained from the municipality, topographic survey and numerous aerial photography firms. Additional tools include infrared and other recordings falling under the heading of 'remote sensing images'.
- exploratory visit to the site, carrying out field observations and soil drillings to take samples.
- investigation into archives, permits and dossiers (under the Nuisance Act) relating to past and present use of the terrain
- interviews with (former) employees and the local community
- use of archives of different municipal, provincial and government institutes
- branch-information concerning past use of the terrain in relation to possible contamination
- historical information from council and water boards.

This information must be incorporated in the report, concluding the exploratory survey.

**Provisional conclusion**
If all (writing desk) investigations indicate the likelihood of soil pollution, the survey must be extended to include information on the nature and concentration of the contamination collected on-site and laboratory analyses. This effectively is the start of the exploratory survey; a certain degree of in-depth research is required. A section of the preceding research must be expanded and deepened, as the results of the exploratory survey indicate a suspected case of soil pollution and a rough understanding of the contaminating substances. The distribution of these substances has also been mapped out in outline. On the basis of this information, a strategy is developed for the research methodology in general, and samples taken. The selected method(s) are subjected to tests, essential for eliminating potential mistakes and focussing the investigation, if need be.
This survey reveals whether we are actually dealing with soil pollution, and is concluded with a report, indicating the presence of soil pollution and recommendations for "follow-up research".

**Additional notes concerning the exploratory survey**
In the event of a contaminated land soil, it is not necessary to examine the groundwater, provided the mobility of the contaminating substances is negligible. It would however be wise to do so, as most contaminating substances are either soluble in water or present in liquid form in the ground.

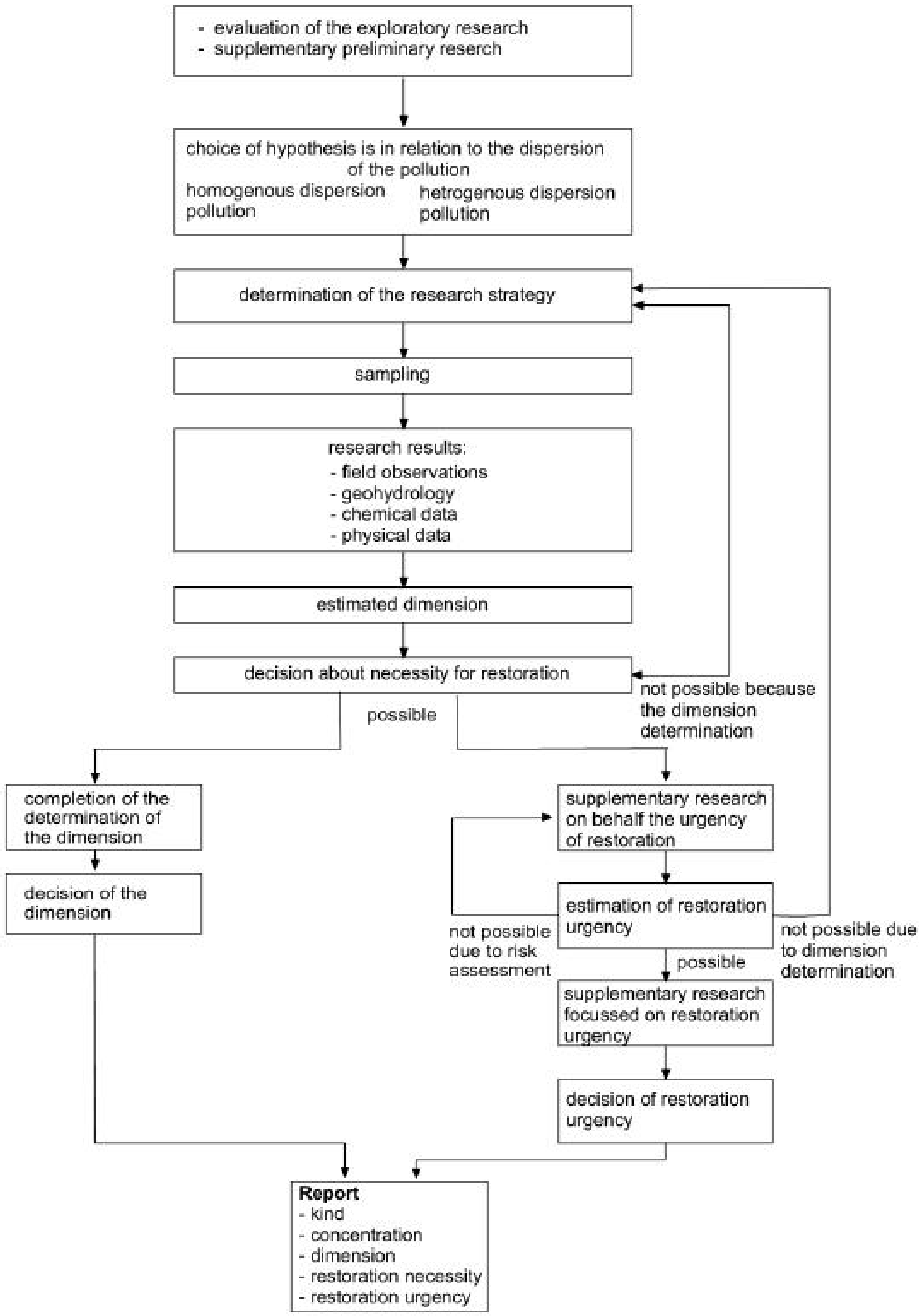
Sensory perceptions of contamination – by smell and/or perception or the identification of something "different" in the ground - is not really objective, but rather indicative. In addition, complicating factors must be taken into consideration, such as potential health risks for the observer.
Visual perceptions can also be clouded by the natural colour of the soil.

With regard to safety, VROM (Environment Ministry) has produced a series of publications. When carrying out a soil sample, a certain degree of care must be taken, not only by those taking the sample, but also by onlookers. As a minimum, warning signs must be displayed in the event of assumed contamination. Even better would be to temporarily close off the site.

**Sampling strategy**
In principle, there are different contamination types and therefore different sampling strategies. Homogenously spread contamination requires evenly distributed sampling. This is based on 1000 m2 spatial units (RE) in the horizontal plane. Per RE, 3 drills must be carried out, whereby the resultant ground samples are put into a mixed sample of the suspect layer and analysed.
An alternative sampling method is used for heterogeneously distributed contamination in known and unknown place of occurrence. As the preceding investigation has determined the type of contamination and its spread, a specific sampling method can be drawn up.
Needless to say, research results will need to be tested.
The exploratory survey is concluded with a report. In the event of actual soil pollution, a follow-up investigation will be carried out in accordance with the applicable norms.

**Carrying out the investigation**
In principle, anyone can carry out the survey, provided the details on past and present use have been incorporated in the final report. The same applies to information on soil composition and the geohydrolic setting. Soil samples that require analysis can be carried out in a specialist soil analysis laboratory on the instructions of the researcher.
The exploratory survey can also be entirely outsourced to a specialist research agency.

### 4.5.5 Follow-up investigation




F.P.J. Lame and R. Bosman (1993)

*Fig. 459 Protocol for follow-up investigation*

Having completed the assessment of the exploratory survey, plans are now drawn up for a follow-up investigation (including additions to the exploratory survey).
The aim of this investigation is to establish the nature and concentration of the contaminating substance(s) and the dimensions in both the horizontal and vertical plane[10].

An insight into the local soil composition is essential, as is soil sampling. Regulations have been drawn up for this purpose. Soil sample analyses and results interpretations must be carried out in accordance with the protocol.
A follow-up report is drawn up on the basis of the results.

This report must comprise the following information[11]:
- nature of the pollution
- concentration of the pollution
- extent of the pollution
- need for remediation
- urgency of remediation

N.B. this report does not offer advice on whether remediation is required, nor on the remediation method. These decisions are taken by the relevant institutions.

**Implementation of the investigation**
In principle, anyone can carry out this follow-up investigation. However, due to the substantially more complex nature of this investigation – in particular with regard to the behaviour of substances and pedologic research, it would be advisable to enlist expert help.

**Determining the level of urgency for soil remediation**
A systematic approach has been drawn up to determine the level of urgency for carrying out soil remediation work. This approach is partially based on the existence of unacceptable risks in the event of serious soil pollution. The eventual decision to carry out remediation work is taken by the competent authority.
This problem falls outside the scope of this chapter.
Further information is contained in the Urgentie van bodemsanering (urgency of soil remediation), published by the SDU.

### 4.5.6 Causes of soil pollution there are many (manmade) causes of soil pollution.

**Industrial sites**
In view of the fact that most incidences of soil pollution are likely to occur in industrial sites, we have confined our research to these areas. It must however be noted, that these terrains are also found in built-up areas, and that a petrol station and garage in a residential area may also be a potential contributor to soil pollution.
In general, the causes of pollution on industrial sites include[12]:
- leaking (underground) storage tanks and company sewers. These types of leaks are frequent occurrences, spanning longer periods. In addition, the replenishment of tanks can cause numerous problems.
  Old storage tanks for central heating oil are often located in the vicinity of residential buildings
- discharges directly into the ground of the industrial site
- dumping company waste on own site
- land fills containing own company waste and/or waste matter such as ash, waste products and cinders from incinerators.
- calamities such as fire, explosions, floods, pipe fractures etc.

Many contaminating substances have entered the ground in the course of time due to ignorance, mistakes, leakages and accidents such as spillages when transferring material or fuel.
The absence of clear operational regulations governing the handling of raw materials and the end product with regard to storage, transfer and carriage, as well as the disposal of waste matter, have almost certainly contributed to soil pollution.
The often lazy attitude of managers and operational staff is a further culprit.

**Terrains other than industrial sites**
In addition to industrial sites, soil pollution regularly occurs in waste dumps (rubbish tips), storage yards of (polluted?) ground, mines, quarries, gas and oil rigs and salt extraction areas etc. Pollution may also be generated by the re-use of, for example, previously contaminated building materials, as concrete aggregate. In Rotterdam for example, contaminated debris of WW2 aerial bombardments is still causing significant problems. Agriculture and horticulture are also potential polluters due to their use of pesticides and fertilizers.

**Standardisation**
The standards governing the most frequently occurring forms of soil pollution are drawn up in a "test table" for ground and groundwater in the Leidraad Bodemsanering (Soil Clean-up Guidelines). These standards are subject to alterations, and can be amended in line with recent surveys. As such, it is essential that the most recent tables be used. It seems best therefore to use the term "indicative target values", which are divided into A, B and C values.

The A value is the reference value. If this value is exceeded, we are dealing with contamination[13]. The A value differs per soil types, as adsorption processes are particularly relevant in clay and peat soils. In other words: if this (contaminated) soil has an A value, it is suitable for all purposes.

The B value is an indicator of contaminated soil; it does not reveal to what extent the soil is contaminated. Further research is required in accordance with the “exploratory survey” protocol.

The C value is the actual test value. In this case, soil remediation is required in accordance with the “follow-up investigation” protocol.

The system of A, B and C values was replaced in 1995 by a system of clean soil target values [14] (new A value) and soil remediation intervention values [15] (C value). The intervention values are based on risk assessments, highlighting risks to the eco system as well as risks to man[16].

**Relationship industrial sector and soil pollution**
Industrial sites are categorised as follows in soil pollution surveys:
- former gas factories
- former and existing industrial sites
- former and existing car and machine wreck depots
- former and existing tips in general
- former and existing goods transhipment sheds
- former and existing borrow areas (coals, oil, salt, gas, clay, rocks etc.)

In 1991, soil remediation costs amounted to approximately 84 billion Dutch Guilders, and primarily concerned remediation of former industrial sites. More recent data are not available.

The relationship between soil pollution and industrial sector is self-evident. The risk of soil pollution is effectively dependent on company operations [17].

| Business operation | Pollution |
|---|---|
| metal and galvanic industry | all kind of heavy metals, cyanids aromates and chlorinated solvents (Tri and Per) |
| paint and dye industry | all kind of heavy metals, PCB's, aromates and chlorinated solvents (Tri and Per) |
| graphic industry | idem |
| textile industry | chlorinated solvents (Tri and Per) |
| chemical lavendaries and textile cleaning service | all kind of heavy metals, pak's and chlorophenol |
| carpentry and wood preserizing | |
| tanning and leather working industry | hydrocarbons and chromium |
| petrol stations | mineral oils, aromatics and lead |
| garages | mineral oils, aromatics, lead and battery acid |
| breaker's yard | all kind of heavy metals |
| pesticide industry | halogenated hydrocarbons, aromatics, mercury, tin and arsenicum. |

J. Verschuren (1993)

*Fig. 460 Overview of prominent forms of soil pollution per operation*

**Pollution types and occurrence in the soil**
Soil pollution can take on different forms, depending on chemical composition, phase (gas, liquid, solid) and soil type. Clay ground particles for example can be contaminated through adsorption, immobilising the particles. The intervention values (previously B and C values) differ for clay soils and sand soils. Sand soil is unable to form a compound with contamination particles.

Incidences of pollution:
- solid form – solid particles: metals, compounds of heavy metals and metalloids
- adsorption - cation: adsorption of soluble salts of heavy metals to clay particles and organic components of the ground (humus or peat)
- adsorption - molecule: molecule adsorption of aliphatic and aromatic compounds to organic components of the ground
- liquid phase (insoluble or poorly miscible in water): mineral oil, petrol and organic solvents. Liquid occurs in the soil in droplet form or as a film surrounding the soil particles. In this type of pollution, the specific weight of the liquid plays an important part. Liquids that are heavier than water will form a layer above a poorly permeable layer, while liquids lighter than water will form a layer on the ground-water table.
- soluble in water: occurrence in groundwater
- gas phase: aromatics (BTEX), volatile components of petrol, diesel oil and other mineral oils, volatile chlorinated hydrocarbons.

The above pollution types can be divided up into a number different categories, which in turn can be categorised per industry sector.
Pollution types:
- heavy metals and metalloids: chrome, cobalt, copper, cadmium, nickel, arsenic, zinc, tin, mercury, lead and antimony. Occurrence as metal and as oxide, sulphate, nitrate, halogenated, carbonated or silicate forms.
- complex cyanides and free cyanides
- aliphatic and aromatic hydrocarbon and mineral oils.
- volatile halogenated hydrocarbon: Trichloroethylene, Perchloroethylene
- non-volatile halogenated hydrocarbon: Polychlorobiphenyl (PCB), different types of pesticides
- other compounds: ammoniac, acids, lye, phosphates, sulphates, nitrates

### 4.5.7 Remediation methods
Remediation techniques have been under development in the Netherlands since 1980. As soil remediation is a relatively new technology, large-scale techniques are still being developed.

Remediation methods can be categorised into two main groups, with a third group acting as a combination of the main groups [18].
1. soil recovery
2. isolating the pollution
3. combination of isolation and recovery.

**Soil recovery**
Soil remediation by excavating, followed by soil purification or dumping.

The primary purification techniques [19] involve:
- thermal and extractive methods for removal and
- biological methods for alteration.

Tipping must be considered, if there are no adequate soil purification techniques for this specific situation[20].
Temporary storage is considered if the purification plant has a limited capacity[21].
Soil remediation through in situ purification is currently under development. In addition to not having to excavate the ground, other advantages of this method include its relatively low costs and no interruptions to the company operations[22]. The techniques applied include flushing out the contaminated soil ("washing"), extraction of polluted air streams, chemical or biological conversion and removing pollution via an electric field.
Most contaminated soils are cleaned up by excavating, followed by soil purification. In situ soil purification occurs on a limited scale, but will become increasingly commonplace in future.

**Isolating the pollution**
This process effectively involves containing the spread of the pollution. This can be achieved in a number of different ways[23]:
- installing vertical and horizontal screens, such as sheet piling, building plastics, mastic layers, bentonite-cement slurry walls etc.
- pumping up groundwater and/or infiltration water.
- using fixation techniques; immobilising the pollution.

Isolation is primarily used in cases of extensive pollution, where "hot spots" – places with the highest pollution levels - are isolated in order to prevent further spread before complete remediation, or in order to be cleaned up first[24].

**Combination of isolation and recovery**
In cases, where it is not (yet) possible to recover the soil for all types of pollution, the unrecovered areas are isolated.

### 4.5.8 Soil purification techniques
Soil purification methods are aimed at removing the pollution or converting the pollution into components that pose a minimal, or acceptable, risk to man and the eco system[25]. The latter method comprises biological degradation and conversion of the pollution. The characteristics, on which the soil purification process is based, are determined by the specific (chemical) properties of the pollution.
The most prominent properties are:
- phase: gas, liquid, solid (volatility, boiling point)
- solubility in water or in another solvent
- adsorption/absorption (electric properties)
- chemical stability
- thermal stability
- magnetic properties
- biodegradability/convertibility
- weight and form of the particles
- size and shape of the particles.

In addition to the soil purification technique, the "remediability" of the ground also plays an important part, as soil purification comes with a price tag attached. Soil remediation experts will need specific information, such as the nature and concentration of the pollution, the presence of other contaminants and debris, plastic, cinders, vegetation remnants etc. Knowledge of the soil in terms of grain-size frequency distribution, organic dust content and moisture content are also essential factors in the world of soil purification.

This chapter will focus on the following purification techniques, see RIVM (1994):
1 techniques for excavated grounds;
2 in-situ soil purification techniques;
3 isolating contaminated sites.

**Purification techniques for excavated grounds**

**Thermal soil purification**
Thermal soil purification involves increasing the temperature of the ground to such an extent, that the contaminating substances are evaporated and/or decomposed and evaporated. The techniques used during this process fall outside the scope of this dissertation.

Application: all types of organic contaminations.
In principle, this method can also be applied to heavy metals and their compounds, provi ded temperatures reach approx. $800^o$ C.
Thermal soil purification can be applied to any type of soil. However, soils with (a high content of) organic material will be susceptible to burning. Clay and loam soils require more energy for this process than sand soil. Furthermore, measures must be taken to guarantee a steady soil supply.
In thermal soil purification, the contaminated substances are evaporated, and the vapours filtered. The resultant emissions are subject to severe criteria under the Wet op de Luchtverontreiniging (Air Pollution Act).

**Purification through extraction**
The extraction process is divided into a number of phases:
- putting the contaminated ground into contact with extracting agent (dissolved in water)
- separating extraction particles from the clean ground through rinsing out
- purifying the (contaminated) extract

Application: suitable for removing heavy metals, metal compounds and organic pollution.
This method is ideal for purifying sand soils, due to the proportionately low adsorptive forces between sand grain and contaminant. Due to the relatively high adsorptive forces of clay and loam grounds, this method is unsuitable, or less suitable, for these soil types.

**Biological soil purification**
In this process, organic contaminants are decomposed or converted by micro-organisms into compounds that are not harmful, or virtually harmless, to man and the eco system.
A distinction is made between a mineralisation process with anorganic end products, and degradation with incomplete mineralisation.
These biological processes are however known to cause highly toxic inorganic compounds such as chlorinated derivatives due to the decomposition of organohalogens. It is of vital importance that employees working on site be adequately protected.
This biologic soil purification method is based on landfarming and bioreactor techniques.

In landfarming, the contaminated ground is spread in a thin layer across a suitable terrain and cleaned by natural microbiologic processes. The degradation process is stimulated by adding oxygen, cultivating the ground (ploughing), adding lime and nutrients for the decomposing organisms, and by proper water management.

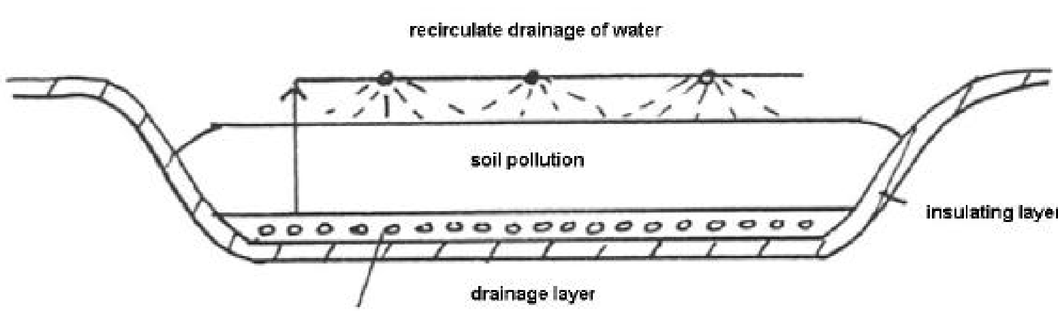


*Fig. 461 Landfarming diagram*

**Bioreactor techniques**
We can identify two bioreactor techniques: a dry form, comparable with composting solid waste, and a wet form in so-called soil slurry reactors.

This technique can only be applied to organic compounds.
In principle, this method is suitable for all soil types, but is usually applied to sand soils due to its high permeability and ease of cultivation.

The disadvantages of this method include the long duration of the soil purification process, and difficulties in reaching the target values.

**In-situ soil purification techniques**
See E. Schut (1994).

**Soil vapour extraction**
Volatile compounds are removed by extracting soil vapours, and subjecting them to surface clean-up. This process is known as soil vapour extraction, and is solely applied to volatile substances such as Perchloroethene, Trichloroethylene, petrol, benzene, toluene, xylene, Ethylbenzene and Methylene Chloride.
This method can only be applied to permeable grounds such as sand.

Disadvantages include difficulties in reaching the target value, longevity of the process (can take several years) and, in the case of mineral oil, the leftovers of heavy components.

**Bio restoration**
The process of bio restoration consists of optimising the conditions for micro-organisms responsible for ground purification.

This method is primarily applied to sand soils, as the contaminant must be easily degradable. As a result, this method is mainly used in pollution types involving mineral oil and low molecular weight polycyclic aromatic hydrocarbons.
This method also has its disadvantages: it takes a long time to achieve the target value, if it is achieved at all.

**Liquid extraction**
Contaminants are extracted from the ground through the infiltration of a water-based extracting agent, causing a chemical reaction. The extracting agent, containing the dissolved contaminants, is then pumped up and cleaned above ground. Liquid extraction can continue until the desired target value has been reached.

Application: primarily in easily permeable soils such as sand soils. This method is suitable for all pollution types that are soluble in extracting agents, including heavy metals, low molecular weight polycyclic aromatic hydrocarbons, low molecular weight halogenated solvents, phenol and benzene.

The total duration of this process ranges from several months to several years. It is not always possible to achieve the target value.

**Electro reclamation**
The method of electro-reclamation is based on three direct current transmission lines: electro-osmosis, electrophoresis and electrolysis.
Ions or ion complexes are transmitted through liquid between the soil pores under influence of an electric field. This causes the polluting ions to be carried to the electrodes and removed via a pumping system.
Application: this method is ideal for purifying clay soils contaminated by heavy metals. Its main disadvantage however is its energy inefficiency.

**Conclusion**
The above in-situ soil purification techniques are currently operational in the Netherlands. A certain degree of experience has been gained with most of these techniques, in particular underground contamination and polluted petrol stations. At present, it is virtually impossible to achieve the A value

using these techniques. Furthermore, they are only suitable for homogenous areas. The remediation methods take a relatively long time to implement. Having said that, these in-situ soil purification methods also have a number of advantages, including underground remediation, tackling deep contaminations without the need for earth moving, and causing minimal disruption.
It is clear from the above, that researchers in the Netherlands are currently on a steep learning curve in terms of remediation techniques, learning from every new piece of technology, unveiling new and at times unexpected information. In my opinion, promoting in-situ soil purification is highly desirable, given its advantages. One solution would be to increase the costs of tipping, and inspecting tipping activities. It might also be useful to carry out a feasibility study into the use of A-value as a follow-up remediation value. Greater flexibility in remediation policy would promote the use of these relatively simple techniques.

**Isolating the contaminated sites**
A polluted soil is screened off, thus containing the spread. This method can involve closing off the site and preventing potential spread via soil vapours.

**Civil-engineering isolation techniques.**
This civil-engineering isolation technique is based on the erection of impermeable walls of steel, bentonite-cement slurry walls and grout curtains. Preventing sideward spread alone will not suffice, as the upper surface and lower surface must also be isolated.
This technique can be applied to all areas. Disadvantages include the behaviour of isolation walls in the course of time. Only steel walls are moveable.

