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URBANIZATION AND WATER MANAGEMENT

TNO

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URBANIZATION AND WATER MANAGEMENT

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URBANIZATION AND WATER MANAGEMENT

W.A. SEGEREN

1. INTRODUCTION

On May 4th 1977, a symposium was held at Lunteren, Netherlands, that had been jointly organized by TNO's Committee for Hydrological Research, the Netherlands Association of Water Boards and the Netherlands Institute for Directors and Engineers of Municipal Public Works Departments. The symposium's central topic was: Relationships between urbanization and water management.

Some of the motives leading to the organization of this symposium may be summarized as follows:

- Hydrologists, in the Netherlands and elsewhere, have these last few years been intensively concerned with the effect that urbanization particularly has on the relation between precipitation and drainage matters. The hydrologists' efforts begin to yield results.
- Increased attention to environmental requirements has triggered developments in the design and construction of sewerage systems, which havestill to take some definite shape. There is no consensus yet on "combined" or "separate" systems of sewers nor on their possibly improved variants.
- Town-planners more and more try to include the open water in their field of action, thus to use the "ever-lively" water as an agent for embellishment and, also, as another recreational facility next to sand boxes, and play grounds or solariums in residential areas.
- However, open water in a town is an expensive issue in view of the bridges, campshedding, conducts for cables, pipes and sewers plus reroutings of road traffic that are involved. Construction investments and maintenance costs are high.
- Level control for open water in urbanized areas is highly complex and its consequences also relate to soil-setting and, accordingly, repairs to roads and sewerage systems. It moreover effects the lifespan of timber pile-foundations. Open water in a town must be connected to some ditch in or reservoir-canal around a polder, or to a brook or river. That connection can be either an open one, or it is one effected by means of a weir or pumping station. Finally, the open-water level directly affects the height as which bridges, etc. have to be over the water surface.

This complex range of factors often induces conflicts between the town-builder, i.e. the municipal authority, and the manager of the water outside the town, i.e. the water board.

A further practical reason for convening this spring 1977 symposium was its affinity to a future congress.

From October 2nd to 7th, 1977, Amsterdam will be the venue for an international congress that Unesco organizes within the framework of the International Hydrological Programme; the theme is: "The effects of urbanization and industrialization on the hydrological regime and on water quality".

This international autumn 1977 congress chiefly aims at an exchange of research results and at inter-attunement of novel modes that research must adopt in the near future.

The spring symposium, the introductory papers of which have been printed in the H_2O-journal in their original Dutch version, was not held for the sole benefit of hydrologists and specialists in the field of water quality; it was also organized to suit, and actually focused on, the interests of directors and engineers of municipal public works departments and engineers of water boards. Those papers which are here presented in translation, hopefully give a general survey of the present situation of pertinent research in the Netherlands.

2. BRIEF DESCRIPTION OF PROBLEMS

The precipitation in urban areas is removed in a way which differs from that applying to rural areas. Therefore, the very water management of urban areas may be lifted from the overall hydrological systems as an individual set of problems. Rain and snow, etc. falling on such hardened surfaces as roads, footways, roofs and so on will largely be removed through the sewer systems.

This precipitation, in the case of a "combined" sewer system, is likely to cause overflow into the open water and, when drainage is effected with a "separate" system, overflow or discharge into that water.

The dimensions required for a sewer system, and those for the open water concerned, are determined by the following factors:

a) the probability of precipitation;
b) the delays, deformations and changes occurring in the process of discharge, right along its route;
c) the stipulations laid down by municipal and water authorities with regard to discharge facilities and water levels;
d) the ratio between impervious and pervious surface.

Over recent years, understanding of the disposal of precipitation in urban areas has greatly advanced thanks to improved input of data on rainfall etc. in calculations, and because of measurement of changes during the discharge process, and mathematical models developed to describe the relation between precipitation and discharge. The papers deliverd by Ir. Slijkoord and Ir. Wiggers supply details on this progress.

In combined sewer systems, precipitation polluted by its contact with roads and streets is mixed with domestic waste-water. Upon overflow and discharge, dirt thus drifts into the open waters of town and countryside. Knowledge of the volume of this refuse means a first step towards pertinent pollution control. Models help to gain further insight, and Ir Wiggers' paper elaborates related aspects.

Groundwater in urban areas had so far hardly beeen devoted expert attention to, in spite of town-builders' experience that high groundwater levels may generate major problems in terms of practicableness of building sites and with regard to cable- or pipe-layings.