**Geo-hydrologic isolation**
Geo-hydrologic isolation involves pumping up the groundwater of a contaminated site, preventing the spread of pollution in the groundwater. This pumping action can be combined with water infiltration from an adjacent area.
Application. This technique is difficult to apply in built-up areas, as soil layers are generally prone to settling during water drawoff. The degree of settlement depends on the ground type.
This technique releases (lightly) polluted water that needs to be discharged. This cannot simply be done into a sewer or open water, so the water has to be cleaned prior to discharging.

All the above isolating techniques require adequate site management and inspection, even in the event of (partial) failure of the technique.

A special isolation method is being applied to a number of urban areas. Ground that is proving difficult to clean due to the surrounding buildings, is isolated from all sides. The overburden is partially excavated and isolated. A layer of clean soil, known as the living layer, is applied on top of the insulating layer. When using this terrain for building work, care must be taken that this upper insulating layer is not "infiltrated". This method is currently being applied in the city centre of Amsterdam.

**General conclusion remediation and soil purification techniques**
One of the biggest problems associated with contaminated sites is that they contain a significant amount of urban, industrial, building and demolition waste in addition to polluted ground.
Pollution is rarely of a singular nature; it is usually characterised by a combination of contaminating substances, which frequently need to be extracted in different ways from the ground.
Some substances are impossible to extract from the ground, or require extraction methods that have not yet been discovered. In this case, isolation is currently the only solution available.

**Consideration**
Purification of contaminated soil requires a lot of shifting of the ground. As such, might it not be wise to draw up a plan of approach for preparing the site, as well as a soil purification plan, and effectively combine these two plans? The underground infrastructure can be installed during or immediately after clean-up.
In instances, where a site is located in the middle of a remediation area, where space is at a premium, this combined approach can yield some surprising results.

The follow-up investigation can be carried out by anyone, provided this is done in accordance with the exploratory survey and follow-up investigation protocols, and the requisite details and documents have been submitted in report form to the relevant municipality. It is however recommended that the relevant surveys are carried out by an expert. Soil samples may prove problematic; these can be analysed by specialist laboratories in accordance with the methods indicated

Technical laboratories carrying out these surveys have acquired a certain reputation in this field and are therefore often readily accepted as authoritative by local authorities. These laboratories usually include an executive body, leading to a conflict of interests.

### 4.5.9 References to soil pollution


Koolenbrander, J.G.M. (1995) *Urgentie van bodemsanering: de handleiding* ('s Gravenhage) SDU.

Lame, F.P.J. and Bosman, R. (1993) *Protocol voor het nader onderzoek deel 1: naar de aard en concentratie van verontreinigende stoffen en de omvang van de bodemverontreiniging.* ('s Gravenhage) SDU.

Lame, F.P.J. and Bosman, R. (1994) *Protocol voor het oriënterend onderzoek: naar de aard en concentratie van verontreinigende stoffen en de plaats van voorkomen van bodemverontreiniging.* ('s Gravenhage) SDU.

Maarel, E.v.d. and Dauvellier, P.L.s., Eds. (1978) *Naar een globaal ecologisch model voor de ruimtelijke ontwikkeling van Nederland, deel 2.* Studierapporten Rijksplanologische Dienst ('s-Gravenhage) Ministerie van VROM ISBN 9012021464 (Leerstoelbibliotheek).

RIVM, Ed. (1994) *Handboek bodemsaneringstechnieken Leidraad bodemsanering, leidraad bodembescherming* ('s Gravenhage) SDU (Leerstoelbibliotheek).

Schut, E. (1994) *In-situ reinigingstechnieken voor vervuilde grond* TU Delft Wetenschapswinkel.

Verschuren, J. (1993) *Bodemsanering van bedrijfsterreinen Praktijkboek voor bedrijf en beroep* (Oosterhout) J. Verschuren, Postbus 6038, 4900 HA Oosterhout.

## 4.6 Site preparation

Any adjustment or improvement to the soil and ground-water table deemed necessary to enable the construction and design of a residential and industrial area, must be carefully considered during the planning stage. The technical possibilities and limitations of the ground itself, as well as the groundwater have to be brought into account for planning. Not only are these considerations vital to the ecological preconditions associated with sustainable planning, they also underpin the existence conditions of an area, and economically sound planning.

Traditionally, differences in soil properties necessitated a differentiated approach to ground use. Nowadays, economic factors and strategic planning prevail when deciding on future use. No consideration is taken into account on behalf of management and preservation of (newly created) environment. Management can prove so costly and complex, that even minimal cutbacks or setbacks will create serious maintenance and environmental problems.

Any intervention in the state of the soil must provide a certain degree of guarantie that the newly created situation can be sustained.
Furthermore, any manipulation to the condition of the soil as a result of fill or lowering of the groundwater level, or a combination thereof, will not only affect the actual site, but also the surrounding area. This manipulation are recognizable by changes in the patterns of plant growth. In addition, abrupt transitions - without any limits – affecting built-up area between different areas will affect the visual and social harmony of an area.

The values of the site earmarked for development, land use, cultural-history, vegetation and ecology of the area covered by the plan and the surrounding area must be analysed to enable sound planning and assessments of future use.

This chapter is divided into two parts:and a bonus

4.6.1 site analyses, including determining the suitability of a site for certain purposes.
4.6.2 preparing sites for development.
4.6.4 water boards

### 4.6.1 Site analyses

Site analyses can be carried out in a number of different ways. The preferred method of analysis depends on the information required for a certain activity. The analysis focuses on the built-up and undeveloped parts of the new to develop area. Furthermore, the analysis must not be confined to the area covered by the plan itself; it must exceed the boundaries of that area, as any manipulation may have an impact on the wider surroundings. All analyses concern the existing forms and condition of the site.

We can distinguish the following analyses:

- topographic analyses
- pedologic analyses
- water analyses
- cultural-historical analyses
- land use analyses
- analyses of existing landscape to gether with the existing built-up forms of the area
- visual analyses
- vegetation analyses

The majority of these analysis types are obvious. The methods deployed are dependent on the researcher and the available material. The methodology is further dependent on the anticipated depth of research and analysis.

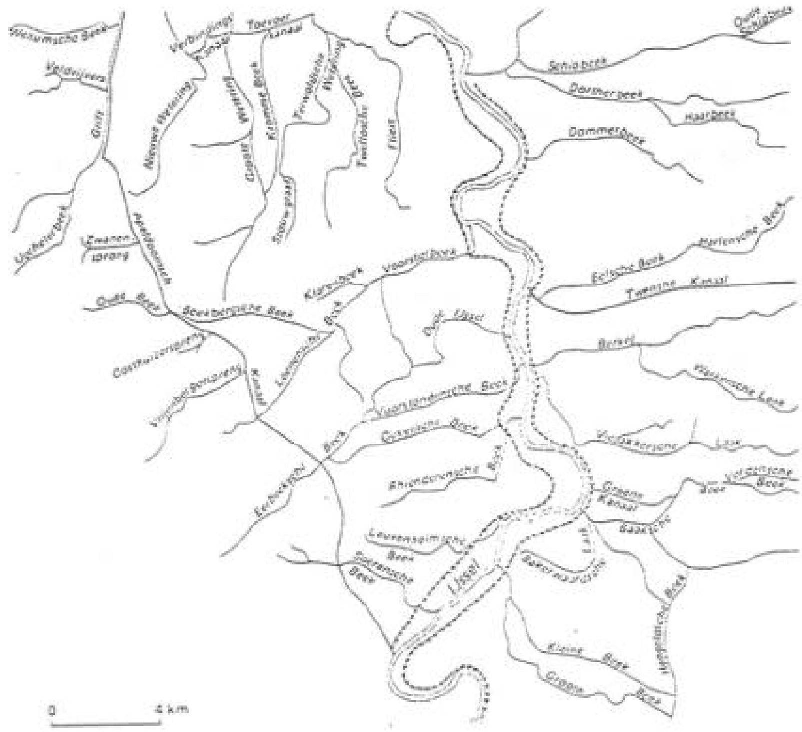


*Fig. 462 Drainage pattern east of the Veluwe*

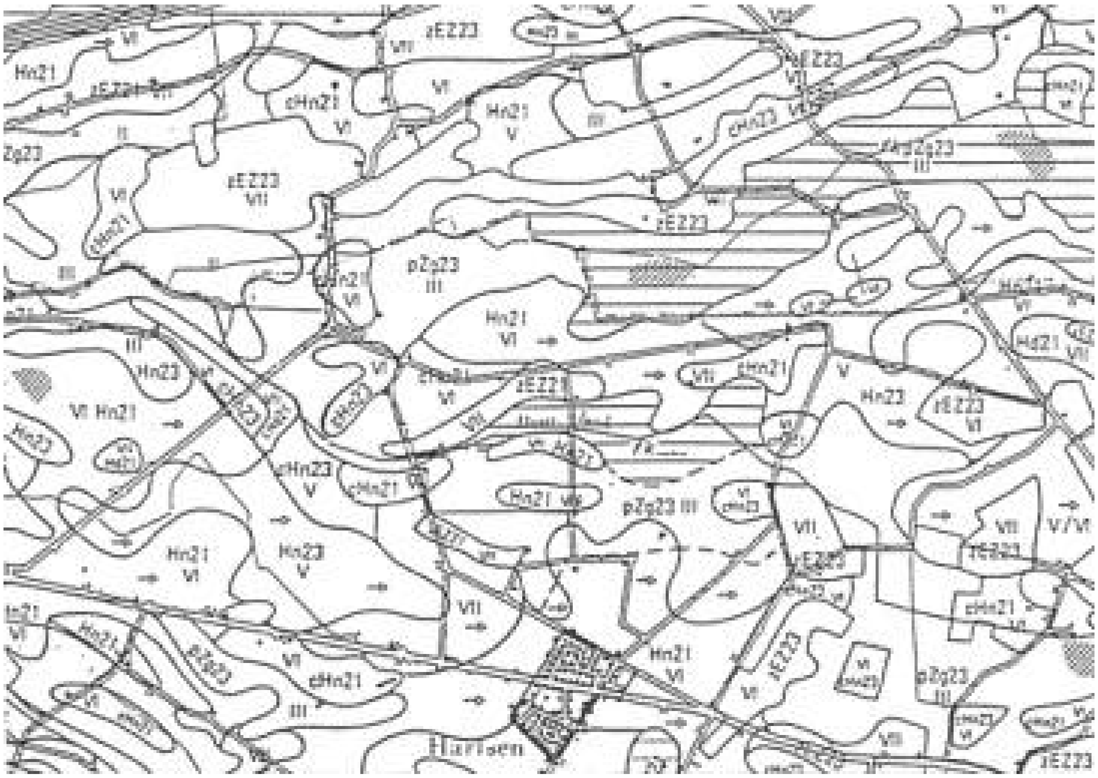
**Topographic analyses**
This analysis involves accurately determining the boundaries of different topographical elements for important urban planning such as buildings, road and rail network, waters (in the form of rivers, channels, ditches and lakes), as well as altitude of the area. The position and spread of the different elements are also incorporated in this analysis.
It goes without saying that this analysis is best served by topographic maps with corresponding legends. Aerial photographs provide additional information, as they reveal all elements and forms found on the earth's surface in real proportion to each other

Scales for topografic map in The Netherlands.
1 : 100.000
1 : 50.000
1 : 25.000
1 : 10.000

First edition topographic and military maps made between 1850 – 1864.
1 : 50.000.

(Topografische en Militaire kaart; TMK)

**Pedologic analyses**

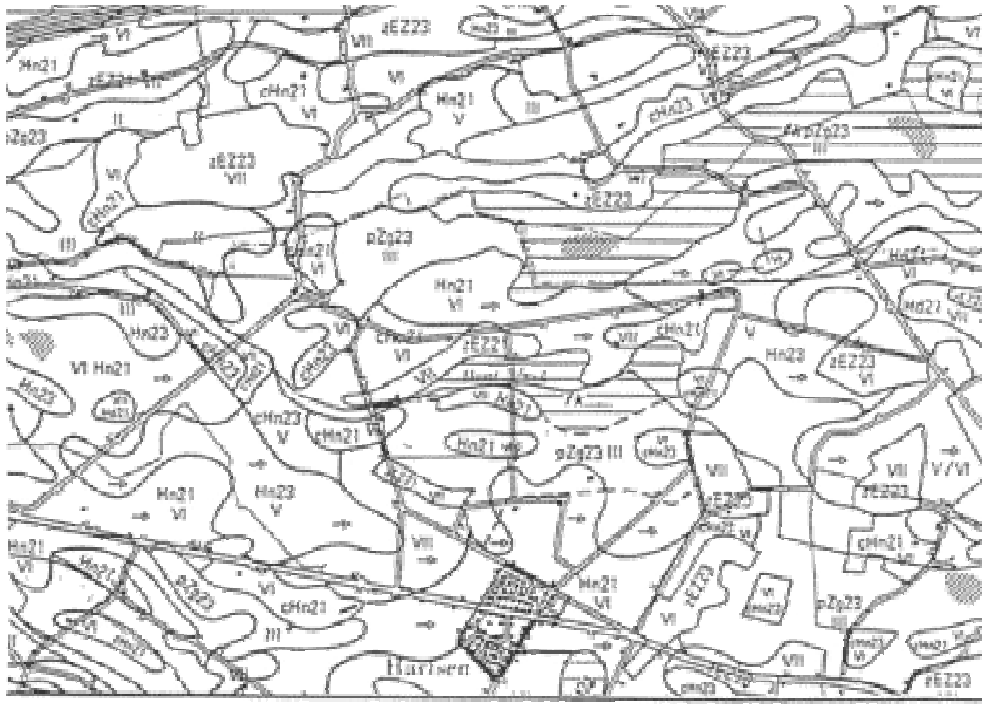


| | | |
|---|---|---|
| HUMUS PODZOL SOIL | ENKEERD SOILS | EERD SOILS |
| Hn: field podzol soil | zEZ: large black enkeerd soil | pZg: brook eerd soil |
| cHn: Laar podsol soil | | |

*Fig. 463 Soil map*

This survey analyses the different soil types present in the designated area. Groundwater data can also be collected, focusing on groundwater quality, depth of the groundwater level, annual fluctuations of the level and groundwater flow.

Potential uses can be determined by analysing the properties of the soil types.
The following soil characteristics are easiest to determine: particle size, particle form, quantity of mineral or organic components, ratio mineral components to organic components, water retainability of the ground, depth of ground-water table, stratification and distribution of the different soil types.*
The groundwater level of a terrain or building pit is easily determined, and is outlined in the appendix.
Scale of the dutch soil map 1 : 50.000.
Scale of the dutch groundwater-table map 1 : 50.000.
The soil map and the groundwater-table map are combined in one map 1 : 50.000.
* Be aware not all these characteristics are interesting for urban/town planners and landscape architects.



| (Gt) | I | II | III | IV | V | VI | VII |
|---|---|---|---|---|---|---|---|
| (GHG) | (<20) | (<40) | <40 | >40 | <40 | 40-80 | >80 |
| (GLG) | <50 | 50 – 80 | 80–120 | 80–120 | >120 | >120 | (>160) |

*Fig. 464 Ground water class map*

Ground-water tables are divided into groundwater-table classes. The class itself is sub divided in the highest and the lowest mean groundwater level. It is a series from wettest, groundwater level (HMGL) and to dryest groundwater level (LMGL) (see *Fig. 455*, page 248). The groundwater level is determined in relation to the ground level; the depth of the groundwater is representative. The annual natural fluctuation of the groundwater in the Netherlands amounts to several tens of centimetres. This movement is characterised by rust stains in the grey-blue groundmass due to the presence of iron in the soil.

Groundwater flows are the result of differences in groundwater levels in an area. Although the general direction of the groundwater flow is known, it will need to be determined for local situations. This is especially the case when there is soil pollution.

In addition to natural groundwater tables, the Netherlands also has artificial groundwater tables, which are kept at a predetermined level by pumping. Such an area is called a polder. Pumping also creates groundwater flows towards the pumping plant. Areas adjacent to the waterways in this polder are characterised by groundwater flows towards these waterways.

In addition to horizontal groundwater flow, we can also identify a vertical movement of water in the ground. This is known as seepage (kwel), where the water ‘surfaces' from the ground-water, and infiltration, characterised by ‘downward movement’ of water.

Soil pollution can spread through the soil through groundwater flow. An insight into the degree, velocity and direction of spread is therefore essential.

For further information on soil pollution and soil remediation, see: previous chapter on soil pollution.

**Soil air**

Soil vapour occurs in all areas where the pores of the soil are not saturated by water. This vapour plays a part in all biogenic activities in the ground (soil animals, decomposition of plant remains). In addition, the presence of oxygen in the soil produces a number of different chemical processes.

The composition of this soil air can vary strongly. The air is usually more or less identical to the atmosphere. However, because of the chemical pedologic processes and soil pollution, the composition can differ significantly from the atmosphere, and even be toxic.

**Processing data**
In line with most analyses, use is made of data already contained on maps. Available maps include soil maps and ground-water maps, as well as geological maps and geomorphological maps. Topographic maps are not only used as a basis for the analyses, but also contain relevant information on waterways and height. All government-produced maps have a scale of 1:50,000. More detailed, large-scale maps are some times also available; 'at the prince or the local council'. These usually serve a specific purpose. They are available from the Soil Survey service or the local council.
The maps that are used to carry out analyses are known as suitability maps or potential maps.
In general, pedologic data is only provided at a depth of 1 metre. As a result, geological maps will need to be consulted for areas deeper underground (i.e. information on load bearing capacity).
When processing the data, remember to use the descriptions provided in the accompanying booklet. This offers extremely valuable information on soil and landscape, and additionally promotes a better understanding of the area.

Lastly, all analyses depend on the expertise and proficiency of the researcher, and knowledge of the area.

**Water analyses**
These analyses can effectively be divided into two parts, namely groundwater analysis and surface water analysis. The analyses share common ground in terms of food gradings and/or water pollution. The analysis also focuses heavily on the issue of public health. The direction of flow of both ground water and surface water must also be taken into consideration when making design choices, as this indicates changes in water quality. The quality of water improves in general the further upstream we move.
Data on water quality can be obtained from the water quality manager, usually the water board, provincial authorities or the RIZA (Institute for Inland Water Management and Wastewater Treatment - Rijks Instituut voor Zoetwaterbeheer en Zuivering van Afvalwater).

Ground-water maps contain information on ground-water depths. They are delivered as standard with soil maps. The appendix contains information on ground-water levels and ground water types.

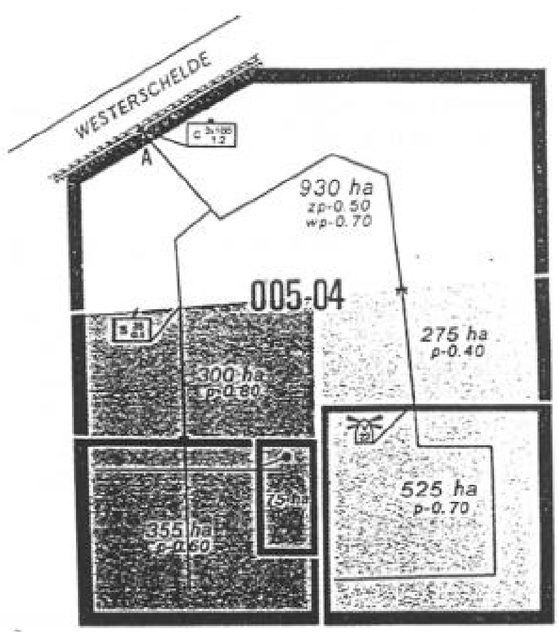



*Fig. 465 Hydrographical chart, section*

Hydrographical charts contain data on surface water, polder levels, drainage basins, pumping-stations etc (artificially managed water). These charts are produced under the supervision of the Water Boards in the Netherlands. As is the case with geological, geomorphological and pedological maps, hydrographical charts in the Netherlands are produced at a standard scale of 1:50,000.
The surface water of flat areas always flows in the direction of the pumping station, which discharges water from the area. In principle therefore, the 'cleanest' water is found the furthest away from the pumping station.
Hydrographical charts marks units with identical ground-water tables, individually managed as polders. Water level fluctuations in a polder do not pose a problem as such; in the worst case scenario, the water level of the bordering polders may fluctuate slightly in the direction of the fluctuation. Matters become a little more complicated, when the water level of a part of the polder needs to be changed for example for building purposes. This can be achieved through, and by reducing the water level by dividing the polder into two new polders with separate water levels raise by sand suppletion

Hilly sites have a set of completely different problems in regulating the surface water and ground water. In general, the lowest sections of these sites tend to be the wettest. In these areas, drainage would cause the elevated grounds to dry up. Interventions of this nature must therefore be carefully considered and used sparingly. In these areas, it would be more advisable to raise the level of the lowest sections (especially if building is to commence anyway). This would render the influence of the elevated sections virtually negligible. One disadvantage of this approach is that the interesting design features, created by the altitude variations, are virtually completely levelled out.
The above provides information on the 'behaviour' of water. This information is used to carry out water analyses for planning purposes.

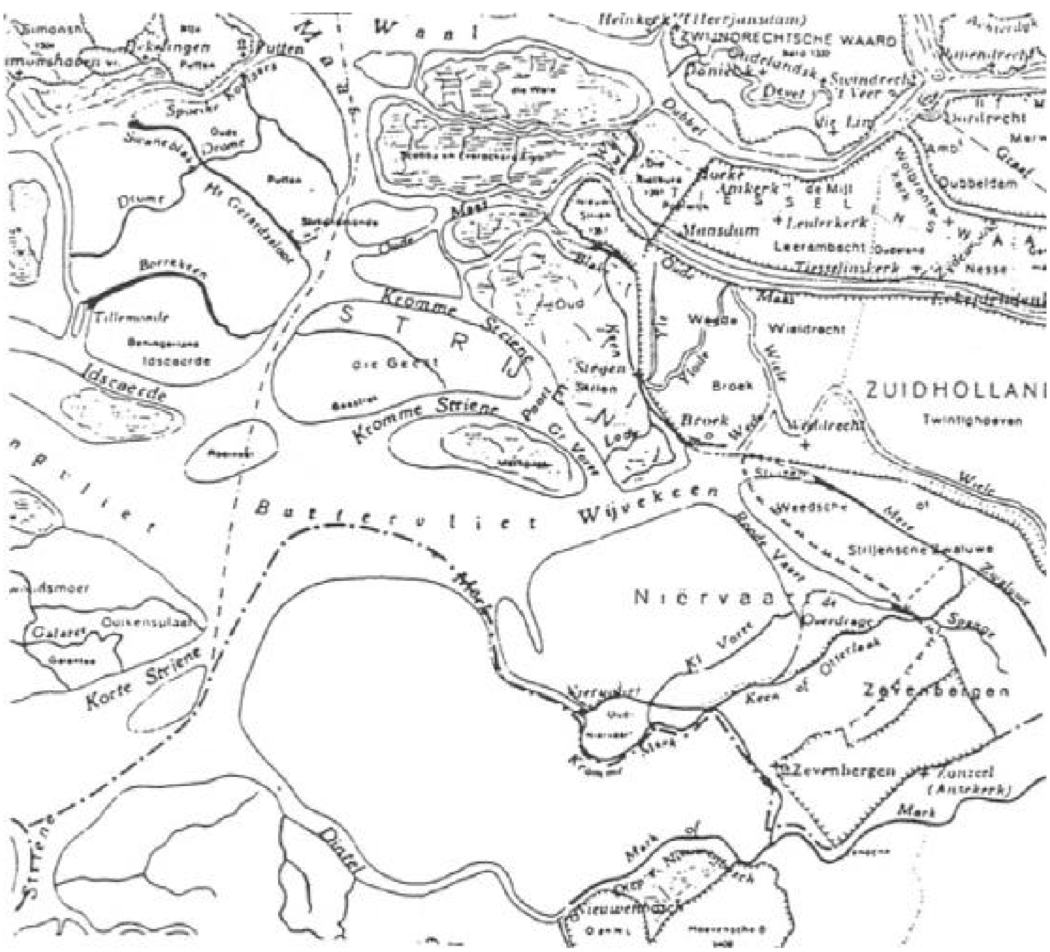



*Fig. 466 Historical map*

**Cultural-historical analyses**
This analysis is based on a variety of perspective, including agricultural exploitation types, historical towns and urban boundaries, historical villages, historical farms, etc.
With regard to the countryside, land divisions are assessed, alongside historical village types, in particular the ‘originality’ or the historic value of the divisions. The subdivisions typify the technological capabilities of man in the given time and circumstances. (common field es)
This type of analysis embraces concepts such as *esdorpen* landscape, *slagen* landscape, (elongeted strip es.)*veenontginningslandschap* (former peat excavation area), *veenkoloniaal gebied* (former fen communities), new (industrial) peat excavation area and *veenweidegebied* (peat meadow).