After the building operations, high groundwater levels are found to effect the maintenance of roads. Changes in those levels may then generate soil-settlement or, through processes of percolation or subsidence, cause impermissible changes in groundwater-levels in adjacent areas. The paper offered by Ir. Kremer and Ir. Schultz gives further details.

3. THE FUNCTIONS OF OPEN WATER

The most vital function of open water is that of collection and discharge of superfluous precipitation. In a largely flat country, as the Netherlands, inherent requirements particularly bear on the aggregate volume of open water that is available in urban areas in order to decrease peak-discharge by temporary storage, and control of the level fluctuations in those areas within acceptable limits.

The water boards generally specify what requirements the discharge capacity shall meet, lest progressive urbanization raises peak-discharges to volumes that cannot be tolerated. Quantitative studies have helped to evolve methods and rules for pertinent calculations.

The groundwater must be allowed drainage at an appropriately low level. Accordingly, studies on groundwater phenomena, along with costs for infra-structure and sewerage, are decisive for establishing the optimum water level in city-canals.

There may well be other functions for open water in a town or village. Such functions are generally recreative in nature, or separative. They may also relate to balanced ecology, transportation features, and aesthetics. All these functions combine to impose certain requirements which the designers and planners of open waters are to take into account.

The recreative features of open waters, in urban areas particularly, relate to fishing, boating and floundering.

Fishing water involves qualitative demands, especially as regards oxygen content.

Discharge of only few pollutants is permissible, and mating grounds for the fish should be available. Though different species have different needs for mating grounds, their requirements may be generalized in terms of shallow, sheltered, plant-grown parts in those open waters. Little is yet known about the area of such water stretches that fish actually needs. The open water should also have rather deep parts for hibernation of the fish. In this context, some interconnected stretches, jointly covering about 5% of the water surface and with depths of over 1.50 m, are essential. Finally, to suit the fishermen, the water banks should be accessible.

As regards boating, the categories of vessels must be known for which the urban waters are to be navigable. Even for moderately sized motorcrafts, the depth should anyway be 1 metre at least. The bridge-height will have to be between 2.25 and 2.75 m. Campsheddings, berths and moorings will have to be provided and maintained. The water quality must be of a proper level and there will have to be means to reach the waterways outside the urban area, either through open connections between those and the town's open waterways or in terms of sluices to be installed. In the former case, the extent to which the water levels in the non-urban waters are exceeded must be permissible for the urban open waterways. And, in the later case, the high costs for the building and maintenance of sluices will have to be taken into account.

For recreative floundering purposes, a high water quality is of the essence; the water shall meet the requirements for open swimming water.

They are laid down in the Interim-report on Swimming Water issued by the Dutch Committee for Surface-water quality (1973), and in the Directive of the Council of European Communities on the quality of swimming water.

Furthermore, special care should be taken in smoothing and clearing the banks and bottoms of the water stretches in question. Their depth will have to be moderate so as to minimize downing risks. In practice, it will only under exceptionally favourable conditions be feasible to obtain open water of a quality suitable for swimming water. This pre-eminently relates to the water's bacteriologic quality and transparency.

Open waters often serve to separate industrial sites from residential districts, and motorways, etc. from such districts. The requirements then to be met are limited; minimum depth: 0.75 m, minimum water width: 1.50 m.

The natural or ecological function of open water can be considered as regards two major aspects. One is that open water may be used to inject certain elements of nature into the urban picture. The natural flora will be the richer, the more gradients from "wet" to "dry" are established. As regards the fauna, the change-overs from rural to urban districts may be considered. Rules and norms cannot easily be given; solutions will have to be found from case to case, in collaboration with biologists. Another natural function of the open water is its very effect on water quality. Research has shown that rushes or reeds in open waters benefit water quality. The water's "residence period", i.e. period of presence, the area of stems of reeds and rushes, plus the nitrogen and phosphate consumption make that, chemically and bacteriologically, the quality of surface water greatly improves with the occurrence of flora, especially in the period of growth.

In that period of growth, about 70% of the overflows from mixed sewer systems take place and the "residence time" required indicates that per ha of impervious surface some 25–30 m^2 of thus overgrown town-water are needed to achieve some considerable qualitative improvement in the water of those discharges. Such reed-patches with their function of flow-through can easily be made in urban areas; they are technically simple, and inexpensive. Further research will probably yield adequate solutions.

Finally, open water's aesthetic function is of interest; open waters tend to liven up the overall picture presented by a town or village.

The pertinent requirements cannot easily be generalized. Though they differ from situation to situation, such things as width of watersheet, and variety in that width, the gradient of the side slope – from vertical to gentle – and the distance from soil surface to water surface certainly are constituent factors. The designer and planner of these waters, however, will have to be allowed as much liberty as feasible within the scope inherent with other functions.

Many of the functions outlined above will have to be simultaneously attributed to one and the same open water. At the planning and design stage, they will be the norm-package generating from various functions to be reckoned with. Actually, since several of those functions are not inter-compatible, some zonal approach is desirable in urban open waters.

4. WATER MANAGEMENT AND MAINTENANCE IN AND AROUND TOWNS

Water that is to serve a plurality of functions by definition calls for maintenance and control that are commensurate with those functions.

Accordingly, various legal and technical problems are involved; the interests of the different categories of users of open waters often conflict. To round off the picture of water management and urbanization in the Netherlands, Ir. Van der Vliet's paper reviews Amsterdam's water management and Ir. Dragt's contribution relates to the qualitative and quantitative problems of Dutch water authorities.

Further to the functions of open waters, as described above, I would add a few words about their maintenance. For a system of town-canals to warrant a certain discharge capacity it is essential to regularly mow off the water-plants growing in them. This should also be done, when these open waters are used for boating and recreative floundering.

A canal with that kind of vegetation intact, however, is generally more attractive visually, it is a more active contributor to improved water quality, and a richer fauna results. As regards maintenance, too, conflicting interests are observable. Another consideration is that because of the regular mowing of water plants, the variety in surviving plants will be poor, if any, whereas occasiional mowing – e.g. once only, in autumn – tends to stimulate a water flora that is rich in species.

This incompatibility of procedures in the maintenance of urban canal systems likewise leads to the zonal approach described above.

5. RECOMMENDATIONS

From the preparations for the symposium, and from its papers and discussions, a number of recommendations may be derived which can improve the water management in urban areas. These recommendations in part relate to the application of existing knowledge in the design and maintenance of water in urban districts, and partly to the signalling of deficiencies in knowledge and the necessity of further research.

A general finding is that the available knowledge in the field of water management for urban areas is tardily introduced in the planning and design of residential districts. As a result, technically difficult and expensive solutions to inherent problems must be implemented, while opportunities for the creation of interplay between original situation and design are used too little. It is recommended to invite the assistance of experts on water management matters in the very earliest stages of planning.

The management and control of the groundwater in Dutch urban districts is inadequate. For its proper management, two types of arrangement should be evolved. Firstly, a statutory regulation will have to be established which clearly defines who is the responsible body for the management of groundwater in an urban district. Secondly, to achieve adequate control, the knowledge should be extended of the levels, fluctuations and quality of groundwater in urban and urbanized areas. TNO's Groundwater Survey is the appropriate body to collect pertinent data, in collaboration with municipal departments.

To warrant efficient management and control of urban waters, intensified research is indispensable. To pinpoint the research programme, and to enable its implementation, it is recommended to establish a framework for joint consultation of municipal public works departments, water authorities and water-management experts.

The available knowledge in the field of properties of sewer systems should be extended through interdisciplinary investigations.

Along with the hydrologists, who – together with the hydraulics experts – have largely thus far acquired and supplied the present knowledge and know-how, other disciplinarians ought to take an active share in the research and development activities. In this context, water-quality experts, ecologists and economists are to be recommended for such participation.

The symposium revealed divergent opinions on the necessity, or otherwise, of further studies on the relationships between precipitation and discharge of effluents, etc. It is recommended to subject this problem to further critical analysis, within the scope of international issues, at the congress which the Unesco has scheduled to be held in Amsterdam, 2nd through 7th October 1977, on: "The effects of urbanization and industrialization on the hydrological regime and on water quality".

CONSEQUENCES OF URBANIZATION IN RELATION TO THE QUANTITATIVE ASPECTS OF DRAINAGE

F. SLIJKOORD

SUMMARY

One of the consequences of urbanization is the care of an adequate system. Roughly there are two important aspects to this problem.

The first one is the formulation of demands that must be made upon (combined) sewerage systems with respect to the fun-off within the sewerage area and the discharge (overflow) in the rural surroundings of the area in question.