This analysis is carried out with the aid of historic maps and topographic maps. These can differ in scale, requiring a certain degree of improvisation. Often the research is also combined with the study of historical documents.

**Land use analyses**

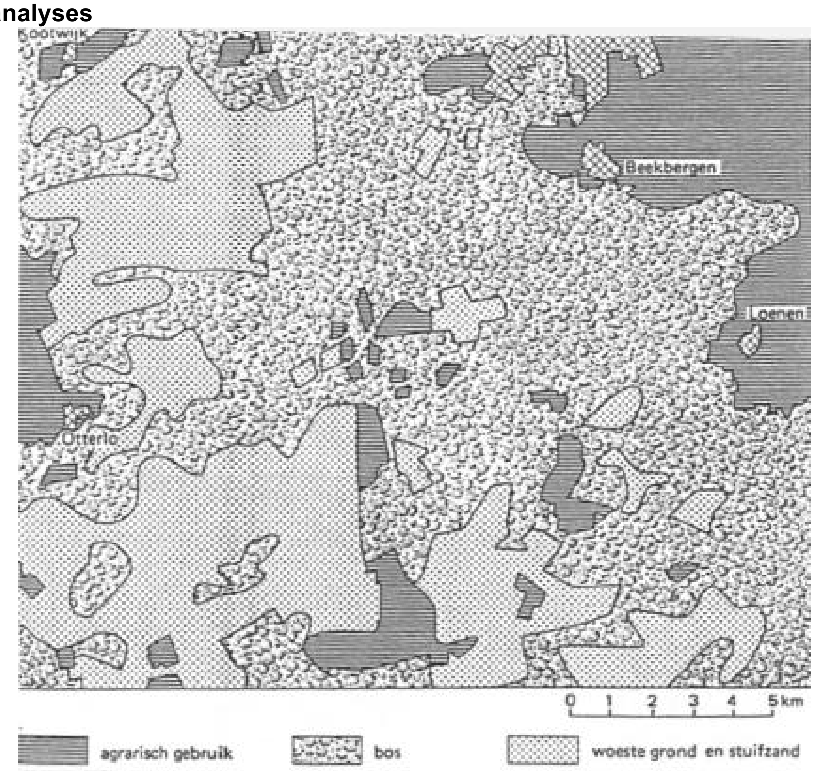



*Fig. 467 Land use map*

In general, this analysis is denoted by the American term 'land use', while the term 'landcover' is reserved for 'unused' and uncultivated land, for example nature reserves and uncultivated territories. A function can be assigned to any area.

This analysis is carried out using the most recent topographic maps or, better still, up-to-date aerial photographs, as these reproduce/give the current situation rather than categories introduced by the "cartographer". This allows the researcher to draw up his own divisions.
Generally speaking, recent aerial photographs are more up-to-date than maps.
Like topographical maps, aerial photographs can be ordered from the topographical service in Emmen and the NLR (National Aerospace Laboratory - Nederlands Lucht- en Ruimtevaartcentrum) in Emmeloord. Special maps are available from local municipalities or provinces.
Aerial photographs vary greatly in scale. Stereoscopes can be use to identify more details on an aerial photograph. If need be, satellite images can also be used, although their scale is generally a hindrance 1997 images have a maximum scale of 1:40,000, but the scale will become larger by the time and the further development of satelite imaging.
Further information on aerial photography and satellite imaging is contained in Moens (2000).

**Visual analysis**
More so than any other analysis, these analyses are keenly dependent on the subjective opinions of the user. We can distinguish a range of visual analysis methods, and they are highlighted in the literature list.
Visual analyses are primarily concerned with visually perceptible external phenomenon of an area. Man is continually interacting with his environment. As humans deploy all their senses to perceive their surroundings; sensory observations are characterised by a high degree of subjectivity. Observations are also influenced by the reference frameworks of the observer and the purpose of the observation. The perceived (landscape) image is described using conceptualised features.

In general, the following concepts are deployed:
- size
- form
- boundaries
- vista
- volume

Certain features are more characteristic, more influential than others.
We can distinguish the following features:
- completeness
- degree and density of use of space (intensity)
- historical records/charasteristics)
- technical qualities
- use and possibilities of use
- unevenness/topography height differences watersystem
- pattern of lines, elements and planes
- degree of care and maintenance
- spatial effect
- atmosphere
- degree of diversity (amount and type of information)
- seasonal aspects
- front and/or back of designing elements (building, line of dunes, direction of land division)
- colour

No hierarchy or level of preference should be derived from the above list. The list could be extended with more items.

When surveying the spatial image of an area, the following elements should be mapped out to create as complete an image as possible of the observation:
- the spatial factors, determining the space such as size, boundaries, form, vista etc.
- the global spatial units, divided into sub-categories if required
- dominant features of the visual observation

The perception of the analysed area is highly personal. A distinction can be made however between perceptions based on aesthetical considerations, and observations based on potential uses of an area.

The analysis is carried out using maps, aerial photographs and "field" observations. In most cases, maps do not provide sufficient information on boundary areas. Furthermore, all maps give an interpretation and (standardised) perception of reality. As such, maps do not always satisfy analysis criteria. Own interpretations can be made using (large-scale) aerial photographs. These interpretations can be supplemented with direct "field information".

**Vegetation analyses**
In this analysis, a distinction can be made between the presence of ‘green’ elements, such as planting avenues, trees, parks, woodland areas etc, the type of vegetation, such as flowers, hedges, shrubs, trees etc, and the types of plants.

The presence of green elements and ground use can be detected with the aid of topographic maps and aerial photographs. Vegetation types can only be identified using aerial photographs or ‘field’ observations, while plant types can only be determined ‘in the field’.

Soil maps are used to determine which plants will grow naturally in a certain soil type. To select those plants that will grow naturally in a certain area is a attractive method to give good result for plantation. Vegetation analyses are effectively an extension of a specific component of either visual analyses or land use analyses.

**Maps**

The following maps are used in landscape surveys to assist the planning and building process:

- geological maps (representation of the deeper underground, including mineral stocks if necessary)* 1 : 50,000
- geomorphologic maps (representation of the pattern and genesis of landscape forms)* 1 : 50,000
- geo-hydrologic maps (representation of groundwater deeper underground with ground-water flows)
- soil maps (representation of soil types, that occur on the earth's surface – up to a depth of 1 m)* 1 : 50,000
- ground-water maps (representation of groundwater depth and fluctuations)* 1 : 50,000
- groundwater quality maps
- hydrographic charts (representation of the water boards and their management)*
- soil suitability maps for different activities
- vulnerability maps for different activities
- subsidence maps (reaction of the ground when extracting water or gas, or during raising)
- foundation depth maps
- industrial sand maps
- terrestrial heat maps
- maps highlighting deep layers of clay for heat storage
- vegetation maps, potential vegetation maps or natural vegetation maps
- cultural-historical maps

N.B. soil maps and ground-water maps are published together.

These maps are not always in stock, and many will have to be produced manually by combining existing maps. The choice of maps required during the planning and design phase depend on the planner/designer and the design principles. Maps marked with an asterisk can generally be obtained from the structural map archive.
The Stichting voor Bodemkartering (STIBOKA, Wageningen), the Rijks Geologische Dienst (RGD, Geological Survey of the Netherlands, Haarlem), Rijkswaterstaat (RWS, Directorate-General for Public Works and Water Management, The Hague) and the Dienst Grondwaterverkenningen TNO (Netherlands Organisation for Applied Scientific Research, Delft) produce several of these maps at a standard scale of 1:50,000.
As this scale is unsuitable for executing plans, further research is required. The maps are however sufficiently detailed to reveal which areas are ideally suited for a certain purpose, and which are wholly unsuitable. The maps can therefore be used during the planning phase to compare destinations on an objective scientific basis. Alternative sites can be assessed in a similar fashion.

**When a destination is definitive**

Separate geotechnical or soil mechanic surveys in detail will also be carried out in particular for building projects, to determine the load bearing capacity of the foundation stratum.
In addition to this soil mechanic survey, soil pollution surveys are essential to obtain a "suitability certificate" for the planned function. (for soil pollution, see sub chapter 4.5, page 246 about soil pollution and remediation).

The different map analyses and theme analyses serve a monitoring role with regard to the consequences of human activity on the surrounding area – such as development and planting – and on the supply of natural minerals, such as water, sand, gravel, gas etc.

### 4.6.2 Site preparation for urban development

A commonly held misconception is that the preparation of a development site is primarily concerned with creating a solid sub-base for buildings.
The term ‘preparing a site for development’, in its narrower sense, generally involves cleaning up sites, creating space for bigger engineering structures, installing drainage systems, sewerage systems, open water systems, engineering structures, and the building of new streets.
The processes of applying road surfacing , cleaning up building sites, installing green areas and recreational facilities as well as cables and wires, placing street lighting etc are denoted by the phrase ‘preparing a site for habitation’.

In the Netherlands, we have two main pedologic concerns:

- foundation stratum, load bearing layer
- drainage

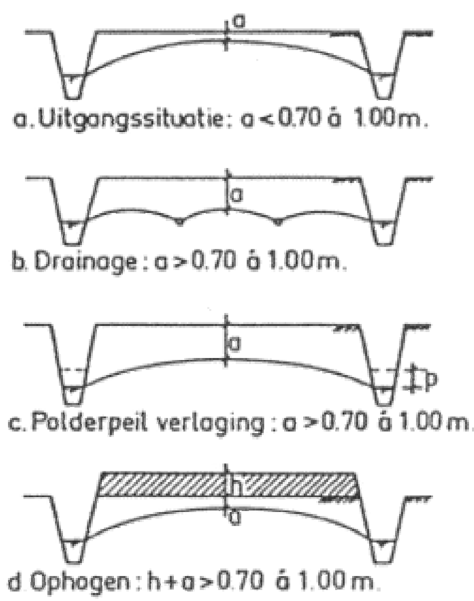
When developing a site for complete development, the following aspects are distinguished:

- identifying a suitable location for urban planning based on soil conditions and soil hydrology (determining location),
- urban design plan and
- selecting construction and foundation methodology.

In other words, potential sites are assessed in terms of their suitability for:

- constructing buildings,
- laying and maintaining roads, cables and wires,
- vegetation growth and
- if required, keeping crawl spaces under residential areas dry.

In general, a minimal drainage of 0.9 m is required with regard to all these functions.




a. original situation a 70 cm
b. drainage: a > 70 cm
c. lowering groundwater level (of the polder) a > 70 cm
d. raising the ground level h + a > 70 cm

*Fig. 468 Principle drainage solutions*

There are three principle solutions for drainage if the groundwater table is to high.

- “pipe” drainage system in the area between the ditches
- lowering the groundwater level
- raising the ground level so far that the goundwater table reaches the alquired depth.

With regard to green space, a drainage requirement of 0.9 m is excessive. Willow, alder, as well as poplar, ash and elm are also capable of growing in conditions with periodically high ground-water tables. In addition, planners could decide to plant greenery capable of adapting to the surrounding area, thus eliminating the need for embankment and/or lowering groundwater levels for planting. This is an ecologically sound way of selecting suitable vegetation, which in turn greatly reduces the need for maintenance.

Using sand to raise an area has a negative impact on vegetation:

- For raising the ground level sand generally has a low nutrient content. Although this may be ideal for certain types of vegetation, the growth of most trees, as well as lawns and general gardening work depend on the availability of soil with a higher nutrient content.
- Due to its dense packing, raising sand is not easily permeable for roots. This is particularly true of reclaimed sand. The area is not suitable for to tree growth; furthermore, filling a small planting hole with a more suitable soil type will not suffice, as the roots will be contained within the planting hole due to the poor permeability of the surrounding soil.
- The weight of the sand compresses the old top layer, creating a layer with poor water and root permeability. These highly unsuitable plant growth conditions got worse during construction activities, when the ground is further compressed by heavy machinery.

**Methods for preparing a site for development**

There are two opposing approaches to preparing a site for development.

- technically, any soil can be prepared for development; in other words, the "foundation" does not determine the site to be developed, but rather the demand. This approach does not focus on sustainability of the newly created situation. Effectively, the issue of management is left out of the equation altogether.
- identifying the site to be developed is dependent on the "foundation"; in other words, a site's potential for various functions must be assessed, taking into account installation and management costs. This 'potential site' selection is more ecologically sound.

Several preparation methods can be identified. The ultimate choice of method has far-reaching implications in terms of management of the existing situation. The choice will also influence the design potentials for the new urban landscape.

In principle are the following aspects considered:

- *Plan Development.* Procedure (in time), organization, designing, fitting in the existing situation, plandimensions, e.g.…
- *Use of sand and topsoil.* Amounts, extraction (transport distance, planprospects), transport, transport route, setting, ripening.
- *Prepare a site for building in relation to soilconditions and watersupply.* Soil profile, drainage depth, possibility to lower the polder level, drainage system, sewer system, waterways, bridges e.g.
- *Building.* Accessibility of the of buildingplace construction site (streets), days with weather not good enough to work in, tidiness of the building terrain, depots of material, building time, flexibility in planning, foundation, e.g..
- *Prepairing a site for development.* Repair of damage, suppletion with sand and soil, take root of plantation, tempo, tidiness of the territory when partial occuppation.
- *Maintenance.* Setting damage of paving, sewer and pipes. Maintenance for a short term, as well as for a long period.
- *Environmental aspects*. Fitting of green in the planning existing, affecting of valuable environment in the area.

*Fig. 469 Assessment for preparing a site for development*

**1 Lowering the polder level**

To obtain a required drainage level of an area, a polder is made of that area, in wich the groundwater level is fixed by man with the help of a pumping station. This can prove problematic if only a section of the polder needs to be developed for other purposes than the original ones, and will either involve creating a new (smaller) polder inside the existing polder, which is adapted to the new requirements then developed, or adjusting the rest of the polder to the new groundwater table in line with use requirements.

The advantages of this drainage method include ease of execution and savings on embankment sand.

The disadvantages, however, generally outweigh the advantages. As the water level drops, air will permeate the overburden, causing settlement of the soil (settlement or “sagging" of the soil caused by the replacement of water by air). Clay and sand soil are characterised by minimal setting. Peat soils, on the other hand, are extremely prone to setting due to their high concentration of water (over 90%). In addition, peat oxidation sets in due to the presence of air, resulting in additional loss of volume.

Loss of water and 'settlement' have negative impacts:

- a downward movement of soil negates the effect of lowering the polder level;
- pile heads in a built up area with buildings founded in wooden piles, will begin to rot above water when lowering the groundwater level;
- older trees are affected by sudden lowering of the groundwater level;
- deeper polders may be more troubled to increased effluent seepage from the surrounding, higher situated, areas.

These problems are characteristic of many peatland areas, where waterlevels have been lowered for land development works to increase crop yield. At first sight it appears that the existing landscape is being spared. The design of a new neighbourhood in the drained peat area the first hand. But after several years of settlement or “sagging” the drainage does no longer meet the requirements.

Given its many disadvantages, this method is not applied to peat ground in urban areas.

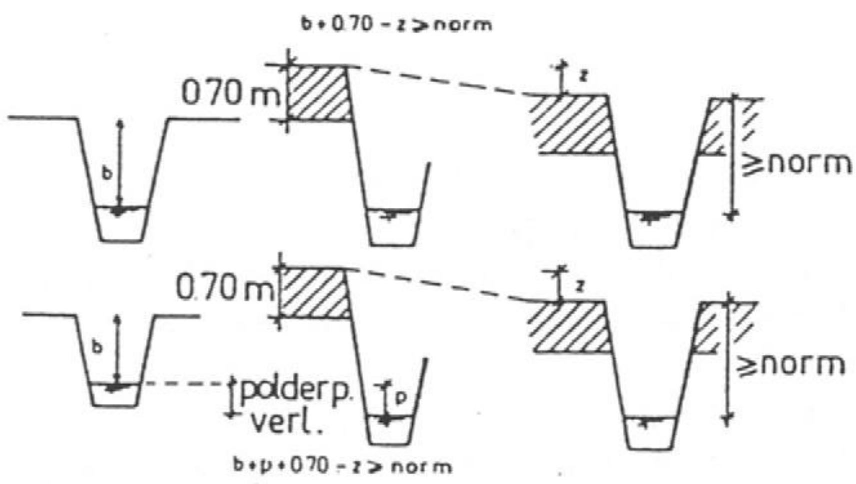



*Fig. 470 Raising with sand and lowering polder level*

**2 Raising with sand**

The required soil is usually derived from a sand extract lake dredge, from where sand is pumped through pipes to the building site to cover the area with a layer of soil. This method destroys all existing structures of the original area. The designer can create his design in a virgin area, and only needs to take account of connections on adjacent neighbourhoods and roads. This is effectively a "tabula rasa" method.

The advantages of this method include the relatively low cost of sand by ‘high-volume dredging’, and the immediate creation of a level building site, making the plan "free" and "flexible". Private and public terrains will lower gradually and feeder roads are not overtaxed by heavy sand transports, as in the following method.

Cost disadvantages include high pre-investment costs due to the need for extra sand for raising the ground level caused by increased subsidence in the early stages. Before actual building can commence, developers will need to wait several years for the subsidence to halt, generating a further cost item. To minimise these disadvantages, a system of vertical drainage using 'sand piles' is exceptionally applied. Water under pression underneath the applied sandlayer can be discharged upwards through the sandpiles. This will cause an accelerated subsidence or settlement of the soil. This method is seldom used for future residental areas.

Following completion of building activities, the site is subject to all the usual subsidence problems. Another disadvantage is that the existing landscape will disappear completely under a layer of sand, requiring extensive soil improvements for urban green areas and gardens.
This method is often used in the west of the country in large-scale urban expansions. The post-war urban expansions in Amsterdam West are a well-known example.

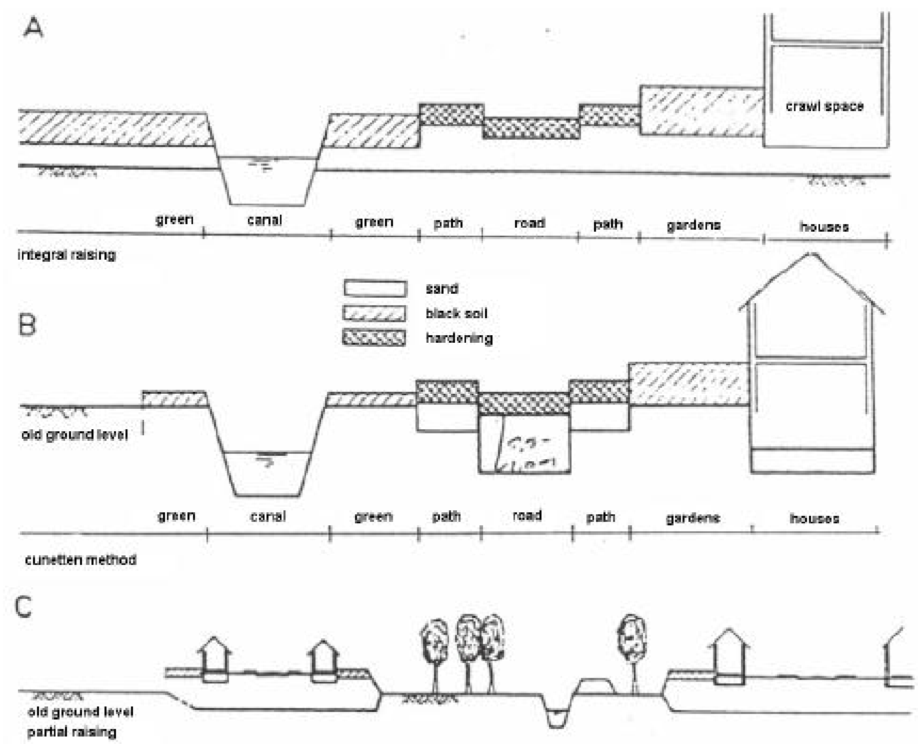



*Fig. 471 Raising with sand*

**3 Sand delivery per 'axle'' by lorries**
This method is similar to the previous one, the main difference being that the sand is delivered by lorry. The advantage of this method is that it enables a more selective approach, allowing for smaller deliveries and thus phased land acquisition. More consideration can therefore be given to the existing landscape features, which in turn might play a part in the design. This method makes also possible to raise only those areas that are essential for the construction of roads and pipelines, and thus do not to affect other areas
If the soil is not all too marshy, urban parks and gardens can be constructed on the original soil surface.

The elevated sections are subject to all the previously mentioned disadvantages of subsidence. Nowadays, vertical drainage is applied to these sections. Additional problems include the provisions and costs involved in transporting sand overland.
This method is primarily applied in new residential areas in the North and East of Rotterdam, in combination with former method of raising by a layer of sand.

**4 Living layer**
A more recently developed method involves the use of a so-called ‘leeflaag’ (living layer). This is a layer of 'pure' not polluted soil, poured onto the groundsurface (separated by a plastic film). The (sub)soil is usually partially polluted, and cannot be purified for a variety of reasons. This method allows developers to build on contaminated ground.

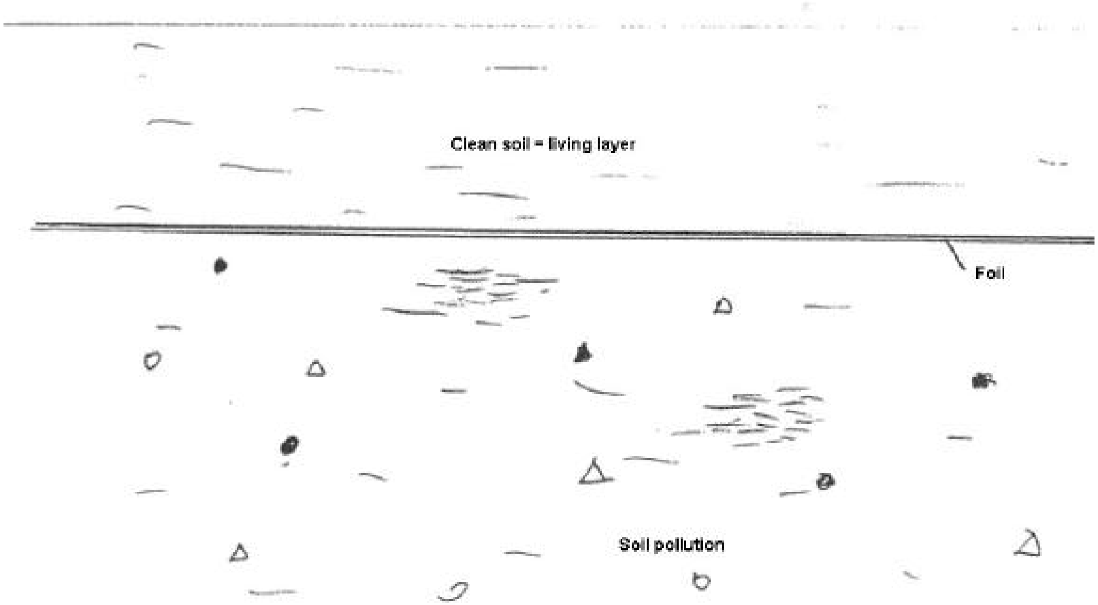



*Fig. 472 Living layer*

**5 Under-reamed platforms and light-weight fill-material**
In this method, residences and streets together with the head mains are under-reamed with (concrete) piles. Alternatively, under-reamed living platforms are created. Access roads and parking places are raised with a layer of Polystyrene, covered with scoriaceous sand, while urban green and gardens are not raised.
The main advantage of ‘living platforms’ is that house building can commence as soon as the platform is complete. In the ‘raising with sand’ method, developers need to wait 5 to 6 years after raising due to soil settlement before building can start. Building can take place in small sections. Elements of the existing landscape can be incorporated easily in the design. Furthermore, there are no problems with subsidence. The raising of an area using lightweight fill-materials has similar advantages.