The second one is the hydraulic problem of the propagation of discharge-waves into the receiving open water.

For organizing reasons the hygienic problems that are connected with this matter are left out of account in this context.

A survey is given of the methods that are employed in the Netherlands for judging the discharge of sewerage systems and open hydraulic systems: permanent flow model and reservoir model. Attention is drawn to the possibilities and the limitations of these models, and it is shown in what way this may effect the evaluation. It is suggested to put these models on trial by taking measurements on sewerage systems. A survey is given of the measuring programs that are – at present – carried out in the Netherlands.

1. INTRODUCTION

1.1. *General*

One of the consequences of urbanization is the care of an adequate drainage system. It concerns the discharge of waste-water of domestic and industrial origin and rainwater run-off from an impervious area. This water is drained away through a system of conduit-pipes (and construction works) usually under ground: the sewerage system. In practice waste-water and rain-water are sometimes drained away through the same sewerage system, sometimes through separate systems.

In the former care we are dealing with a so-called "combined" sewerage system, in the latter we are dealing with a "separate" system.

In the Netherlands the combined system is the most usual one. If henceforward a sewerage system is mentioned, the combined type is always meant.

Two important functions are ascribed to the sewerage system:

1. The discharge of water to a waste-water-treatment-plant (transportation function).
2. The storage of water if, as a result of precipitation, the discharge to the waste-water-treatment-plant is much larger than the capacity of the sewerage pumping plant (retention-function).

One of the demands made upon the sewerage system by Dutch municipalities is that the discharge of water must take place without water running into the street.

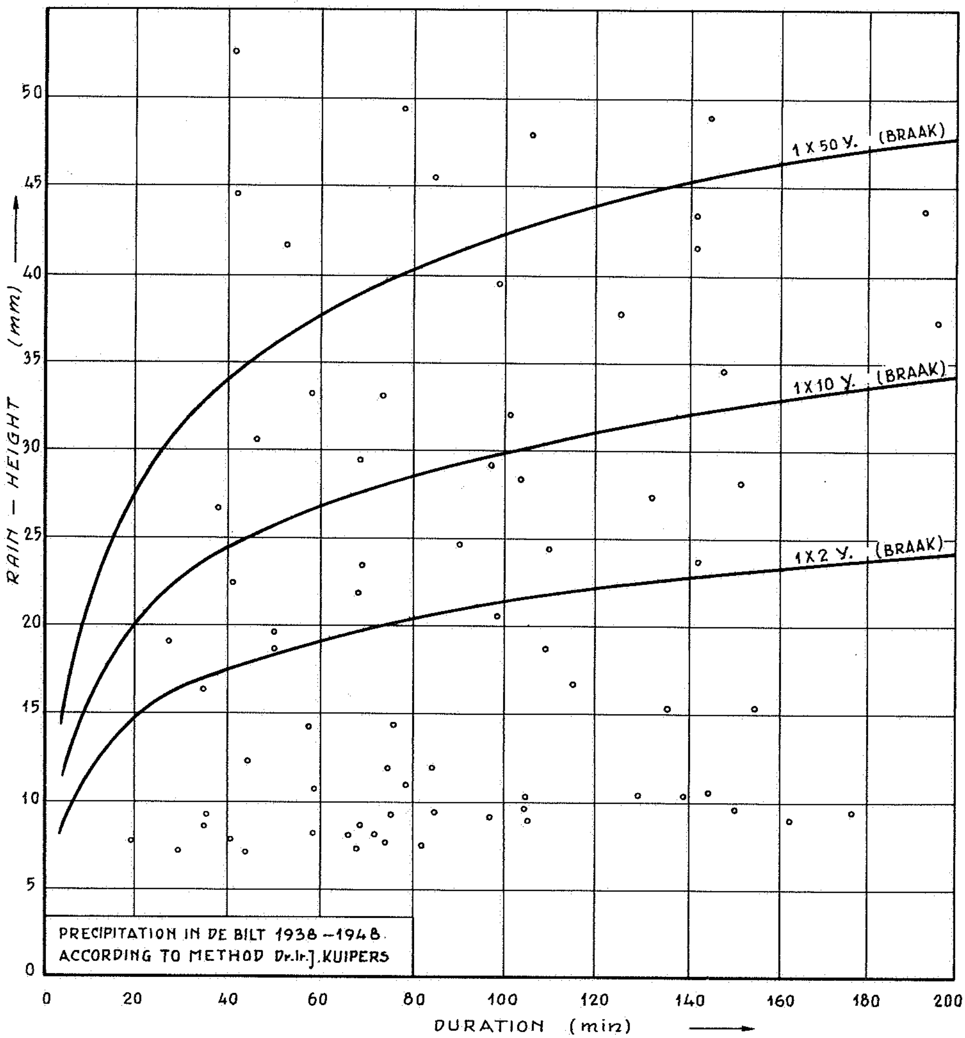

Fig. 1 Schematic representations of rain-registrations and of rainfrequency curves.

This is a problem of the dimensions of the sewerage system. The basic datum for the design of the sewerage is the precipitation in the area that must be sewered. Precipitation is an extremely capricious, and uncertain natural phenomenon, both in time and in place. If one wants to give a reasonably reliable judgement upon unreliable matters it is necessary that registrations of precipitation are statistically worked up. Consequently, for years on registrations of precipitation must be made. These registrations are obtainable from the Royal Dutch Meteorological Institute (KNMI) at De Bilt.

The most simple statistical observation is restricted to the height and the duration of each individual rainy spell.

In Fig. 1 these rainy spells are represented by dots. With the help of statistical methods a distribution has been found. In Fig. 1 this is indicated by a number of curves of various frequencies, the so-called "rain frequency curves".

Each rain frequency curve envelops all rains which occur with certain reliability with a frequency of that curve. This work is the merit of Kuiper, Braak, Reinhold, and others [3].

Knowledge of precipitation in successive periods is essential for the description of the discharge processs. Consequently not only the periods of precipitation must be examined, but also the dry intervals. For this purpose statistical operations have been carried out on year-long sequences of registrations of the precipitation in successive periods of 5 minutes. In such "timeseries" a precipitation of 0 mm is given for each period of 5 minutes in dry intervals.

Statistical operations have been carried out on these timeseries, in the course of which (various kinds of) rain frequency curves were calculated. This work was done by Levert, Talsma, v. Kregten, v.d. Herik and Kooistra: [3], [5], [6], [8] and [9].

1.2. *Feasible design criteria*

Considering the rain-statistics of the Dutch climate it is obvious that it is practically impossible – on account of extravagant expenses – to design a sewerage system that has an adequate capacity for discharge and storage under all circumstances. Therefore the following conditional design criteria are formulated with respect to a sewerage system:

- a transportation capacity, based on the discharge of waste water in dry spells and on the run-off from a "design-rain" of sufficiently low frequency.
- a storage capacity being too "inadequate" several times a year. The water that cannot be stored any longer is drained off by overflowing, without purification, into the surroundings of the urban area.

1.3. *Consequences*

The consequences of such a management are that

– inundations in the urban area must be taken into account. The estimation of the average frequency depends on the frequency of the chosen design-rain.
– the open water in the rural surroundings of the urban area will be polluted by peak-discharges of overflow water.

This causes problems of

– a hydraulic nature, such as inundations and subsidences behind weirs, and of
– a hygienic nature: pollution.

The two last-mentioned aspects are indissolubly linked up together. For reasons of organization only the hydraulic problems are here discussed.

1.4. *Aspects of administrations*

Various official bodies in the Netherlands are entrusted with the responsibility for the control of the discharge and the quality of surface water. The municipalities have control of the sewerage systems; the open water of the rural areas is controlled by the Provinces (delegated to water-boards and/or purification water-boards) or by the Government (delegated to Public Works.)

When the Pollution Surface Water Act (Wet Verontreiniging Oppervlaktewater = V.W.O.) had come into operation in 1972, these administrative aspects were regulated.

For every discharge of water from the urban area dispensation must be granted by the proper authorities. Moreover, absolute limits are set to the annual maximum of the overflow-frequency and the maximum quantity of overflow-water. Everything calculated in accordance with a method of calculation previously agreed upon (see "Water boards and urban development areas", Dragt).

1.5. *Definition of the problem*

Roughly speaking, the consequences of urbanization regarding drainage can be reduced to two related problems, namely the assessment of

– the transportation capacity and the storage of the sewerage system. The criteria for this can be deduced by relating the characteristics of the sewered area with those of the precipitation.
– the transportation capacity of the system of open channels in the rural surroundings of the urban area.