Both methods have one main disadvantage: high costs, roughly twice as high as raising with sand. However, the long-term benefits include far lower maintenance costs. Urban development (sub) plans must be entirely laid down in writing beforehand. Light-weight raising methods are however characterised by slight subsidence in the course of time. Raising after all increases the weight, thus causing further subsidence.

To prevent the light-weight construction from floating, excessive groundwater rises must be prevented in the event of heavy rainfall.
The preconditions for this method include good drainage and open water storage of at least 10% of the surface.

The method of light-weight raising has been applied in Capelle a/d IJssel; concrete living platform designs have also been drawn up, such as Piet Blom’s expansion plans for Monnikendam.

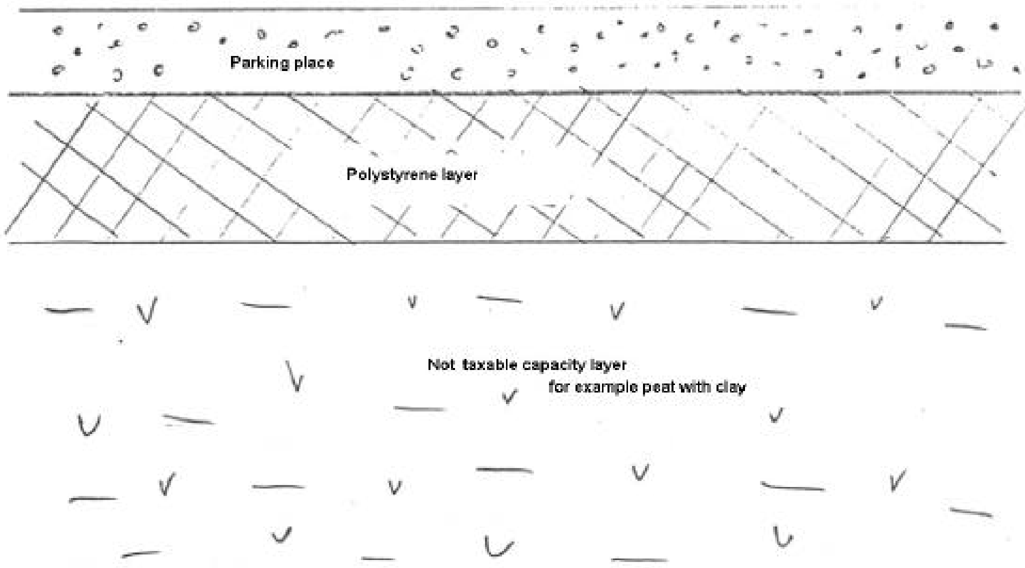



*Fig. 473 Lightweight fill-material*

**6 Other forms**
As well as the above mentioned methods, an additional option involves floating constructions, as demonstrated for example by Hans Huber's graduation project of his 'Eco Building' in the TU district. For his experimental project in Haarlem, Herman Herzberger designed floating homes that follow the sun's movement.
Other development ideas include houseboat parks with their own mains infrastructure.

**'Situation-conscious' site selection.**
Situation-conscious urban designers tend to prefer methods 3, 5 and 6. An accurate analysis of the soil conditions and water management, coupled to the issue of preparing a site for development, are an integral part of planning.
The abovementioned concepts are far from new. As early as 1948, the garden and landscape architect Jan TP Bijhouwer carried out a study into the potential development of the village of Kethel near Schiedam. Soil maps revealed that's the location of the old village is situated on top of a creek ridge, a sturdy clay ridge, that is deposited by the flood current of the sea. Bijhouwer projected his development plan on the position of the creek ridges in this area, while he chose the peaty basin between the ridges to design a park. This park was eventually situated here, by selecting suitable vegetation and installing generously sized bodies of water. The development itself partially adhered to his original ideas.

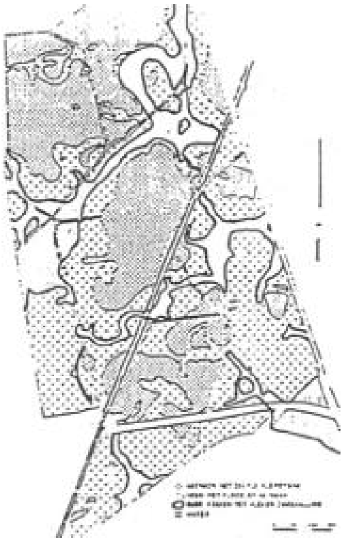


*Fig. 474* Bijhouwer, soil map of Kethel and surroundings

*Fig. 475 Bijhouwer, development plan of Kethel and surroundings*

Fig. 476 Maas and Tummers Haagse Beemden

The graduation project of Peter Dauvelier, which touches on the issue of preparing a site for development, compares the approach taken in Kethel to that of the Holy district in Vlaardingen an example of 'universal' approach (integrated raising).

In those parts of the Netherlands where smaller peaty basins are intersected by wide sturdy ridges, Bijhouwer's approach is ideal. These soil situations are not exclusive or special: in many areas of the Netherlands, peat is intersected by interstream ridges, creek ridges and cover sand ridges, such as The Haagse Beemden, a big expansion district in Breda, designed by the urban developer Leo Tummers and the landscapes architect Frans Maas.

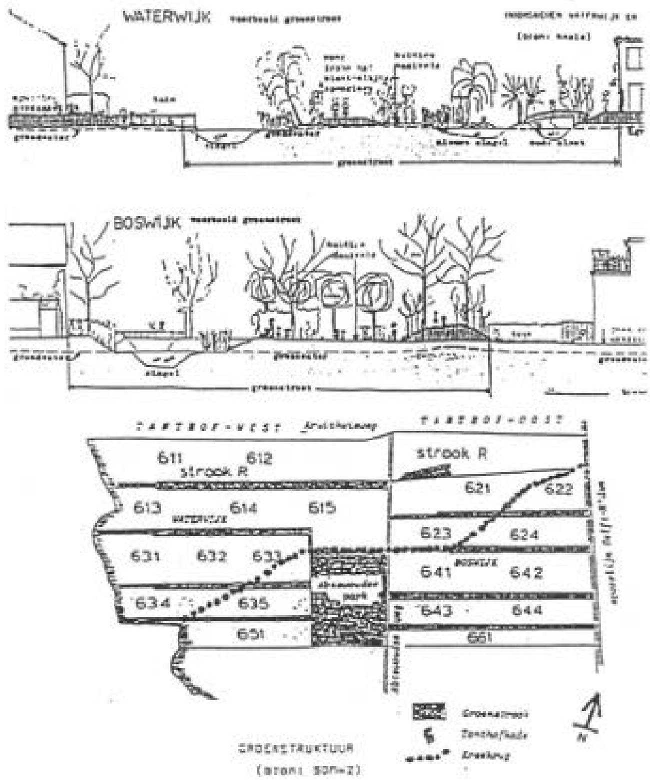



*Fig. 477 Tanthof, Delft*

A (special) remark must be made of Tanthof, a district in Delft.
The design of this area has been met with substantial criticism because of its complex, 'drab' layout. This criticism is however primarily targeted at the pattern of building blocks and roads.
The main layout is sensitive to the underlying landscape. One key feature concerns the narrow creek ridge that diagonally intersects the plan, deployed as a green zone with a slow traffic route, known as the Kethelrugpad. This ridge was far too narrow to allow for concentrated development (as with the Kethel plan). So, the designers decided to take account of the local soil, loam and clay, and plant ash and elm, slow-growing tree species that will take several years to play a part the district. These tree species and will not do as well in the rest of the neighbourhood.

In the heart of the district, a park was designed around several old farms, also built on the spurs of creek ridges. A narrow space was left for this park during raising; it forms the transition with the open pasturage of Midden-Delfland.
In this respect, the chief layout is in sharp contrast to the districts of Voorhof and Buitenhof, where the landscape plays no part, and where more 'universal' traits prevail. Unfortunately, the diagonal green zone has been kept extremely narrow, and made ‘spatially subordinate’ at road junctions. The orientation problems of this district are therefore not the result of the design being excessively tailored to the landscape, but rather stem from the fact that the landscape has been given too subordinate a role to play.

**Drainage**
Water underneath houses in the crawl space and boggy gardens are common occurrences in many parts of the Netherlands. This phenomenon is known as flooding, and can be minimised by installing drains in built-up areas, which discharge water from streets and concreted areas. The not by buildings or parsement coverded soil will continue storing water when necessary.

What measures can be taken to prevent, cancel or reduce the risk of flooding?
Sand soils can be left out of the view, as drained of easily permeable soil give hardly any problem. Clay and peat soils pose the biggest draining problems, as they do not allow for easy water discharge due to adhesion, retaining the water in narrow pores and (root)channels.

Prior to being prepared for development, the soils were used for farmland or pasturage. To prevent excessive rise of the ground-water table during wet periods, clay and peat areas are equipped with a drainage system in the form of cut trenches and/or drains. In order to maintain the predetermined polder level (water level), excess water is discharged via ditches through a pumping station or drainage sluices.

When preparing a site for development, drainage series are disrupted and ditches filled up, as they do not "suit" the urban development plan. Thus given the urban developer sufficient freedom for his design. In a modern townscape, most of the precipitation will eventually be discharged via the sewer drainage system, as urban areas primarily consist of hardened (paved) surfaces, so that water can only be discharged artificially. Conversely, the 'unhardened' build-on and urban areas, the gardens and parks, must have and maintain their storage capability to prevent the risk of flooding. The rise of the ground-water level can be partially absorbed by underground storage of water (uncovered) and in sand bodies. This is however not an ideal situation, as water in underground crawl spaces can give rise to unpleasant smells, rising damp, and affect beams, floor heating pipes and cables. Water in sand bodies underneath roads can cause subsidence, affect the load bearing capacity and encourage frost heave.

In most cases, flooding can only be tackled with the aid of a new drainage system, as the "old" system is in many cases unusable for preparing a site for development. An other solution is to design waterbodies (channels and ponds) that cover at least 10% of the surface of the site. The extra store of water consist of the space above the water level of pond or channel till the height of the embankement. See *Fig. 478*

### 4.6.3 Detailed elaboration for urban functions

Urban development and/or destination aspects apply completely different criteria to the ground. Buildings and infrastructure requirements are more or less identical, while planting criteria are far less stringent and more dependent on use. The designer's standpoint also plays an important role in this respect: vegetation and use adapted to the soil, or vegetation tailored to use.

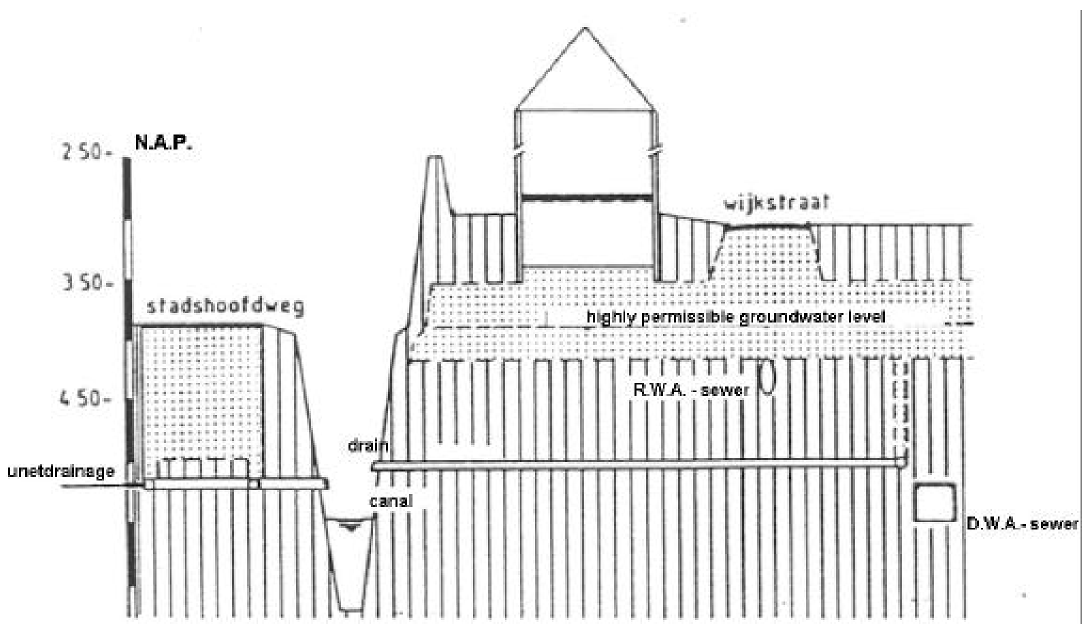



*Fig. 478 Water control in urban areas*

**Criteria applied by all destinations.**
Per destination and implementation technique, various 'ground criteria' apply, including:

- load bearing capacity: ability of the ground to support buildings, roads and sewers (static load);
- passableness: load bearing capacity of the ground for carrying people (and machines) and dynamic load;

- relief: altitude variations of the surface;
- drainage level: the difference between the ditch level and the surface level to be drained;
- drainage: water discharge from the ground to the ditches;
- water retainability: ability of the ground to retain water without capillary connection to the groundwater
- infiltration ability: the amount of water that can penetrate the ground per unit of time;
- closed water storage: additional amount of water that the ground is capable of absorbing in addition to the amount already present (depending on pore space, humidity level and ground-water table);
- open water storage: the amount of water that open water like ditches, channels and ponds are capable of storing at a certain water level. This amount on open water surface area and the water level of the ditch in comparis on to the embankements); and
- drainage: discharge of excess water from the ditches to the discharge point.

**Urban development suitability criteria.**
As a general rule, urban development features apply the following suitability criteria to the soil:

With regard to drainage:
- for building: foundation frost-proof (frost line 0.6 m below surface level), foundation 'in the dry', house service connection of pipes 'in the dry', no water in crawl spaces (if required) – ground water at least 0.2 m below the crawl space floor and groundwater below the foundation level due to the risk of cracking to buildings caused by reduced load bearing capacity with increased water levels;
  (based on these criteria: ground-water table at least 0.8 m below surface level);
- for roads, parking areas and paths: top of the capillary water below the frost line due to frost heave and thaw during hardening; the substrate must always maintain as constant a bearing capacity as possible;
  based on these criteria: ground-water table 0.7-1.0 m below asphalt;
- for paths: good drainage, resistant to wind and water erosion;
- for pipes (water, gas, sewers): install house service connections 'in the dry'; water pipes and sewers must be frost-resistant; separate double sewerage system with one tube for the house hold water and the other for the discharge of rain: hydraulic slope to open water (R.W.D. = rainwater discharge); mixed sewerage system: discharge to emergency spillways; groundwater main sewers may be below the frost line;
  based on these criteria: ground-water table 1.0 m below surface level;
- for electric wires: minimum cover layer 50 cm, situated above groundwater;
- for parks: minimal fluctuating ground-water table, good water retainability of the ground, no hard, impermeable layer prohibiting root growth, favourable global ground-water table, 1 m for trees;
- this may be less for plants;
- pH groundwater: broadleaf 5
  coniferous 4.5
  N.B. other drainage requirements apply to botanical gardens: keep the situation as natural as possible);
- for sports fields: ground-water table in winter a maximum of 50 cm below surface level due to passableness following rainfall;
- for playing fields and camp sites: quick-drying after rainfall; excessively low water levels affect grass growth in summer

With regard to open water, size and position is determined by:
- civil criteria in relation to drainage, storage, emergency spillways and overflows
- urban design criteria; ditch levels lower than permissible maximum ground-water table.

With regard to bearing capacity;
- for buildings: Pleistocene sand layer must be sufficiently strong for building foundations (impermeable layers may be perforated when hitting in poles; this may result in effluent seepage); high-rise buildings will almost always have to be founded with piles on Pleistocene substrate; for low-rise buildings, pending sufficient bearing capacity of sand and clay layers in peat and overflow embankments in clay areas, shallow foundation of these layers is also allowed;

- for roads: dig out sand or earth body above surface level or *cunet* and fill up with sand; sand body on solid foundation or to spread the load, use sand and clay ridges in the landscape if possible;
- for parks and landscaping: bearing capacity less relevant than drainage criteria.

**Buildings**
As a general rule, buildings apply the following suitability criteria to the ground:

With regard to drainage;
Buildings:
- foundation frost-proof (frost line 0.6 m below surface level),
- installing foundation 'in the dry', (under dry conditions)
- house service connection of pipes 'in the dry',
- no water in crawl spaces

Conclusion: ground water at least 0.2 m below the crawl space floor and groundwater below the foundation installation level due to the risk of cracking to buildings caused by reduced load bearing capacity with increased water levels;
based on these criteria: ground-water table at least 0.8 m below surface level;
With regard to open water, size and position is determined by:
- civil criteria in relation to drainage, storage, emergency spillways and overflows
- urban design criteria; ditch levels lower than permissible maximum ground-water table.

With regard to bearing capacity;
- Pleistocene sand layer must be sufficiently strong for building foundations (impermeable layers may be perforated when hitting in poles; this may result in effluent seepage);

Conclusion: high-rise buildings will almost always have to be founded with piles on Pleistocene substrate; for low-rise buildings, depending of sufficient bearing capacity of sand and clay ridges in peat and natural levels in clay areas, shallow foundation of these layers is also allowed;

**Infrastructure**
As a general rule, infrastructures and mains apply the following suitability criteria to the soil:

With regard to drainage
- for roads, parking areas and paths: top of the capillary water below the frost line due to frost heave and thaw during hardening; the subsoil must always maintain as constant a bearing capacity as possible; in the case of paved surfaces
  based on these criteria: ground-water table 0.7-1.0 m below paved surfaces;
- for paths: good drainage, resistant to wind and water erosion;
- for mains (water, gas, sewers): install house service connections 'in the dry'; water mains and sewers must be frost-resistant; separate sewerage system: hydraulic slope to open water (R.W.D. = rainwater discharge); mixed sewerage system: discharge to emergency spillways; groundwater main sewers may be below the frost line;
  based on these criteria: ground-water table 1.0 m below surface level;
- for electric wires: minimum cover layer 50 cm, situated above groundwater;

With regard to open water, size and position is determined by:
- civil criteria in relation to drainage, storage, emergency spillways and overflows
- urban design criteria; ditch levels lower than permissible maximum ground-water table.

With regard to bearing capacity:
- for roads: dig outsoil that has no sufficient bearning capacity and fill the cunet up with sand; sand body on soils, use natural sand and clay ridges in the landscape if possible;

**Vegetation**
As a general rule, vegetation applies the following suitability criteria to the ground:

With regard to drainage
- for parks: minimal fluctuating ground-water table, good water retainability of the ground, no hard, impermeable layer prohibiting root growth, favourable global ground-water table, 1 m for trees;
- this may be less for plants;
- pH groundwater: broadleaf 5

coniferous 4.5

N.B. other drainage requirements apply to botanical gardens: keep the situation as natural as possible or use only those plants that will grow under given criterium stances. See p… about natural vegetations

- for sports fields: ground-water table in winter a maximum of 50 cm below surface level due to passableness following rainfall;
- for playsites fields and camp sites: quick-drying after rainfall (no puddles); excessively low water levels affect grass growth in summer

With regard to open water, size and position is determined by:

- civil criteria in relation to drainage, storage, emergency spillways and overflows
- design criteria for different vegetation functions such as parks, sports fields etc; ditch levels lower than the maximum permissible ground-water table.

With regard to bearing capacity

- for parks and landscaping: bearing capacity less relevant than drainage criteria.
- passableness or access criteria apply to sports fields.

**Industry for building**

Industry criteria governing the ground will generally correspond with criteria applied to buildings in general, and infrastructure. Additional criteria must always be specified.

**Site preparation Check lists**

**Criteria set by all destinations.**

- bearing capacity
- passableness
- relief
- drainage depth
- drainage
- water retainability
- infiltration ability
- closed water storage
- open water storage
- discharge

**Condition of soil and water management**

Soil condition can be defined on the basis of the following basic details:

- soil type (part of the below basic details are derived from soil type),
- soil composition (stratification),
- depth load-bearing layer,
- compressibility of the higher layers,
- bearing capacity of the upper layers,
- altitude,
- relief,
- ground-water table,
- permeability,
- water retainability,
- capillary height of rise,
- piezometric level of deep groundwater and
- open water.

**Measures to improve soil and water management**

The following are eligible for improvement:

- drainage depth and drainage,
- raising (depending compressibility of the soil, raising with sand results in settlement, necessitating raising the level to a greater height than is required for increasing the drainage depth),
- lowering of the level (depending on the soil type, the lowering of water levels may create settlement, necessitating lowering the level to a greater depth than is required for increasing the drainage depth),
- draining,

- profile improvement,
- changing distance of open water,
- combinations of the above;
- water retainability: ground consolidation by reducing or bringing in top soil,
- ground consolidation through deep ploughing;
- closed water storage: raising with sand,
- lowering the polder level.

Improving drainage;
- open water storage: increasing surface area of open water,
- lowering the polder level (and maintaining maximum permissible ditch level);
- draining: adjusting pumping station capacity, adjusting profiles of the ditches and canels;
- passableness: raising or excavating and filling with sand or cinder bed, installing steel (temporary) sheets, constructing roads with temporary paving;
- bearing capacity: adjusting foundation to building methods, for low-rise buildings: possibly shall foundation or sand fill;
- relief: accentuating or levelling; and
- infiltration ability: improve by deep ploughing, improve by sand fill.

Drainage, dewatering, drainage depth and water storage must be carefully tuned to each other. There is no point in improving dewatering ability without good drainage; likewise, increasing open water storage capability without good drainage is also pointless.

The dewatering processes are interconnected as follows:

| | |
|---|---|
| drainage depth | drainage |
| | open water storage |
| | dewatering |
| drainage | drainage depth |
| | open water storage |
| | dewatering |
| water retainability | infiltration ability |
| closed water storage | infiltration ability |
| open water storage | drainage |
| | dewatering |
| dewatering | drainage depth |
| | drainage |
| | open water storage |
| infiltration ability | water retainability |
| | closed water storage |

### 4.6.4 Water boards

**History**
The earliest inhabitants of the Netherlands initially protected their territory from flooding by damming-up. Gradually, this defensive approach was supplemented with an offensive approach, involving reclaiming land by designing dykes. To execute this specialist task as effectively as possible, separate bodies, water boards, were established around 1200 AD. Not only the creation, but also the maintenance of the north and west of the Netherlands is largely due to the activities of these institutions.
As many small areas had their own water management authorities, the number of water boards grew steadily over time. In 1937, our country had no fewer than 2,838 water boards. Concentration became inevitable to enable an efficient execution of tasks. As a result, many small water boards have been amalgamated over the last 50 years to make way for water boards that cover a bigger conservancy area. In 1970, the number of water boards in our country had shrunk to 1275.

**What is a water board?**
A water board is a public corporation established for a certain area to protect the (defined) water management interests of that area.
The tasks of the water board are laid down in water board regulations.

On a local and regional level, water boards are responsible for the care and maintenance of water management activities, as laid down in the Constitution and the Water Boards Act.
The Provinciaal Bestuur (provincial government) is authorised to establish water boards, to terminate their operation, determine their tasks and operational area, as well as the composition and election of the board.
In accordance with Article 206 of the Dutch Constitution, the Provincial Council is charged with the supervision of the water boards. The Provincial Council is authorised, with the approval of the Crown, to terminate the existing organisation and regulations of the water boards, establishing new ones, and drawing up new regulations. The water management authorities are entitled to submit proposed changes to organisation or regulations to the Provincial Council.
Water boards are additionally authorised to lay down rules, which must be adhered to (under police enforcement if need be). These so-called bye-laws may only contain provisions deemed essential to protect the interests of the water board (art. 207 of the Constitution).
Water boards are not responsible for drinking water.