2. EVALUATION OF THE WATER-DISCHARGE SYSTEMS

2.1. *The transportation capacity of the sewerage system*

The transportation capacity of an existing, improved or newly designed sewerage system is assessed by calculating the watertable in the wells of the system as a result of a design rain of a constant intensity of 60 to 100 l/s ha) on the impervious area in the catchment. In this case the boundary value for the calculation is imposed by the watertables in the discharge points.

Inundations are traced by comparing the waterlevel and the streetlevel in each well (node).

In calculating this it is assumed that the flow in the sewers is staionary and uniform: permanent flow. Computer programs have been developed for this model of "permanent flow" [3].

2.2. *The storage capacity of the sewerage system*

The storage capacity of the sewerage system consists of two parts:

- the content of the sewerage system below the level of the lowest crest of the overflow: the "below-crest-storage" (S).
- the product of overcapacity of the sewerage pumping plant (P_{oc}) and the duration of the pumping.

The below-crest-storage and the overcapacity are related to the impervious area of the sewered area. In the dotted graph of Kuipers (Fig. 1) they are chosen in such a way that

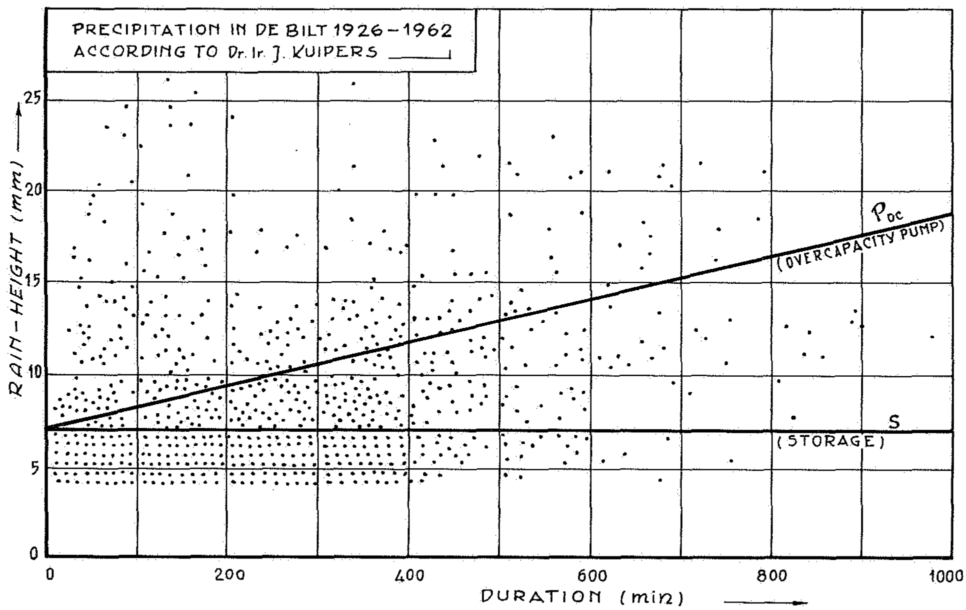

Fig. 2 Dotted graph of Kuipers with the "total" storage of a sewerage system, related to the surface of the impervious area.

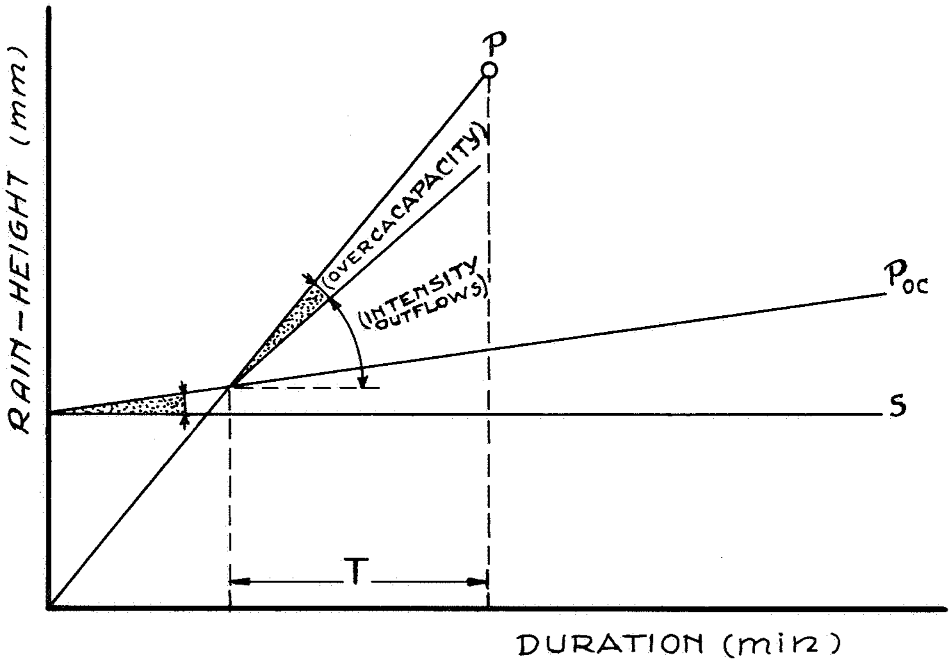

Fig. 3 Overflow duration, T, of a precipitation, P, of constant intensity for a sewerage system with below-crest-storage, S, and overcapacity, P_{OC}.

the number of rainy spells that leads to an overflow does not exceed the desired number per annum on the average (6 to 10 times), see Fig. 2.

We are in fact dealing with a water balance for the storage and overcapacity of the present system, on the basis of the precipitation fed to it.

The sewerage system has been simplified in terms of "reservoir" with a content similar to the below-crest-storage and a leak, the size of the overcapacity of the sewerage pumping plant. This representation of reality is called the "reservoir model" [2].

Comment: The overcapacity of the pumping plant is measured in such a way that the entirely filled storage can be pumped dry in approximately 10 hours.

2.3. *The discharge capacity of the system of channels of the open water*

It is also customary to assess the discharge capacity of a system of open channels with the permanent flow model. In principle the same procedure is followed as with the evaluation of sewerage systems. In this case the indirect feeding consists of the output of overflows.

If the urban area has one overflow, the output is estimated from the impervous area and the overcapacity of the sewerage pumping plant, and the average intensity of the chosen design rain.

Should there be more than one overflow, the output of the various overflows is calculated with the help of the model of permanent flow for the sewered area.

In both cases the duration of the overflow (T) is estimated according to the reservoir model, see Fig. 3.

3. VALIDITY OF THE MODELS USED

3.1. *Permanent flow model for sewerage systems*

For the calculation of the discharge capacity according to the permanent flow model, a stationary flow in every sewer is assumed.

With a constant intensity of precipitation this situation will only be attained with extremely long periods of rain.

All this also depends on the characteristics of the sewered area.

Apart from the fact that "design-rains": 60–100 l/(s ha), of such a duration hardly ever have a constant intensity in reality, they only occur with very low frequencies according to the 5 min.-analysis, see Fig. 4.

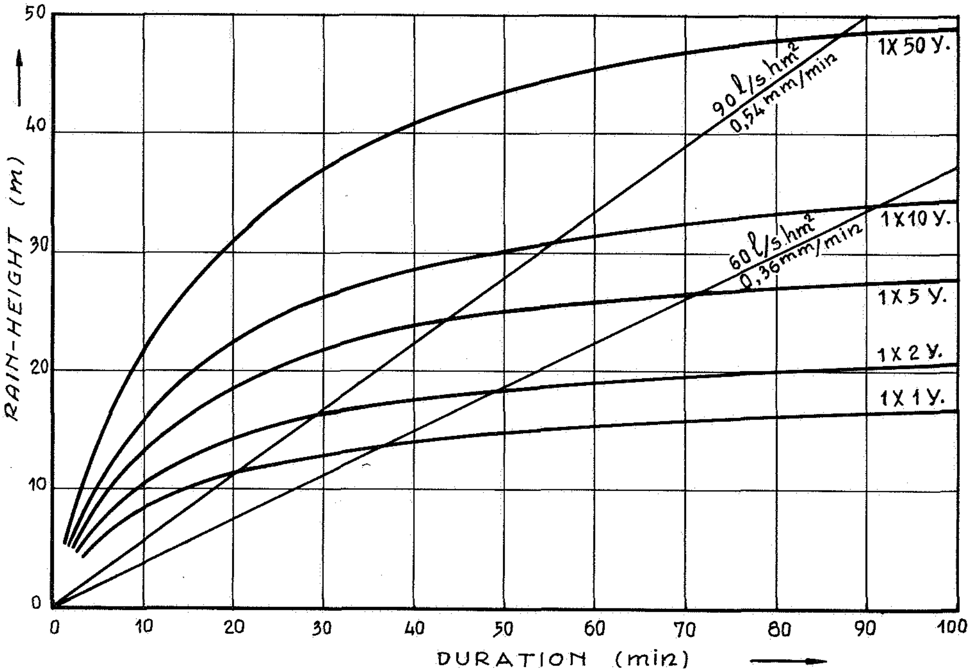

Fig. 4 Rain duration and frequency of design-rains of constant intensity, according to the 5 min.-analysis.