In general, water boards can be assigned the following tasks:

- care of water-control structures to protect adjoining land against external water; these consist of maintaining dunes, sea and river dykes, as well as storage basin and polder embankments; care of quantitative water control (water-level control) by discharging or supplying excess water and suppletion water during dry spells;
- As of 1 January 1975, in accordance with Royal Decree no. 39 of 18 June 1974, they may also be charged with qualitative water control by purifying wastewater, preventing and/or combating salination (active purification), and by granting, withdrawing or refusing permits to discharge wastewater (passive purification);
- care of roads; this is often considered an inappropriate task of the water board;
- as a special task: the care of waterways.

Pinpointing the division of responsibilities of water boards is a difficult task; often, this involves a close collaboration between the water board on the one hand, and central government, provincial authorities and, in certain cases, municipalities (for example dock quays) on the other.
To enable effective operation, essential water control activities need to be carried out, which, as a rule of thumb, are managed and maintained by the water board.

The ultimate responsibility for proper water management care lies with central government, which exercises "chief supervision" on the provinces. Central government, and in particular the Ministry of Transport, Public Works and Water Management (Ministerie van Verkeer en Waterstaat) is responsible for water management issues that are of national interest: the North Sea and the Waddenzee, the big rivers, water from inlets and the Delta works. The Ministry of Transport, Public Works and Water Management has its own executive service for this purpose, namely the Rijkswaterstaat (Directorate-General for Public Works and Water Management).

**The water board on the Water management map**
The main map of the ‘waterstaatskaart’ only specifies those water boards that have a quantitative control task; this is done by incorporating the name and the management boundary of the water board in brown. The management boundary of a water board is denoted by a dotted line; the management boundary of a coordinating water board is denoted by a bracketed line, while the water board’s name is shown in capital letters in the margins of the map.

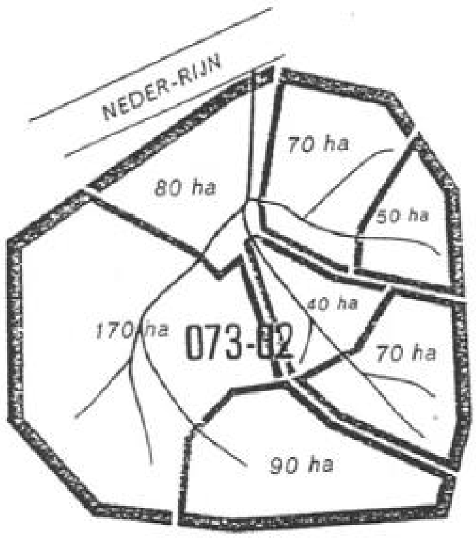



*Fig. 479 Example water management map 'hoog Nederland' with sloped water table*

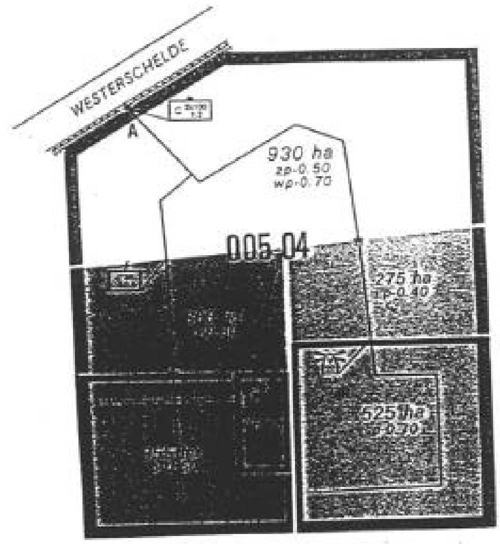



*Fig. 480 Example Waterstaatskaart 'laag Nederland' with horizontal water table*

### 4.6.5 References to site preparation

Moens (2000) Remote Sensing (Delft) Faculty of Architecture DUT monograph no. 69:

## 4.7 Cables and pipes

Urban development plans are increasingly impeded by the urban ‘underground’.
Problems associated with, and criteria applied to, groundwater and load bearing capacity can be solved technically (see sub chapter 4.6).
An additional dilemma involves the construction of underground infrastructures in the form of cables and pipes or drains. Our underground infrastructure is becoming increasingly congested. Coupled to this, increasingly stringent demands are being made on the relative position of drains, cables and pipes, which in turn requires more underground space. The list does not end here, as we also have the issue of underground storage of for example glass, paper and other recyclable material containers, all clustered in the urban environment. Locating and creating underground space is not an easy task, so much is clear, no matter how keen we are to ‘dump’ these rather hideous-looking containers underground.

This chapter focuses on the underground use of space, as well as the physical reservation of space for beam transmitters and other forms of overhead and underground infrastructure.
The branch points and transitions from regional networks to urban networks also play an important part in urban development, including for example the transition from overhead high-voltage transmission lines via transformers to an underground electricity distribution network. Furthermore, certain regions are interspersed with pipes that do not occur in the urban landscape, yet are relevant to this landscape.
On an ultra-regional level, pipes generally have a different impact on the use of overhead space than in towns, such as large underground distribution pipes (gas and water) and underground conveyor pipelines from dock areas to users, including oil pipelines to the Ruhr region and Antwerp. Certain urban underground pipes occur aboveground in rural areas, such as the many high-voltage transmission lines that crisscross our country.

In addition to pipes, the laying of tunnels is becoming increasingly popular, including road tunnels and rail tunnels running beneath various waterways and railway lines to conserve the landscape.
Examples evident in 2001 include the Rotterdam rail tunnel, beneath the Nieuwe Waterweg, and the Betuwe railway line (under construction) for goods transportation, as well as the high-speed rail link through the “Green Heart” (also under construction).

### 4.7.1 Regional scale, countryside

Although the spatial use of pipes is less restrictive on a regional scale than in urban areas, careful consideration must be given to pipe installation in the countryside, as the transition from rural to urban areas poses limitations on urban land use and other urban developments due to the presence of pipes and cables.
This chapter focuses on different pipelines and the corresponding restrictions and limitations.
The installation of underground drains and pipes obviously involves much earth moving. As of 2002, statutory investigations must be carried out into the presence of archaeological artefacts and traces prior to commencement of building activities. The decision to commence digging is taken depending on the importance of the find, as specified under the Malta Convention (1999). This convention has been implemented in the *Nederlandse monumentenwet* (Monuments and Historic Buildings Act) [a]

An archaeological survey was carried out as a sample project prior to the installation of the *Betuwegoederenlijn*. During this archaeological survey, important finds were made, dating back to prehistoric times as well as more recent discoveries, including the oldest skeleton of a Dutch woman (Treintje) ever found, fishing-related finds such as a prehistoric boat, fishing nets and other fishing gear, as well as Medieval houses / farms.

### 4.7.2 Types of pipes and cables

This chapter does not profess to offer a comprehensive list of all pipes and cables that occur on a regional scale.
The emphasis is on large distribution networks such as gas, electricity and water, as well as wastewater discharge pipes, telephone networks, data networks, fibre optic networks and pipes for transporting raw material between harbours and processing plants (many of these pipes run as far as Germany, such as the Ruhr region).

[a] The legal side of this Historic Buildings Act is specified in the *Stedenbouwrecht* [laws governing urban development].

Not all pipes in outlying areas are run underground. High-voltage transmission lines for example are a clear example of overhead cables.
In addition to distribution pipes, we can also identify underground discharge pipes such as sewerage pipes and sewage pressure pipelines.
In order to supplement the drinking water in the densely populated western corner of the Netherlands, water from the rivers Rhine and Meuse are pumped to dune areas through pipes, where the water is filtered and purified into drinking water, and distributed to customers.
All these pipes and cables come with their own package of requirements, which the surrounding area and underground must satisfy, i.e. underground conditions and groundwater, as well as overhead conditions (including designated use).
The examples used in this chapter concern the positions of cables and pipes in the street profile outside built-up areas in accordance with the Nederlands Normalisatie Instituut (Netherlands Standardisation Institute).

Plaats van leidingen en kabels in wegen buiten de bebouwde kom.

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|---|---|---|

NEDERLANDS NORMALISATIE-INSTITUUT

**1. Doel en toepasbaarheid**

Deze norm geeft richtlijnen voor de plaats van leidingen en kabels in wegen *buiten* de bebouwde kom.

Voor andere dan in deze norm genoemde leidingen en kabels zijn geen richtlijnen vastgesteld. Over de plaats hiervan dient men van geval tot geval te beslissen.
Indien een bedrijf over eigen telecommunicatiekabels beschikt, behoren deze in de voor dit bedrijf bestemde sleuf te worden ondergebracht.

**2. Aanduiding van leidingen en kabels**

Al naar gelang van hun aard zijn de leidingen en kabels in deze norm op tekeningen als volgt aangeduid:

E = kabels van elektriciteitsbedrijven, waarbij:
LSK = laagspanningskabel
HSK = hoogspanningskabel
G = enkelvoudige gasleiding tot een maximale nominale binnenmiddellijn van 200 mm
PTT = PTT kabels
W = enkelvoudige waterleiding tot een maximale nominale binnenmiddellijn van 300 mm

**3. Maten**

De in fig. 1 en 2 aangegeven maten moeten als wenselijke maten voor horizontale afmetingen worden beschouwd.
Indien een bredere bermstrook beschikbaar is, verdient het toch aanbeveling deze maten zoveel mogelijk aan te houden, met het oog op eventuele uitbreidingen.
Met in leidingen en kabels voorkomende voorzieningen, zoals hulpstukken e.d., is geen rekening gehouden.

**4. Mantelbuizen**

Bij de aanleg en(of) verbetering van de weg verdient het aanbeveling op daarvoor in aanmerking komende plaatsen mantelbuizen voor de doorvoer van eventuele toekomstige leidingen en kabels aan te brengen.

**5. Verharding**

Onder verharding wordt verstaan de wegverharding inclusief eventuele kantstroken.

**6. Plaats voor lichtmasten in de bermstrook**

De plaats voor eventuele lichtmasten in de bermstrook is in fig. 1 en 2 schematisch aangegeven.
Indien lichtmasten worden geplaatst, behoeft de aangegeven minimumbreedte van de desbetreffende bermstrook niet te worden vermeerderd met de ruimte die voor de plaatsing van het verlangde type lichtmast en bijbehorende voedingskabel is vereist. Deze op verschillende afstanden langs de weg te plaatsen lichtmasten met betrekkelijk dunne voedingskabels zullen in de ruimte tussen de verschillende leidingsoorten of aan de buitenzijde van de bermstrook kunnen worden aangebracht.

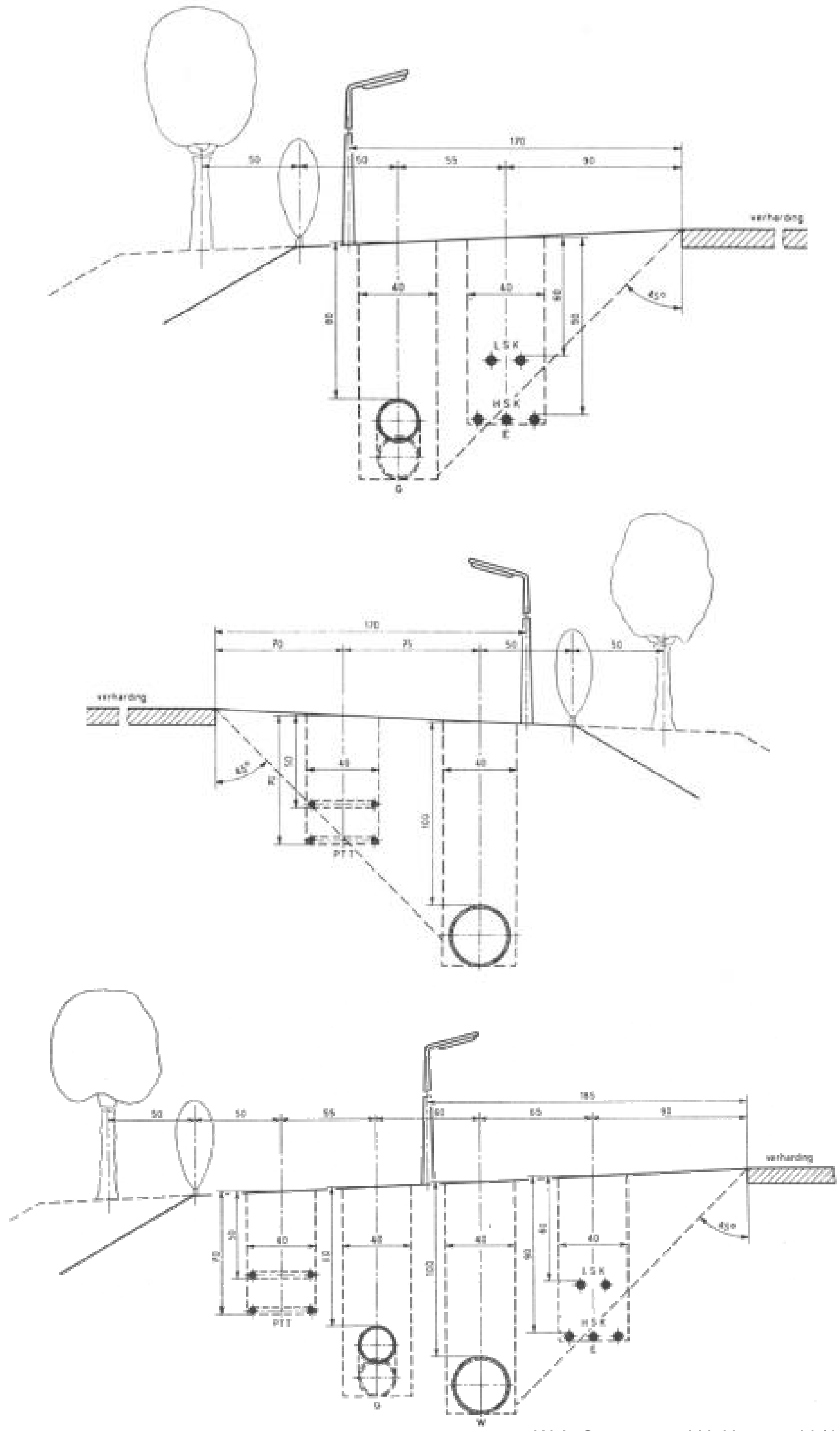
**7. Boom- of struikbeplanting**

In de dwarsprofielen is de mogelijkheid voor boom- of struikbeplanting aangegeven.
Wordt een beplanting aangebracht, dan kan in het algemeen de binnenste bomenrij resp. de voorste rij struiken op 100 cm resp. 50 cm buiten het hart van de buitenste sleuf komen te staan. Dit is afhankelijk van houtsoort en(of) bodemomstandigheden.
Wordt in het dwarsprofiel volgens fig. 2 een beplanting aangelegd, dan dient in het algemeen de binnenste bomenrij op ten minste 100 cm afstand van de PTT-kabels te staan. Bij een struikbeplanting mag deze afstand tot 50 cm worden teruggebracht.

| | |
|---|---|
| **Plaats van leidingen en kabels in wegen buiten de bebouwde kom** | **NEN 1738** |
| The place of pipes and cables along roads OUTSIDE built up areas | mei 1964 |
| Auteursrechten voorbehouden | UDC: 625.78:711.522 |

W.A. Segeren and H. Hengeveld (1991) p. 27

*Fig. 481 NEN 1738*




W.A. Segeren and H. Hengeveld (1991) p. 273

*Fig. 482 Position of cables and pipes outside built-up areas*

### 4.7.3 Space taken up by cables and pipes.

At first glance, it seems logical (and, from an aesthetic point of view, even *desirable*) to place obstacles such as pipes and cables underground whenever possible. Furthermore, underground cables and pipes do not result in the dividing and/or barricading effect associated with overhead installations.

However, underground installation of cables and pipes *does* have implications for the terrain above the cables and pipes. From a maintenance and management point of view, land above the cables and pipes is kept open (not developed). In addition, neither shrubs nor trees are tolerated, as deep roots can disturb the pipes and cables and (partially) affect their performance (tree roots could penetrate newly installed sewage drains, causing blockages or subsidence). Moreover, pipes and drains are less easily accessible and more difficult to dig up in areas vegetated by trees, hedges and plants. Depending on the type of cable or pipe, a strip of land is reserved on both sides, ranging from 1m to 30m. In certain cases, even roads and cycle lanes are prohibited.

The risk of explosion of the transported material and standstill of underground transport also plays a part in the decision to keep overhead space free from obstacles.
The price tag of underground transportation is occasionally a determining factor in the decision-making process, including construction on substrate with less load-bearing capacity. Many sewage drains are under-reamed.
For electricity networks, taking into account risk considerations and loss of power, it has been decided to transport aboveground in outlying areas, across greater distances.

In summary, we can pose that the expansion, repair (maintenance and management) and remediation of faults and disruptions to overhead cables and pipes are less costly, and characterised by a reduced transportation risk factor.
In view of the above considerations, pipes and cables are installed as much as possible in open areas. The Nederlands Normalisatie Instituut has drawn up standards, the so-called NEN standards[a] for marking out, occupied space, depth and relative distance of the different pipes and cables.
The bundling of pipes not only discourages fragmentation of space and excessive use of space, but also reduces the barricading effect within the space.
For each new planning development, establishing the presence of underground pipes and cables is recommended, as is the marking out of this underground infrastructure. Further information is available from the provincial authorities.

### 4.7.4 The electricity network

We assume that there will be no changes to the power supply via electricity networks in the foreseeable future.

**Technical data**

A distinction is made between high-voltage grids with high kilo voltages and low-voltage urban distribution networks (220 V).
High-voltage transmission lines have stress levels of 380 kV, 220 kV, 150 kV and 110 kV.
The mains voltage is driven up as high as possible, as current intensity causes loss.
After all: power (watt) = current intensity (ampere) X voltage (volt)
High-voltage transmission lines form an overhead distribution network in outlying areas. In substations, high voltage in urban areas and industrial areas is transformed to medium voltage (usually 10kV). This substation functions as a distribution centre for urban and industrial supply areas. In residential areas, this medium voltage in transformer kiosk is transformed into low voltage (220 V).

In principle, high-voltage grids are located above-ground. The area beneath the high-voltage cables must be free from obstacles due to swing length in the event of breakage in the cable. In areas that are 100m wide, building work may not take place below a high-voltage line. In other words, a land strip of 50m must be free from obstacles on both sides of a high-voltage line. For further information on the width of a strip of land, see the relevant NEN standards. High-growing vegetation is also not allowed in this case, though (temporary) land use such as recreational areas and agricultural areas and nature reserves is. In addition to recreational use such as parks or nature reserves, waterways and roads may cross the strip of land containing the high-voltage transmission line.
In addition to safety measures that prohibit building activities below high-voltage transmission lines, human health must also be taken into consideration. Health aspects primarily concern magnetic fields surrounding high-voltage cables, and the presence of copper in these cables (a heightened concentration of this metal is found around high-voltage lines). Further general research into the health risks is certainly recommended.

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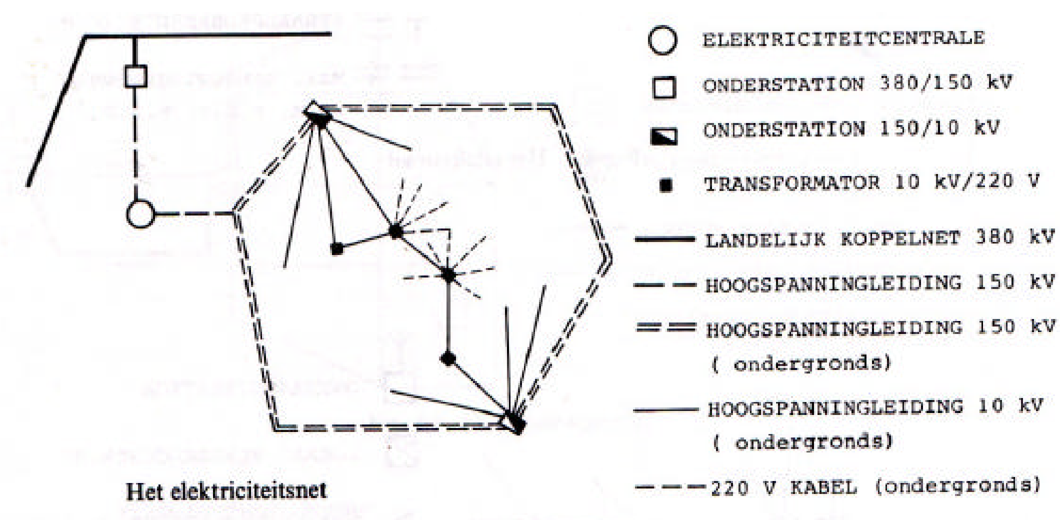
[a] NEN normen zijn te vinden in de zogenaamde normbladen uitgegeven door het Nederlands Normalisatie Instituut.

High-voltage transmission lines are only installed underground if no other solution can be found. The primary reason for overhead construction is the loss of power underground due to the fact that the conductor, the oil insulating layer used as a dielectric, and the earthed cable covering form a condenser, which has a disruptive effect on the phase, resulting in loss in (frequently wet) grounds; air is a better insulator.

The national electricity network is divided into interconnected regions, allowing instant deployment of another network in the event of cuts and peak loads.
The Netherlands additionally sources electricity through an international network. For example, during times of mass use (mainly in winter), electricity is sourced from the Alps region (hydroelectric power stations). Conversely, at low-peak times, we supply electricity to the Alps regions, maintaining the impounding reservoirs in those regions. Coal or gas-powered plants must always run at a minimum capacity, to keep them on stand-by and for technical reasons. Excess capacity can then be used to supply other regions in Europe.

**Design considerations of installing an electricity network**




*W.A. Segeren and H. Hengeveld (1991) p. 267*

*Fig. 483 The electricity network*

In the Netherlands, high-voltage transmission lines usually terminate at urban boundaries. Via substations, distribution stations and transformers, electricity eventually reaches the meter box in our homes.

Design considerations can be viewed from two angles:
1. Marking out new high-voltage transmission lines, switching stations and plants
2. Change of designated use of the area around and below existing high-voltage lines

**Marking out**
The marking out of new pipes must satisfy the abovementioned NEN standards, also taking into account future land use and/or reservations. Future adjustments will only be made in exceptional circumstances. Cost factors play an important role in this respect, as well as stagnation of transportation and potential risks involved.

**Change of use**
This change in use will obviously require huge adjustments with regard to the expansion of an urban area. Fitting pipes into a narrow strip of a residential area is not an easy task!

1. Due to health and safety limitations, high-voltage lines will often be used to circumscribe an expansion.
2. With regard to urban development, another option is to keep the strip of land that is intersected by high-voltage lines free from development. Temporary land use can be assigned to this strip, such as recreational facilities, unorganised sporting events etc.

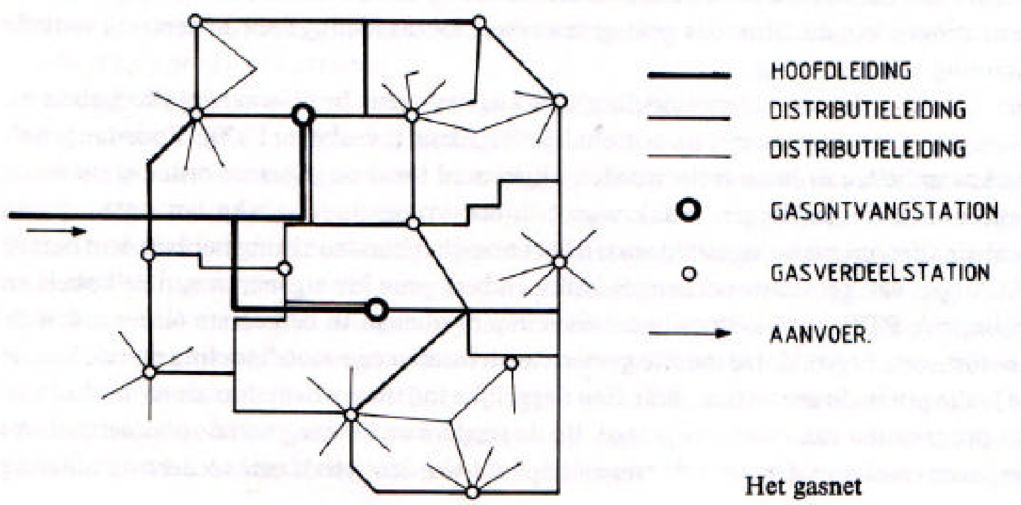
3. In extreme circumstances, the underground cables can be removed. Compared with overhead installations, the costs of this operation are markedly higher, coupled with considerable loss of power and increased maintenance costs. In this case, development of the strip is not allowed, although recreational use such as parks may be assigned. Roads will pose no problems, provided that the pipes and cables are not “covered” by obstacles. This usually involves installing the pipes in a public green zone, as the area to be marked out must remain accessible for safety reasons and maintenance work.
4. A final option involves the construction of a distribution station with transformers, from where pipes may run underground as distribution networks. When selecting an appropriate location, remember the distribution station, which can be quite noisy due to the operation of switches and use of compressed air.

### 4.7.5 The gas network

The Netherlands has had a national gas network ever since the discovery of natural gas in exploitable quantities. This network is connected to the natural gas extraction in Groningen and the North Sea. One network runs from Groningen and one from Noord Holland, from the landing point of the North Sea gas pipes. The two networks are interconnected.
Traditionally, urban gas had been extracted from coal. This production was related to urban centres or regions, and correspondingly had an urban distribution network. These networks were interconnected to absorb calamities in supply and to provide additional gas at peak times. Most rural areas were not connected to a natural gas network. People used bottled gas (butane gas) to cook, while homes were heated with solid fuel such as domestic fuel oil or coal.

Like the electricity network, the natural gas network has a distribution system. Gas pressure in rural areas is slightly higher than in towns and cities. At a lower level, we can distinguish distribution stations, where the gas pressure (40 bar) of rural areas is lowered to the gas pressure level (25 bar) of house service connections.

**Design considerations of installing the gas distribution network.**




*W.A. Segeren and H. Hengeveld (1991) p. 266*

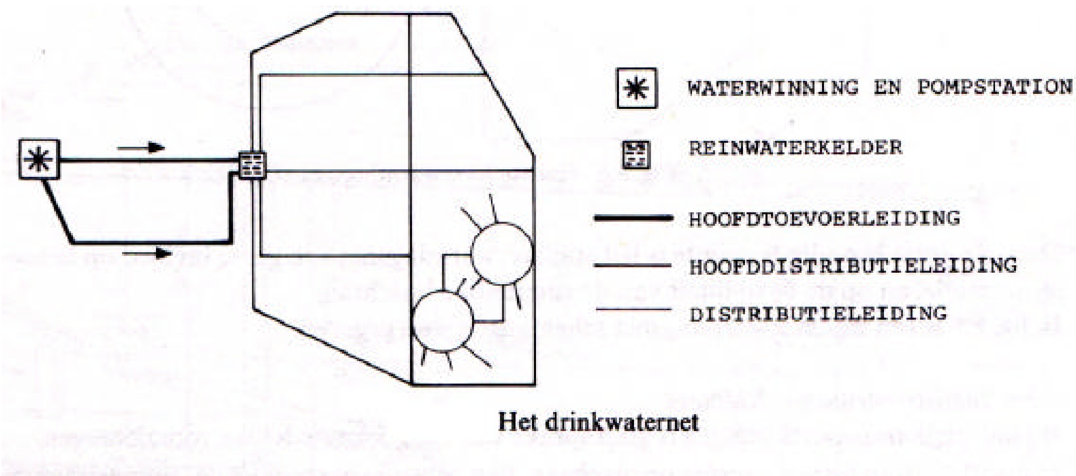
*Fig. 484 The gas network*

Rural natural gas distribution networks run entirely underground. They are governed by the same restrictions with regard to obstacles as the (overhead) national electricity network in terms of maintenance, management and safety (including risk of explosion). In other words, a strip of land must be kept free from obstacles (buildings and high-growing vegetation) to allow installation of these pipes. The required width of this strip is significantly smaller than that of the electricity network, being approximately 10-20 metres (see applicable NEN standards). Connection and maintenance problems are also posed by tree roots.

### 4.7.6 Water pipes

Due to the water shortage in a number of water-catchment areas[a] (such as dunes), water is filtered from elsewhere to supplement the shortage in these areas. To supply the western corners of the Netherlands with drinking-water, large pipes have been constructed from the Rhine to the dunes, where water is infiltrated and purified into drinking water. A similar process takes place with water pipes of different storage reservoirs in the Biesbos to water treatment plants in urban agglomerations, such as Rotterdam and surroundings.
The network of water treatment plants to residential areas is additionally characterised by a branch system with one or more water mains supplying towns and villages, and a further 'branching off' on district level and residential level. To guarantee a more reliable supply of water in districts, the pipes are installed in a ring structure.

**Design considerations of installing rural water pipes.**




Segeren and Hengeveld 1984 p. 269

*Fig. 485 Drinking-water network*

From a design point of view, the maximum space occupied by rural distribution pipes is ten metres for, while urban distribution pipes take up less space. Space usage depends on provincial and municipal bye-laws. In general, rural pipes are connected to the road network. Vegetation is not recommended due to maintenance; furthermore, the mains can be disrupted by roots. The distribution network must be covered by a minimum layer of ground of 90 cm due to the frost line of the soil.
In the Netherlands, the fire brigade makes use of domestic water (drinking water) to extinguish fires. To enable sufficient water pressure and water supply, the pipes must be 3 inch thick in diameter.

### 4.7.7 Pressure pipelines for sewage water

The countryside is usually equipped with wastewater purification plants. Contaminated water, wastewater, is transported by pressure pipelines from the urban area to the water treatment plant. These installations usually perform a regional collection and purification function. From the wastewater treatment plant, pressure pipelines run (where possible) to the sea and the big rivers to discharge the purified wastewater. In other cases, purified water is immediately discharged into the storage basin[b]

These pipes are also subject to criteria governing the use of the space above the pipes. Pipe dimensioning depends on the amount of sewage water and interspersed waste. The option of installing two adjacent smaller drains (in the event that reduced discharging capacity is required due to a change in supply) is currently underused.
The standards apply to pipe maintenance and the prevention of pipeline breakage. NEN standards have also been drawn up, occasionally supplemented by municipal bye-laws.

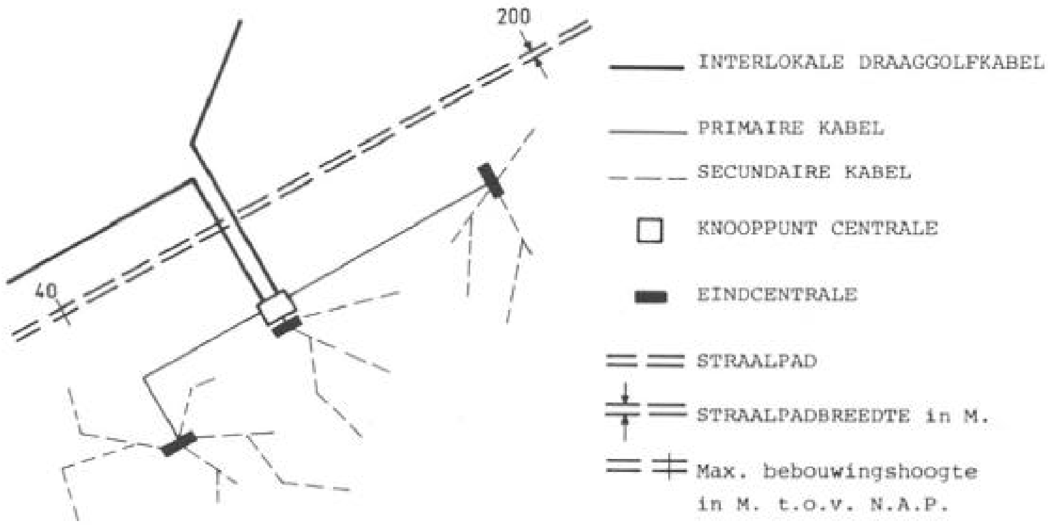
[a] Groundwater is extracted from water-catchment areas through pumping, and used as drinking water following purification. Water-catchment areas are protected against infiltration of contaminating substances such as fertilizers, petrol, etc. As a result, these areas are not suitable for all purposes.
[b] A storage basin is a system of lakes, channels and ditches, where water from lower-down areas is spread out (lifted) and temporarily stored prior to being spread out to outward waters (sea and rivers in direct contact with the sea).

**Design considerations of installing pressure pipelines.**
The space above pressure pipelines is subject to the same design requirements and restrictions concerning use and vegetation as water pipes.
A further installation problem has been identified, concerning the weight of the pipes. Appropriate measures must be taken for grounds with less bearing capacity, so that the pipe system is protected against subsidence. This explains why many sewage systems are under-reamed.

### 4.7.8 The telephone network

Most telephone networks run underground. Special NEN standards apply to the installation of this network.
Per region, the structure of the telephone network consists of an underground cable running between residential areas and the central exchange, and an underground connection to the nodal point. From the nodal point, a connection is established via beam transmitters to nodal points in other areas. In addition to this underground network, we can identify an overhead network in the form of beam transmitters. These beam transmitters are situated on tall buildings, where the transmission paths must be kept free from high-rise; this applies in all cases to the direction of the beam transmission. Ongoing developments in mobile telephony and other connection technologies will certainly influence the spatial use of beam transmitters. A network of lower-scale beam transmitters, masts and receivers has also been especially developed for the mobile telephony market.

Developments in telephone satellite connections will certainly play a prominent part in future.

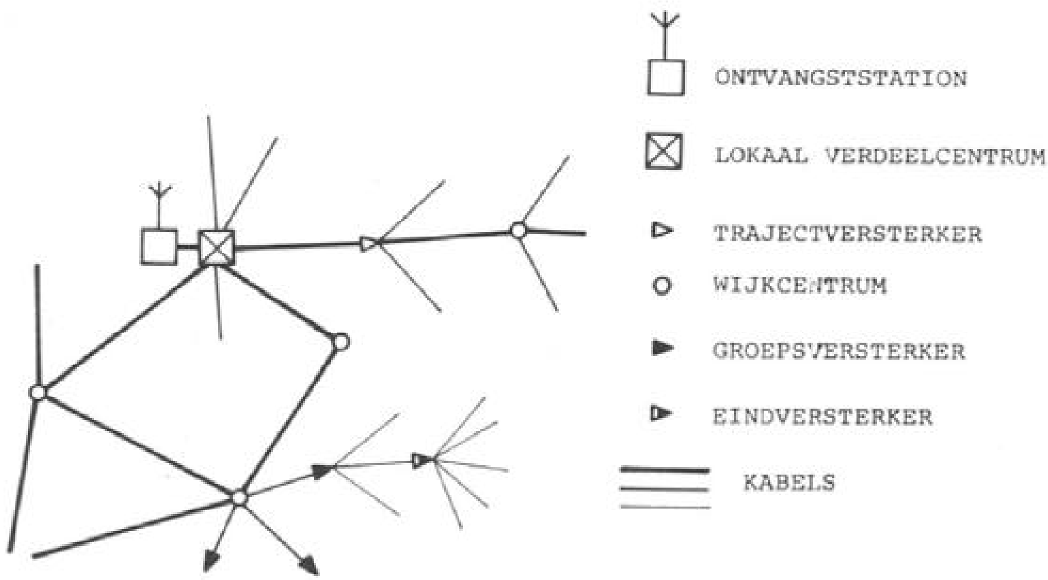



W.A. Segeren and H. Hengeveld (1991) p. 268

*Fig. 486 Telephone network*

### 4.7.9 Radio transmitters and television transmitters

In the Netherlands, a portion of the physical space is used for transmitting radio and television signals using transmission masts, which transmit signals to receivers (aerials). Obstacles can cause interference or distortion.




Segeren and Hengeveld 1984 p. 268

*Fig. 487 Central antenna installation*

In urban areas, the transmission of these signals has partially been replaced by cable. The increased use of satellite connections will also result in changes to spatial use.

### 4.7.10 Raw materials network

Underground and overhead pipes are increasingly being used to transport raw materials from (sea) ports to industrial areas. Depending on the materials to be transported, a number of restrictions must be observed. These measures encompass safety for the surrounding area (such as buildings and roads) and method of transportation (pressure in gaseous substances, solution / dilution in liquids,

suspension etc.). Certain substances also carry a risk of explosion. Docking can cause problems as a result of static electricity. This phenomenon can cause devastating fires, such as oil fires in sea ports. In general, these pipes connect the port (the unloading quay) to processing plants. Although these pipes primarily run overhead, we can also identify many longer underground pipes, connecting the port of Rotterdam to e.g. the Ruhr region and the port of Antwerp. Materials, transported through these underground pipes can range from oil products to semi-finished products for industry.
The Netherlands has also installed pipes in the North Sea to extract oil products such as gas and oil (the oil platforms) on behalf of processing plants and distribution companies.
In the Netherlands, approximately 20% of raw materials are transported underground through pipelines.

**Design considerations of installing pipes for the transport of raw materials.**
In terms of design, the use of space and corresponding restrictions governing pipelines is comparable to those of the gas network, provided that, depending on the material to be transported, additional measures are taken.
With regard to the load bearing capacity of the ground, arrangements must be made to prevent subsidence and breakage.

### 4.7.11 Tunnels

Tunnels constitute a special group of pipes.
The best-known tunnels in the Netherlands run under waterways, and are designed for motorised traffic. The oldest tunnel, the Maastunnel in Rotterdam, dates from before the Second World War. Amsterdam has several (urban) tunnels below the IJ, which connect different (new) districts such as IJburg.
In addition to these tunnels, recent developments have seen the construction of tunnels for rail transport. The first rail tunnel to run beneath a waterway was also constructed in Rotterdam, and is a relatively short tunnel. The Schiphol tunnel, which was constructed beneath a runway, is another example of a short tunnel. Both train tunnels form a combination with underground stations. Compared with railway tunnels, these tunnels are subject to a number of additional safety measures.
More innovative plans include the construction of a tunnel with a railway link for goods transportation between Rotterdam and the Ruhr region, and a tunnel for the high-speed railway link (HSL) below the “Groene Hart”. These underground tunnels span big distances. In principle, the goods transport railway tunnel requires no ventilation, provided transport is organised fully automatically. The HSL tunnel, on the other hand, will need to be equipped with ventilating ducts and escape routes. These tunnels have been constructed for a variety of reasons, such as nature conservation, reduction of noise pollution, fragmentation of the area, visual considerations etc.

Detailed surveys must be carried out for these tunnels, both into location and method of construction as into the safety of the products to be carried (humans or raw materials). Recent calamities include the 1999 fire in the Mont Blanc tunnel between France and Italy, the Tauern tunnel in Austria (2000) and the Gotthard tunnel in Switzerland (2001)

Underground metro networks are currently being constructed in Amsterdam and Rotterdam. In general, these underground systems are subject to the same criteria as tunnels, with the exception of location within the city and underpass of buildings (construction under existing buildings and the presence of tunnels under buildings in particular will necessitate specific construction and usage demands). Metro systems must also come complete with escape routes.

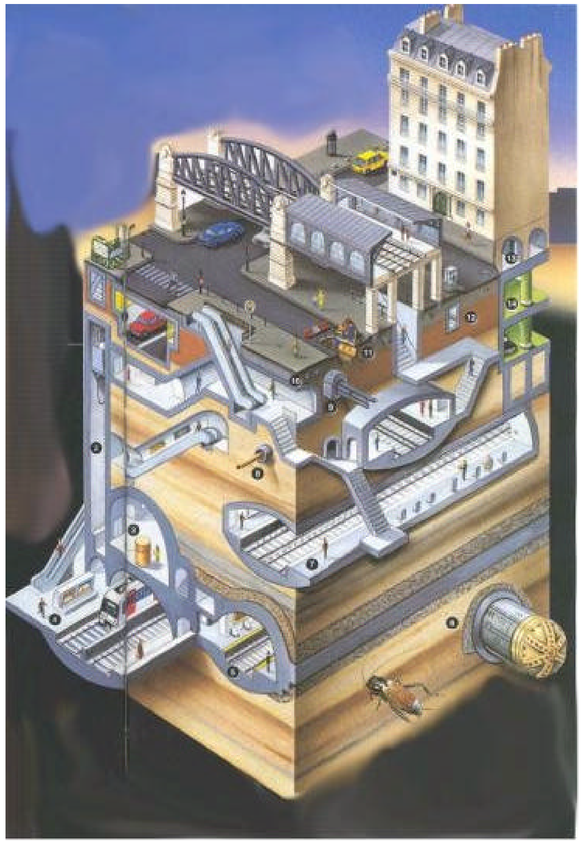
We can identify a number of risk factors for tunnels, such as:

1. risks arising from the material, in which the tunnel is being constructed
2. risks arising from the method and the construction
3. risks arising from tunnel use (calamities!)

Ref 2 For example: choice of one or two separate tunnel tubes (one-way traffic), or one tube for freight transport and another for carrying passengers, such as the Channel tunnel (freight and passengers), which uses ‘car trains’ and ‘lorry trains’

Ref 3 The reliability of the vehicle and the type of products to be carried.
Human errors in the construction, as well as traffic errors, cannot be ruled out. The management and maintenance of these tunnels must be carefully monitored

Needless to say, use of space is dependent on tunnel size and length. In principle, few restrictions apply to the use of space above tunnels. However, the construction of foundations will always need to take account of each individual tunnel.



Standaardgidsen (1999)

*Fig. 488 Tunnel*

### 4.7.12 Urban scales

**Differences compared with previous scale**

In rural areas, electric cables primarily run overhead. On an urban level, on the other hand, they tend to ‘go underground’ following transformation from high-voltage to a medium voltage of 50KV or 10KV. At district level, voltage is again increased (via a transformer kiosk) to 380V (industrial voltage) and 220V (domestic voltage). Transformer noise is caused by switching, and compressed air.

In urban areas, the gas pipe pressure is adjusted to domestic pressure. This takes place in distribution stations, from where the gas is distributed across towns via underground pipes.

Drinking water is distributed across urban areas via underground pipes.

The sewerage system is featured in a separate chapter, as is the drainage system.

The urban scale is also characterised by underground conveyor pipelines for materials transported from harbour areas. These conveyor pipelines are often bundled in pipe alleys, for which space has already been allocated and/or reserved at a higher scale. On an urban scale, this space must be sufficient to satisfy criteria governing safety and accessibility (e.g. for repair work to conveyor pipelines). In general, this implies that the pipes are installed in public green strips, or incorporated in larger park areas.

Underground transport tunnels such as metro lines, tram tunnels and car tunnels take up a lot of space in urban areas. Decisions on transport type and construction have a major impact on the urban

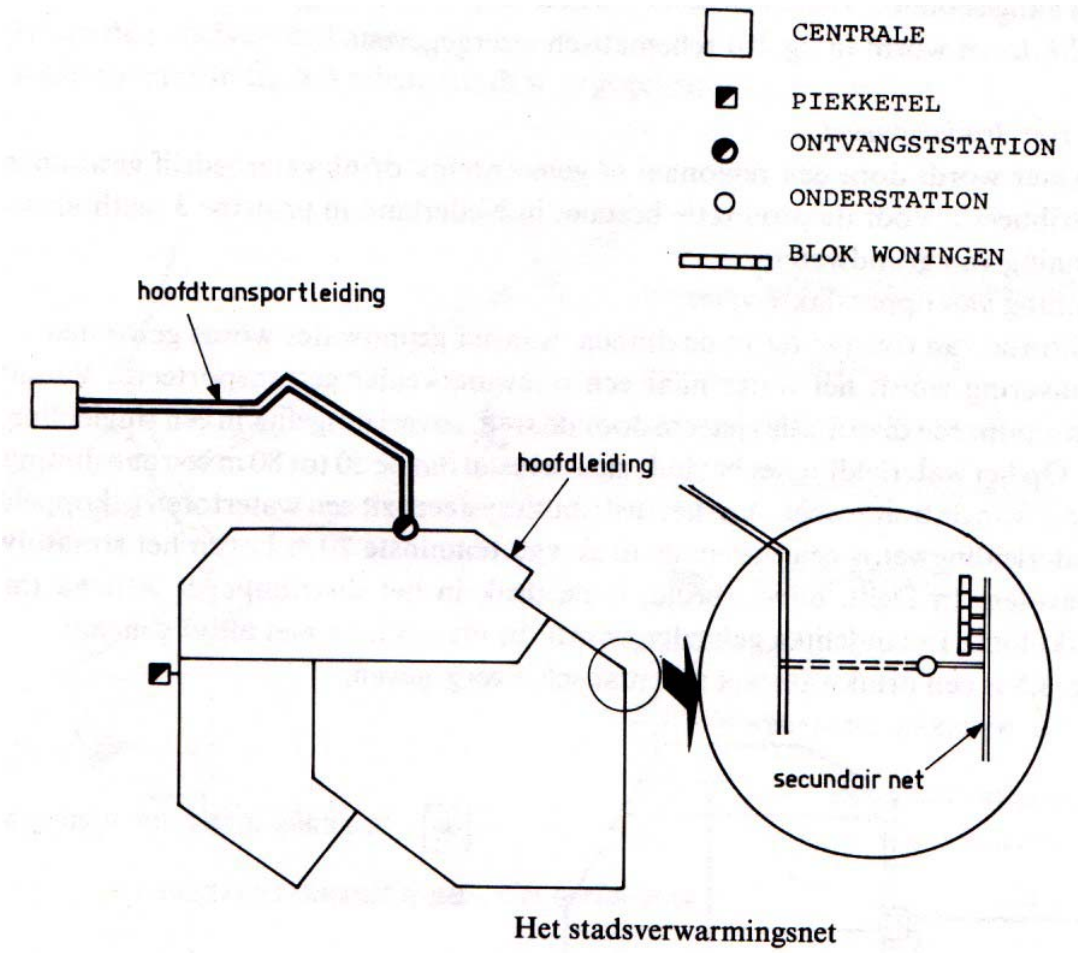
area. Similarly, underground parking garages have a major impact on urban development, as space will need to be allocated for their construction; alternatively, they will need to be built in unison with visitor-intensive buildings.
Innovative plans for underground bus stations also require space, and will need to be incorporated in the planning process. The same applies to underground distribution centres.

On an urban scale, innovative decisions are also being taken with regard to small-scale underground material storage, such as the storage of glass, paper and other small-scale domestic waste not suitable for refuse collection. This underground storage takes up considerable space, and is often difficult to incorporate in existing street profiles due to the high density of underground cables, pipes, wires and drains. The storage must be safely accessible and not installed in a random location.

With regard to planning, the installation of cables and pipes forms part of the process of preparing a site for habitation. The advantage of incorporating this time schedule is that it minimises the risk of damage caused by other activities. Building activities do however require “building power” and “building water”. In effect, this means that these pipes and cables are installed in “building streets” prior to commencement of building activities.
The installation of cables and pipes in a new district usually kick-starts with the construction of sewage systems and district heating pipes. House service connections are installed at a later stage. Following completion of building activities, house service connections for sewerage and district heating are installed, and the remaining cables and pipes (including connections) put in place. Approximately 6 to 13 weeks prior to completion, local municipalities release the terrain for the installation of underground infrastructures. Negotiations have meanwhile taken place concerning the municipal “green plan”, as pipes and cables are often located in green zones.

An example of a public works time schedule is included below (Rotterdam):
- No more than 4½ months before completion, plans relating to the preparation of sites for habitation must be made available. Relevant information includes tender-specifications, shop drawings of the utilities companies, which can only be made once the road schemes (complete with layout plans of the roads) are in place. Drawings and tender-specifications of the green plan are also relevant to the construction of cables and pipes, and must therefore be ready.
- Open tender. This procedure can take up to 6 to 8 weeks.
- 8 weeks before completion, branch pipes are installed.
- 7 weeks before completion, drinking water is installed for statutory surveys. Surveys can prove time-consuming.
- 6 to 5 weeks before completion, gas pipes and electric cables are delivered to the utilities companies. Installation of house service connections can commence (building pipes are converted for the distribution network, or removed)
- 4 weeks before completion, house service connections are completed, and telephone and central antenna system installed.
- The remaining 2 to 3 weeks are used to install discharges and carry out additional paving.

**Mains systems in the street profile**
Distribution networks are planned for urban and rural areas, including water, gas and electricity, as well as cable networks for telephonic and audio-visual appliances (including computer networks - nowadays, computer cables are primarily made of glass fibre - fibre optic cables - rather than old-fashioned copper wires).
The choice of district heating with corresponding pipe system is also made on this scale, and fitted into the street profile. We must of course not forget the discharge system for wastewater, sewage systems that are either stand-alone or combined units.




W.A. Segeren and H. Hengeveld (1991) p. 270

*Fig. 489 District heating network*

The use of available space and the relative position and safety measures of the different networks are laid down in municipal bye-laws. Although they may differ in terms of depth and pipe combination, they tend to adopt similar principles. These bye-laws are available from the Grondzaken (Ground Affairs) department of local municipality, as are maps containing information on the position of cables and pipes in the street profile, in districts and in towns. Most municipalities can provide these maps in digital format. Please note however, that these maps will not specify all pipes, and that some areas are found to contain old “forgotten” or “unknown” pipes. This is particularly the case for computer network cables.

Computer networks are a separate issue. They have often been installed without specific permits, and are therefore not included on plan drawings. This means they cannot be marked out afterwards. These networks are usually found at a shallow depth (± 30cm below surface level).
A number of municipalities have begun constructing networks using empty cables (‘empty shells’), which are deployed at a future date. The advantage of this method is that it does not require streets to be opened up in order to install new networks. Another recent development concerns the combination of networks. In Amsterdam for example, experiments are being carried into with combined installation of fibre optic cables in sewage drains.

In addition to these networks, installed specifically for the supply and discharge of materials and transmitting information for domestic and industrial use, built-up areas with an excessively high ground-water table deploy a drainage network in the form of open water systems of canals and ponds and a closed underground drainage system to collect excess ground water, store it for shorter or longer periods of time, before discharging it.

NEN standards governing the location of cables and pipes in the street profile of built-up areas have been included for reference purposes.

Plaats van leidingen en kabels in wegen binnen de bebouwde kom.

| NED. MIJ. VOOR NIJVERHEID EN HANDEL | | KON. INSTITUUT VAN INGENIEURS |
|---|---|---|

NEDERLANDS NORMALISATIE-INSTITUUT

**1. Doel en toepasbaarheid**

Deze norm geeft richtlijnen voor de plaats van leidingen en kabels in wegen *binnen* de bebouwde kom.

Voor andere dan in deze norm genoemde leidingen en kabels zijn geen richtlijnen vastgesteld. Over de plaats hiervan dient men van geval tot geval te beslissen.
Indien een bedrijf over eigen telecommunicatiekabels beschikt, behoren deze in de voor dit bedrijf bestemde sleuf te worden ondergebracht.

**2. Aanduiding van leidingen en kabels**

Al naar gelang van hun aard zijn de leidingen en kabels in deze norm op tekeningen als volgt aangeduid:

E = kabels van elektriciteitsbedrijven, waarbij:
LSK = laagspanningskabel
HSK = hoogspanningskabel
G = enkelvoudige gasleiding tot een maximale nominale binnenmiddellijn van 200 mm
PTT = PTT kabels
W = enkelvoudige waterleiding tot een maximale nominale binnenmiddellijn van 300 mm
R = huisaansluiting riolering

**3. Uitvoering**

Leidingen en kabels worden bij voorkeur onder de trottoirs gelegd. Afhankelijk van de plaatselijke omstandigheden kan een keuze worden gedaan uit de uitvoering volgens de figuren A, B of C, waarbij een uitvoering volgens fig. A of B verkieselijker is dan volgens fig. C.

**4. Maten**

De in fig. A, B en C aangegeven maten móeten als wenselijke maten voor horizontale afmetingen worden beschouwd.
Indien meer ruimte in de trottoirstrook (met eventuele parkeerkommen) beschikbaar is, verdient het toch aanbeveling deze maten zoveel mogelijk aan te houden, met het oog op eventuele uitbreidingen.
Indien er minder trottoirbreedte ter beschikking is, zal
– de riolering in aanmerking komen voor verplaatsing onder de rijweg;
– verder de ruimten voor de leidingen en kabels naar verhouding verminderd worden.
Indien er leidingen voor stadsverwarming worden aangelegd, dient de ruimte van 60 cm tussen de gas- en waterleiding zodanig te worden vermeerderd, dat er plaats komt voor de stadsverwarmingsleidingen. Indien de trottoirbreedte met eventuele parkeerstroken hiervoor onvoldoende is, moeten de stadsverwarmingsleidingen onder de rijweg worden gelegd.
Met in leidingen en kabels voorkomende voorzieningen, zoals hulpstukken e.d., is geen rekening gehouden.

**5. Mantelbuizen**

Bij aanleg en(of) verbetering van de weg verdient het aanbeveling op daarvoor in aanmerking komende plaatsen mantelbuizen voor de doorvoer van eventuele toekomstige leidingen en kabels aan te brengen.

**6. Plaats voor lichtmasten in trottoirstrook**

De plaats voor eventuele lichtmasten moet worden gevonden in de voor de riolering bestemde strook en is in de figuren schematisch aangegeven.

**7. Boom- of struikbeplanting**

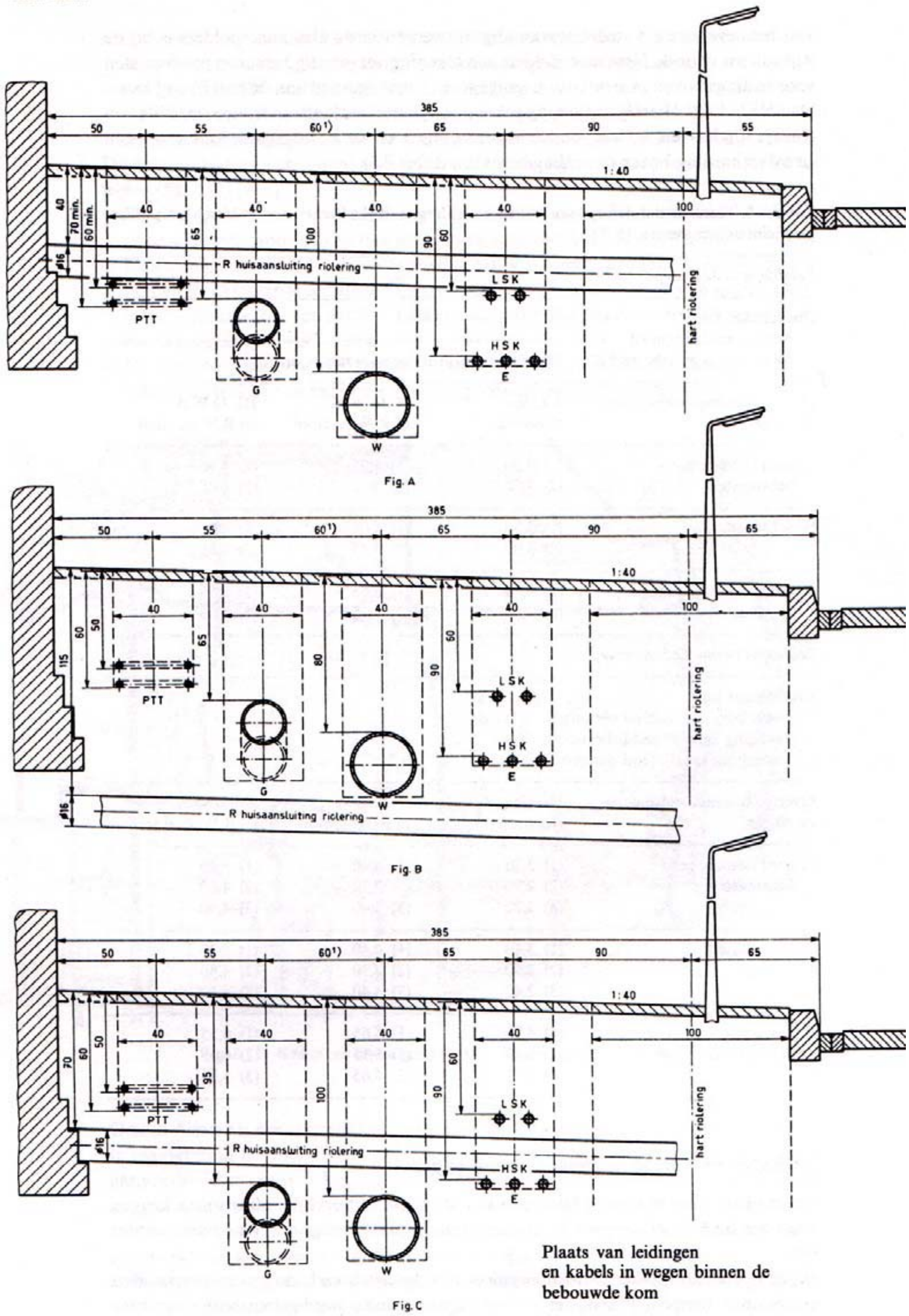
In de dwarsprofielen is de plaats van de boom- of struikbeplanting niet aangegeven, maar deze moet, afhankelijk van plaatselijke omstandigheden, van geval tot geval worden overwogen.

| **Plaats van leidingen en kabels in wegen binnen de bebouwde kom** | **NEN 1739** |
|---|---|
| The place of pipes and cables along roads IN built up areas | mei 1964 |
| Auteursrechten voorbehouden | UDC: 625.78:711.522 |

W.A. Segeren and H. Hengeveld (1991) p. 274

*Fig. 490 NEN 1739*

Maten in cm




**Plaats van leidingen en kabels in wegen binnen de bebouwde kom**

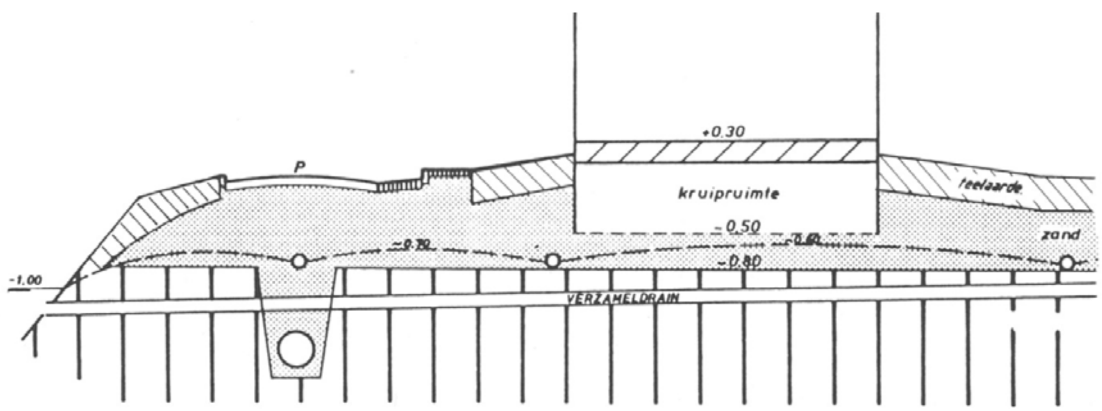
¹) Indien er leidingen voor stadsverwarming worden aangelegd, dient de ruimte van 60 cm tussen de gas- en waterleiding zodanig te worden vermeerderd, dat er plaats komt voor de stadsverwarmingsleidingen. Indien de trottoirbreedte met eventuele parkeerstroken hiervoor onvoldoende is, moeten de stadsverwarmingsleidingen onder de rijweg worden gelegd.

W.A. Segeren and H. Hengeveld (1991) p. 275

*Fig. 491 Location of cables and pipes in built-up areas*

**Drainage**
The initial purpose of drainage systems is to make sites earmarked for development suitable for e.g. habitation, and maintaining that area's suitability (in other words: site management). On the one hand, drainage systems are designed to keep the ground-water table in built-up areas at an appropriate level (i.e. to enable proper functioning of foundations, cellars and pipes), and on the other to discharge excess (ground) water. The groundwater table is artificially kept at a predetermined level by the municipality using pumping stations. The minimal depth ranges from several decimetres to approximately 80 cm below surface level. Depth is determined by existing foundations and pipes. Areas with wooden piled foundations for example have a different depth (piles made entirely of wood must remain submerged to combat rotting) than newer areas, which are equipped with concrete and other types of foundation. The climate also determines the depth and temperature of the groundwater. In times of severe frost, ground saturated with water can freeze up to approx. 80 cm below surface level. The frozen ground can cause pipe breakage as well as holes in the asphalt road surface. Pipes are therefore always installed at a depth greater than 80 cm below surface level in the Netherlands.

In addition to discharging excess groundwater (excess ground-water table), drainage systems also serve to discharge rain water and melt water, which permeates the ground via the unhardened subgrade. In built-up areas, excess water from hardened surfaces (streets, squares and roofs), is usually discharged via a sewerage system.
Underground, the drainage network consists of drainage pipes. Above ground, it comprises of ditches, canals and (receptive) ponds, the so-called 'open water system'. Water from drainage pipes is either discharged in open waters in urban areas, or transported to storage water (this is also open water) in rural areas. The excess water (excess water level in open water such as in canals, navigation canals and ponds) is discharged from the urban area to open water outside the urban area via a system of waterways. The water is then carried to the rivers and/or sea via a system of storage water and pumping stations.

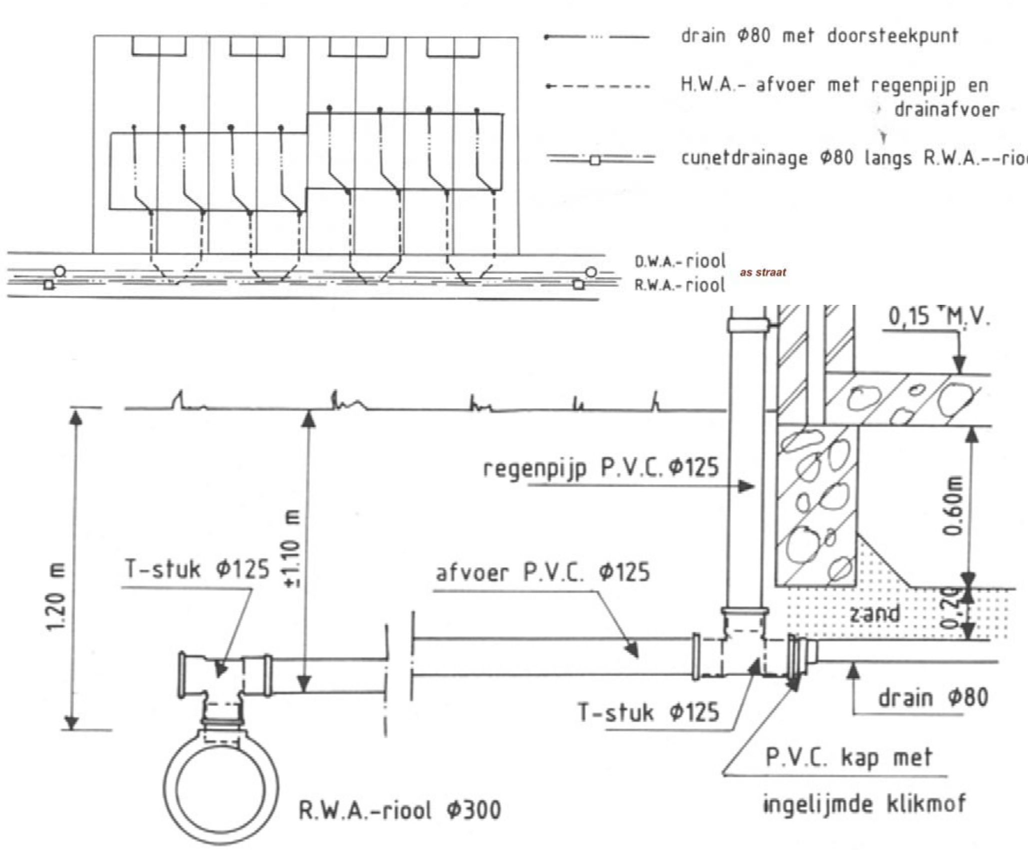


W.A. Segeren and H. Hengeveld (1991) p. 150
*Fig. 492 Urban drainage*

**The sewerage system**
Up until the early 20th century, domestic and industrial wastewater was usually discharged directly onto surface water. Some 19th century towns already had various pipe systems at their disposal to carry this wastewater to sites outside the built-up areas. During the course of the 20th century, successive sewerage systems were installed throughout the whole of the Netherlands. Isolated farms and houses are not always connected to the sewage system. Nevertheless, these homes must also satisfy wastewater purification requirements. This can be achieved by using individual water catchment and water treatment plants.
Sewerage systems are designed to discharge domestic water, industrial water and excess rain water safely, posing no risk to (public) health. Contaminated water is purified to such an extent, that the residual water can be safely discharged into open water.

Requirements governing buildings that use their own sewerage systems for grey water re-use (rain water for sprinkling gardens, cleaning buildings and washing cars, shower water and flushing water), and for purifying wastewater using a separate purification systems such as helophyte filters etc, fall outside the scope of this dissertation. These systems are highlighted as part of the so-called "eco-friendly building".

A sewerage system effectively consists of a catchment system, a transport system and a purification system. The catchment system is particularly relevant in the context of this dissertation. This system consists of a system of pipes, which "catch" wastewater and rain water and carry it to the sewage purification or discharge point.




W.A. Segeren and H. Hengeveld (1991) p. 156

*Fig. 493 Building block drainage*

We can distinguish the following sewerage systems:
- combined system (including various improvements)
- stand-alone systems (also including various improved versions).

Needless to say, the choice of system depends on the scale of the district or village. System unity is a prerequisite; a system is only as efficient as its weakest link.
The sewerage system is based on discharge quantities. These can be classed into dry weather discharge (d.w.d.) and rain water discharge or precipitation discharge (r.w.d.). the hourly required discharge capacity for dry weather discharge is approximately a tenth of the daily discharge. Water use per person is between 100 l and 150 l. Rain water discharge, on the other hand, is characterised by extreme fluctuations, as the amount of precipitation is spread unevenly over the year. In addition, the level of discharge is decreased due to surface evaporation of the precipitation, water absorption in the soil and by plants. This reduction in comparison to the original amount of water is known as the runoff coefficient.

| Building type | | Content/ha . | Runoff coefficient |
| --- | --- | --- | --- |
| Old city centre | high-density building | 350 | 0.8 |
| Newer districts | closed buildings | 250 | 0.6 |
| | open buildings | 150 | 0.4 |
| | with parks and gardens | 100 | 0.25 |
| Undeveloped, unhardened terrains | | | 0.15 |
| Parks | | | 0.5 |

| Nature of the surface | 0.9 |
| --- | --- |
| Closed road surface | 0.9 |
| Clinker paving | 0.8 |
| Metalled roads | 0.45 |
| Gravel and cinder roads | 0.25 |

M.R.r. Creemers, J.A.J. Atteveld e.a. (1983)

*Fig. 494 Runoff coefficients*

**The combined system.**

In this system, all domestic and industrial water and precipitation, rain water and melt water of snow and hail are discharged via a combined system of pipes. Domestic connections and road connections are sloped towards the collecting sewer system. The collecting sewerage is pumped by a sewage pumping-station. Sewage water is transported to the sewage purification through a pressure pipeline.

The big variable of this system is the amount of rainwater present. Large quantities of rainwater will dilute the “dirty” sewage water, thus resulting in less efficient purification. The management of the sewage purification is extremely complex due to strong fluctuations in concentration of the sewage water and discharge peaks.

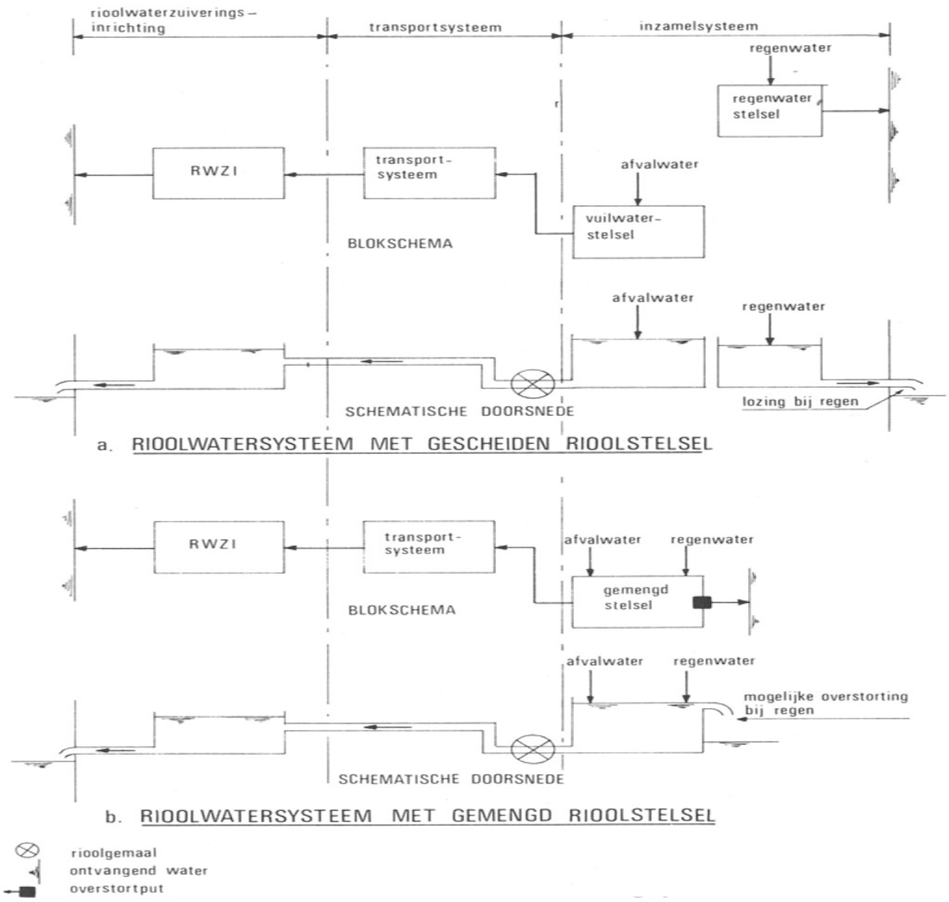
Dimensioning the system is also problematic. It does not make economic sense to adjust the diameter of the pipes to the biggest expected quantity of sewage water that needs to be discharged. In order to combat peaks in discharge and rainwater dilution, certain measures have been taken, such as additional storage, connected directly to the system. If this additional storage proves insufficient, overflows have been installed that connect with open water. Contaminated water, rainwater and sewage sludge are then discharged onto the surface water. This is obviously a weak link in the entire process. The overflow system is constructed in such a way, that the predetermined number of annual overflows is not exceeded. In the Netherlands, this has been calculated to be 3 to 10 overflows per year. Approximately 10% of rainwater is carried to surface water via overflows. This system is not the most hygienic or efficient. As a result, researchers are diligently looking for improvements, and have eventually come up with a new system: the stand-alone system

**The stand-alone system.**

.In this system, rainwater is separated from domestic and industrial wastewater and discharged via its own pipe system. Excess rainwater is always discharged directly onto surface water via street inlets. Surface water is also affected by street contamination in the form of spillages of petrol, oil, tyre abrasion and litter. In addition to combating this pollution, discharge points are equipped with filters to collect contaminants. This system often uses earlier installed drainage systems (installed in the past to prepare a site for development). The combined drainage system, incorporating a system for discharging excess rainwater, is also a popular choice.

Domestic and industrial wastewater sewerage is pumped by a sewage pumping-station and discharge for sewage purification. Pipe dimensioning is based on the mean average wastewater production, with a maximum production on an average day.

Drainage of rainwater is a different matter altogether. The amount of annual precipitation, in the form of rain, hail and snow, is subject to fluctuations. Furthermore, only part of the precipitation enters the drainage system due to surface evaporation of the precipitation, and water absorption in the soil and by plants. Water that enters the system is collected and usually discharged directly onto open water in built-up areas. Water from the streets is collected via street inlets and enters the open water via a mud trap and, more rarely, via helophyte filters.



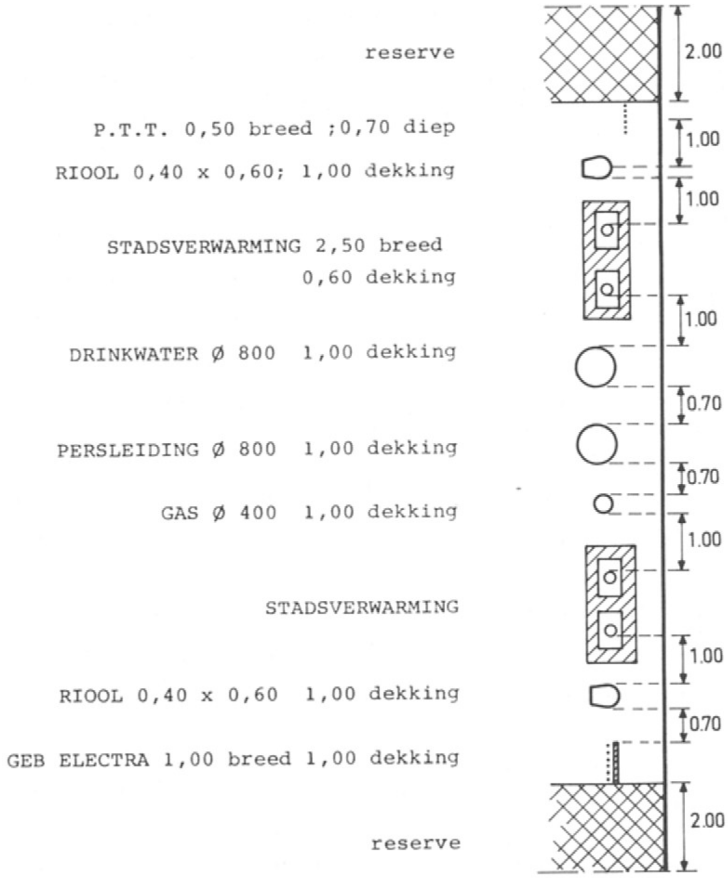

W.A. Segeren and H. Hengeveld (1991) p. 190

*Fig. 495 Sewage systems*

**Design considerations for installing cables and pipes in built-up areas.**

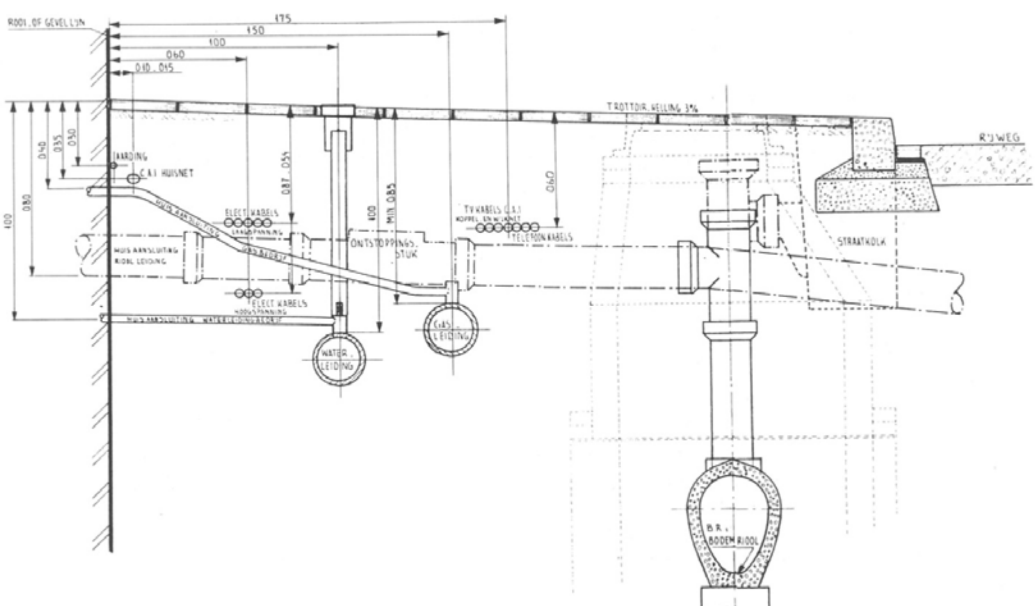
Built-up areas are intersected with rural cables and pipes. On this level in particular, a host of NEN standards and municipal bye-laws apply, causing significant complications, as the limitations from rural networks stand in the way of urban developments in rural areas. This involves many hours of negotiation to find a solution.

Every municipality in the Netherlands has its own bye-laws, which can be inspected by the general public. By and large, they are all identical; bye-laws contain information on relative position and depth in relation to the surface level. Municipal differences primarily reflect different load bearing capacity of soils, as well as ground-water tables and groundwater levels tolerated by each individual municipality.




W.A. Segeren and H. Hengeveld (1991) p. 271

*Fig. 496 Standard layout of cables and pipes in Rotterdam, Zevenkamp*




W.A. Segeren and H. Hengeveld (1991) p. 271

*Fig. 497 Standard layout of cables and pipes Den Haag*

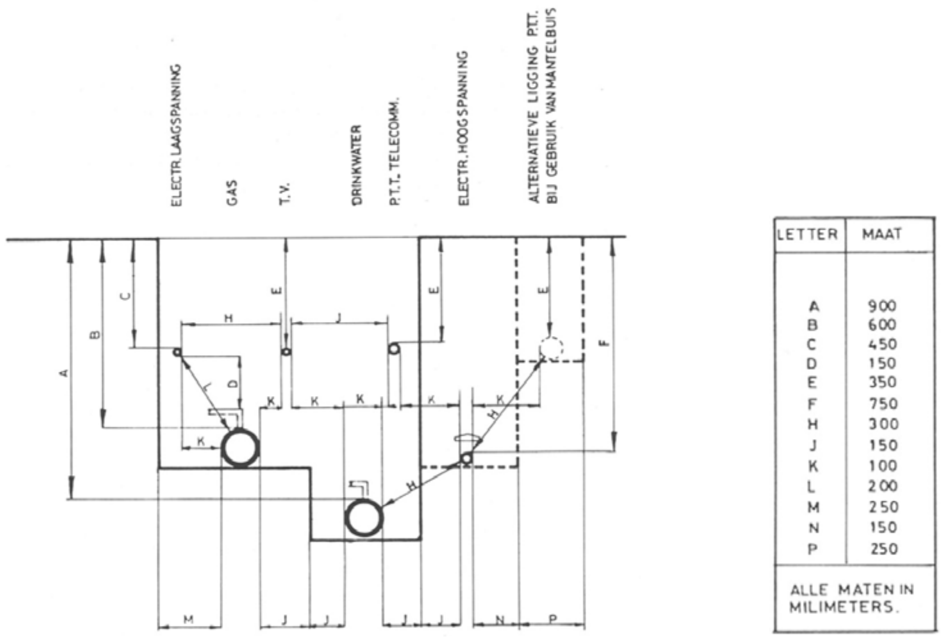
Negotiations on the position of cables, pipes and drains in a new district, and corresponding municipal services, take place during the design phase of an urban development plan. During these negotiations, alternatives and potential design solutions are drawn up, taking into account technical aspects of installation such as house service connections, pipe radius, junctions of pipes, cables and drains, relative influence of the difference pipes, and the position in the street profile.

The position in the street profile determines the management and maintenance of pipes and drains, as well as 'street furnishings' such as trees, lighting and street furniture.
The design of shrubberies is also heavily dependent on the underground infrastructure. "Eco parks" and underground dustbins such as glass and paper containers are installed near squares (or, in any case, near open urban spaces). These should not be obstructed by cables and pipes. The implementation plan regarding cables, pipes and drains for new districts is laid down at the outset in the land registry, and is available from the local municipality. In principle, the position of all cables and pipes in existing developed areas is traced out on land registry plans, which can also be consulted in the event of changes to town planning.

The municipality of Rotterdam is a good example: this municipality has stored all relevant information pertaining to underground networks digitally. Other municipalities are in an advanced stage in digital processing of data, or have also already fully completed this process. Nevertheless, there may still be a few surprises in store, as not all installed and defunct cables or pipes have been drawn up digitally (some are drawn in by hand). In addition, some (manually drawn) information may have gone missing.
The development of a new district will also need to take account of different beam transmitter networks that require physical space in towns (height and position of the buildings). Buildings can form an obstacle for these beam transmitters. A covering beam transmitter range must be installed in towns to enable proper and profitable operation of installations. This can cause problems in existing buildings, requiring the installation of a more compact network to guarantee adequate transmission range.

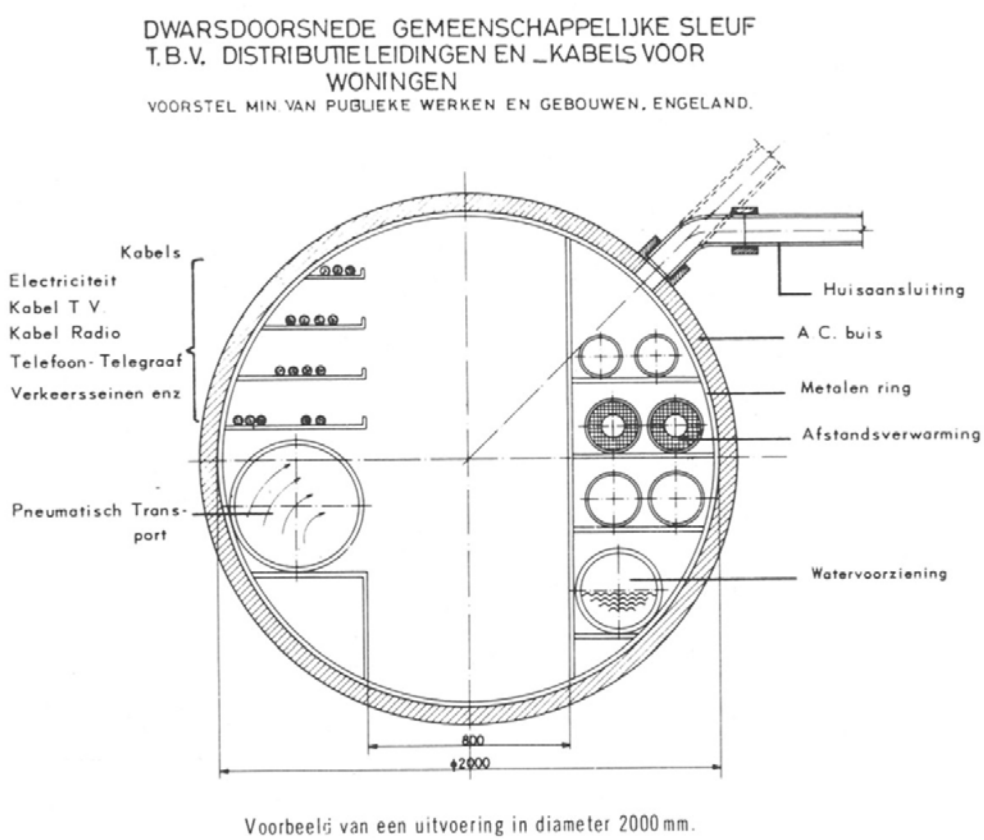
#### 4.7.13 The future.
New distribution networks in the form of pipes, cables and wires are vital to satisfy future demands for fast communications and connections. This may involve a combined installation of cable and wire drain pipes, a combination of sewage drain with fibre optics cables (in experimental stage in Amsterdam). The installation in drain pipes is a particularly interesting option due to the high degree of accessibility of these pipes. Unfortunately, the position of these drain pipes poses several problems. If they are located beneath buildings, private-law issues regarding access to buildings may come into play. Load bearing capacity of the ground will also need to be taken into consideration, if these drain pipes have not been incorporated into the building.
Examples include communal trenches for cables and pipes in England, as well as cable and pipe tunnels.

The municipality of The Hague is currently installing "empty" pipes which can be filled in future with cables to provide extra capacity to accommodate new, innovative applications.




W.A. Segeren and H. Hengeveld (1991) p. 279

*Fig. 498 Communal trenches for cables and pipes*




W.A. Segeren and H. Hengeveld (1991) p. 279

*Fig. 499 Cable and pipe tunnel*

### 4.7.14 References to cables and pipes


Creemers, M.R.r., Atteveld, J.A.J. and e.a., Eds. (1983) *Polytechnisch zakboekje* (Arnhem) Koninklijke PBNA bv / A. Huson ISBN 90-6228-015-3.

Segeren, W.A. and Hengeveld, H. (1991) *Bouwrijpmaken van terreinen* (Delft) TU Delft Civiele Techniek (Leerstoelbibliotheek; Leerstoelbibliotheek).

Standaardgidsen (1999) *Parijs* (Antwerpen) Standaarduitgeverij ISBN 90-02-19744-6 (Leerstoelbibliotheek).

## 4.8 Map analysis

*Adapted from Casseres (1926)*
*The availability of a good and comprehensive set of maps is essential for carrying out practical town planning research. The absence of maps will considerably delay research progress and may even render it impossible.*

Specific problems associated with urban development within rural areas necessitate knowledge of the city itself and of the surrounding countryside. This task requires up-to-date and reliable planning information, including (national) development strategies, processes that take place in and around the city and the spatial spread of features and elements. Maps are a good method for illustrating all the information and processes. For the town planner, analyses and interpretations are essential methods for identifying and understanding the processes, the possibilities and limitations of a region. Regional analyses and interpretations constitute the most important arguments and motives for a design. Knowledge of the city and surrounding countryside can be derived from maps. When maps are not available or out of date, we can use aerial photographs and satellite images.
The Dutch term for 'map' is *kaart* or *kaartblad*. Maps of the Netherlands are numbered according to grids.

**Maps**
What kind of maps do we need to give us an overall impression of the existing landscape and the information we need for a solid spatial or urban development plan?
Put otherwise: what knowledge of the surrounding countryside do we need to implement urban development? We could draw up a list of information we need, or, conversely, produce a list of existing maps from which we can derive useful information. The next step is to match up these two lists and establish where they lack spatial information. This might be up to date information or specific information not available on maps. For this kind of information, we need to rely on recent aerial photographs or satellite images, and enlist the help of specialists.
For example, a specialist on soil conditions can derive information needed for urban planning directly from aerial photographs and draw up the map on our behalf.

### 4.8.1 Types of maps in the Netherlands
The government of the Netherlands is responsible for the production of maps of the country. The Topographic Survey is officially assigned the task of producing topographic maps on the scales 1:10,000 1:25,000 1:50,000 1:100,000 and 1:250,000. Other standard maps produced include soil maps, geomorphologic maps and geological maps. A total coverage of the whole country is not provided by geomorphologic maps and geological maps using the new stratographic classification. Soil maps, geomorphologic maps and geological maps have a scale of 1:50000 and 1:100,000. These maps are based on 1:50,000 topographic maps, which are printed in grey on these maps.

Several other maps are also in existence, such as historical maps, older topographic maps (the most important is maybe the topographic military map dating from around 1850 on a 1:50,000scale) waterway maps, sea charts, water board (water council) maps, motorway maps, cycling maps, maps highlighting administrative boundaries , maps revealing demographic spread, etc…..
All topographic maps, as well as maps based on topographic maps, are listed (see *Fig. 500*). The list is based on a grid of 1:50,000 maps, beginning with map 1 in NW of the country, and ending with map 62 in SE of the country. All these 1:50,000 maps are categorised into Western and Eastern (=oost) maps. (for example : Amsterdam no 25 O.) The following, larger, scales are based on 1:50,000 scale grids (see *Fig. 501*).

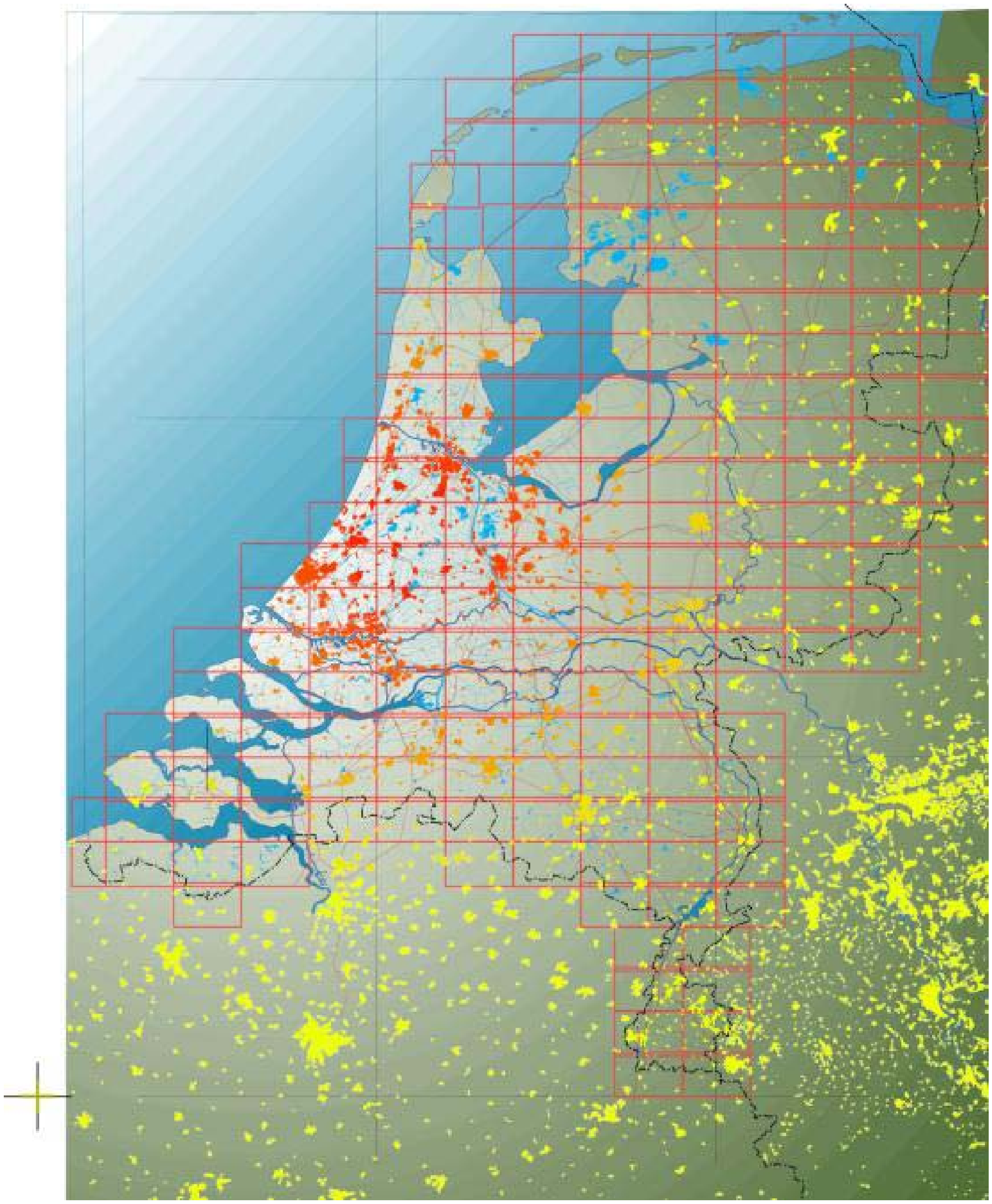


*Fig. 500 Subdivision of topographical maps 1:50,000*

<table>
<tr><td rowspan="2">25 west</td><td rowspan="2">25 oost</td><td>25A</td><td>25 B</td><td>25E</td><td>25 F</td><td rowspan="2">25 AN<br>25 AZ<br>25 CN<br>25CZ</td><td rowspan="2">25 BN<br>25 BZ<br>25 DN<br>25 DZ</td><td rowspan="2">25 EN<br>25 EZ<br>25 GN<br>25 GZ</td><td rowspan="2">25 FN<br>25 FZ<br>25 HN<br>25 HZ</td></tr>
<tr><td>25 C</td><td>25 D</td><td>25 G</td><td>25 H</td></tr>
<tr><td colspan="2">1:50,000</td><td colspan="4">1:25,000</td><td colspan="4">1:10,000</td></tr>
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*Fig. 501 Coding of related maps on different scales*

### 4.8.2 Fields of map research
Map research encompasses a range of applications.
The following applications are usually carried out using topographic maps:
- Urban land use such as
- Built up area
- Traffic area
- Urban green area
- Commercial area
- Industrial area
- Combined area (dwelling and industry)
- Historic area
- Physical constraints

- Land use such as
    - Urban or built-up land
    - Agricultural land (crops and meadows)
    - Rangeland
    - Forest land
    - Water
    - Wetland
    - Barren land
    - Tundra *
    - Perennial snow or ice *

- Physical constraints
    - Water
    - Wetlands or marshes
    - Slopes
    - Snow and ice*

* not found in the Netherlands.

Other maps such as soil maps, geomorphologic maps and geological maps use the topographic map as their basis. On this basis the information collected by research in the field and specific knowledge on this field of study is represented in a map. These maps provide information on:
- Soils
- Bearing capacity of the soil
- Depth of the water table
- Water capacity

- Natural hazards (combination of geomorphologic and geological maps)
    - hazards from landslides
    - flood hazards
    - earthquake hazards
    - volcanic hazards

Historical maps serve two purposes: to register historic monuments or features, and to identify the development or growth of for example cities. Changes to the parcelling-out of the countryside are also examined. Different types of data are deployed for development and change maps. The registration of monuments on a map is based on field research on the one hand, and the study of historical maps and documents on the other.

### 4.8.3 Research methods
Map-based research encompasses the study of inventories and source material, as well as more conventional research methods such as describing, comparing, evaluating and identifying problems. Instead of maps, we can also use remote sensing images such as aerial photographs and satellite images.

Research comprises the following activities:
- choosing of research topic

- compiling maps and / or remote sensing images.
- scaling material by reduction and enlargement[a]
- examining maps and remote sensing images
- interpreting forms
- comparing forms
- incorporate the conclusions of the study, be it in the form of a map or not

The research topic determines the name, the contents and the legend of the newly generated map. Normally, topographic maps are used as base maps, because these maps are regarded as an objective representation of reality.

### 4.8.4 Morphological research

In order to obtain knowledge of an area with regards to the position and the structure of buildings, landforms, infrastructure, parcelling-out, distribution of elements etc. morphologic research is carried out. Maps and remote sensing images are frequently used when carrying out a town planning survey, as the emphasis of this research lies on space and especially on the elements that form or determine space. The distribution, form and direction of space and space-forming elements play an important part during the analysis.

The key questions of this research are:
- Is the form of the space sheer coincidence?
- Have form and space-forming elements, and the position of these space-forming elements, been influenced by certain circumstances?
- To what extend has history influenced the current shape of a town, village or landscape?

A number of forms are the result of historical events and geomorphologic processes. Building techniques and legislation also play an important role.

Palmboom's research into landscape and urbanisation between The Hague and Rotterdam (1990) is an example of morphologic research. The purpose of the analysis was not only to describe in words the character of the area, but to explain the forms of the area by using maps. By using a large number of maps it is made clear how the area is formed and what the area looks like. In short: how the form of the area can be explained. The study encompassed the following aspects: (small) height differences, parcelling forms, subsoil and geomorphologic landscape forms. The aspect of time is presented in a series of historical maps. Irrespective of how insignificant these aspects of space and time appear, all have had an effect on the present landscape. Palmboom uses his research results not only to draw comparisons with the present situation, but also to identify potential future developments. According to Palmboom, the aim of the analysis is "to find possible starting points for design proposals in the current situation, which can assist in directing a gradual, lengthy and partially unpredictable process of change".
Similar research was carried out by Buro Maas for the Province of Zuid Holland "An image of the Zuid Hollands landscape" (1984)
See Moens(2002) for other examples.

### 4.8.5 References to map research

Maas, Bureau (1984) An image of the Zuid Hollands landscape (Breda) Assignment of the Province of Zuid Holland
Moens, M.J. (2002) Map research in: Jong, T.M. de; Voordt, D.J.M. van der (2002) Ways to study urban, architectural and technical design (Delft) DUP Science
Palmboom (1990) …

http://www.bk.tudelft.nl/urbanism/TEAM/Databases/

a Please note: information contained on maps is unaffected by enlargements.