Actually sewerage systems are evaluated (and designed) at relatively low statistical frequencies. In other words, the sewerage system meets the requirements more often than had been assumed at the outset.

The chance that the discharge will stagnate is smaller as the (average) intensity of the precipitation is chosen larger.

3.2. *Reservoir model for sewerage systems*

At the time when the reservoir model was evolved, the following assumptions were made:

- the intensity of the precipitation is constant in time and place (throughout the entire area);
- the inlet-hydrogram is identical to the pluviogram; in other words all precipitation falling on the impervious surface is without transformation discharged to the storage;
- the overcapacity of the sewerage pumping plant is constant in time, independent of the elevation head. Directly when the precipitation starts, the sewerage pumping plant comes into operation, and
- the below-crest-storage is entirely available when the precipitation starts. See [2] and [3].

Certainly all these assumptions form a schematic representation of reality. One of the most important objections against the present reservoir model is that no attention is paid to the transformation of the precipitation into discharge: run-off from the impervious area and flow through (part of) the sewerage system. The model used at present is not more than a zero-order system, whereas it is in fact a system of the first order or a higher one. In consequence of this the statistical distribution of the discharge is – generally speaking – not equal to the distribution of the precipitation.

3.3. *The permanent flow model for open channels*

The evaluation of the discharge capacity of a system of open channels with the help of the permanent flow model will only be realitic in a limited number of cases.

Fig. 3 has already shown that the duration of an overflow is shorter than the duration of the design-rain. For reasons mentioned above, in reality both the duration and the intensity of the overflow will largely differ from the calculated values: transformation of precipitation into discharge, and not constant intensity of long-lasting precipitation. On the basis of these considerations, in many cases the situation of permanent flow will not be reached in the receiving water either. It appears that it is useful in those situations to calculate with "peak discharges" from the overflows, spreading into the system of channels of the open water: non-permanent flow model. Computer programs have been developed for these calculations.

The time-dependent overflows are introduced into this model as lateral inflows for the system of open channels.

The characteristics of the overflows (intensity and duration) are estimated from the chosen design-rain on the impervious surface of the sewered area in question, see 3.2.

In order to derive a determinative discharge for the open water a sensitivity-analysis must be carried out beforehand. Therefore, for various design-rains on the impervious area, the characteristics of the overflows are estimated. The system of channels in question is evaluated for the lateral inflows from each rain in succession with the help of the model of non-permanent flow.

In order to minimize the calculation time the considered system is stripped down to its most important part with respect to the propagation of the discharge waves.

Determinative are those overflows which give rise to the highest waterlevels in the channels. Finally the most critical overflow is calculated once more through the entire system.

In practical situations the discharge capacity of a system of channels and construction works is generally assessed to be larger with this model than on the basis of the calculation with the permanent flow model. This is caused by the fact that in the non-permanent flow model the temporary storage of the system is reckoned with.

The results of such a calculation of part of a system of channels is given in Fig. 5.

Obviously, in the upstream sections the output changes its direction as the brook gets filled up in the long run, because of the pressure generated by the culvert.

3.4. *Concluding remarks*

About 1965 Dutch advisory agencies and local authorities made inquires into possible differences in their methods of evaluating sewerage systems. For this purpose the sewerage system of one and the same object, Tuindorp-Oostzaan, was calculated throughout. It was put on record that similar results showed a deviation of a factor of 2 [12].

An identical example is known from a test-object in Western Germany.

4. TRIAL OF THE USED MODELS IN PRACTICE (HYDROLOGY OF URBAN AREAS)

The objections against the models used at present are not new. They were already recognized by those who have contributed to their development [4], [11] and [13].

For a variety of reasons various authorities are interested in putting the highly schematized reality of the models to the test. For that matter, measuring programs for urban hydrology have abroad already been in progress for years.

In Table 1 a survey is given of those in the Netherlands who are engaged in the hydrology of urban areas.

Fig. 5 Course of the calculated waterlevel in a brook as function of time, as a result of the time-dependent indirect feedings into discharge points.

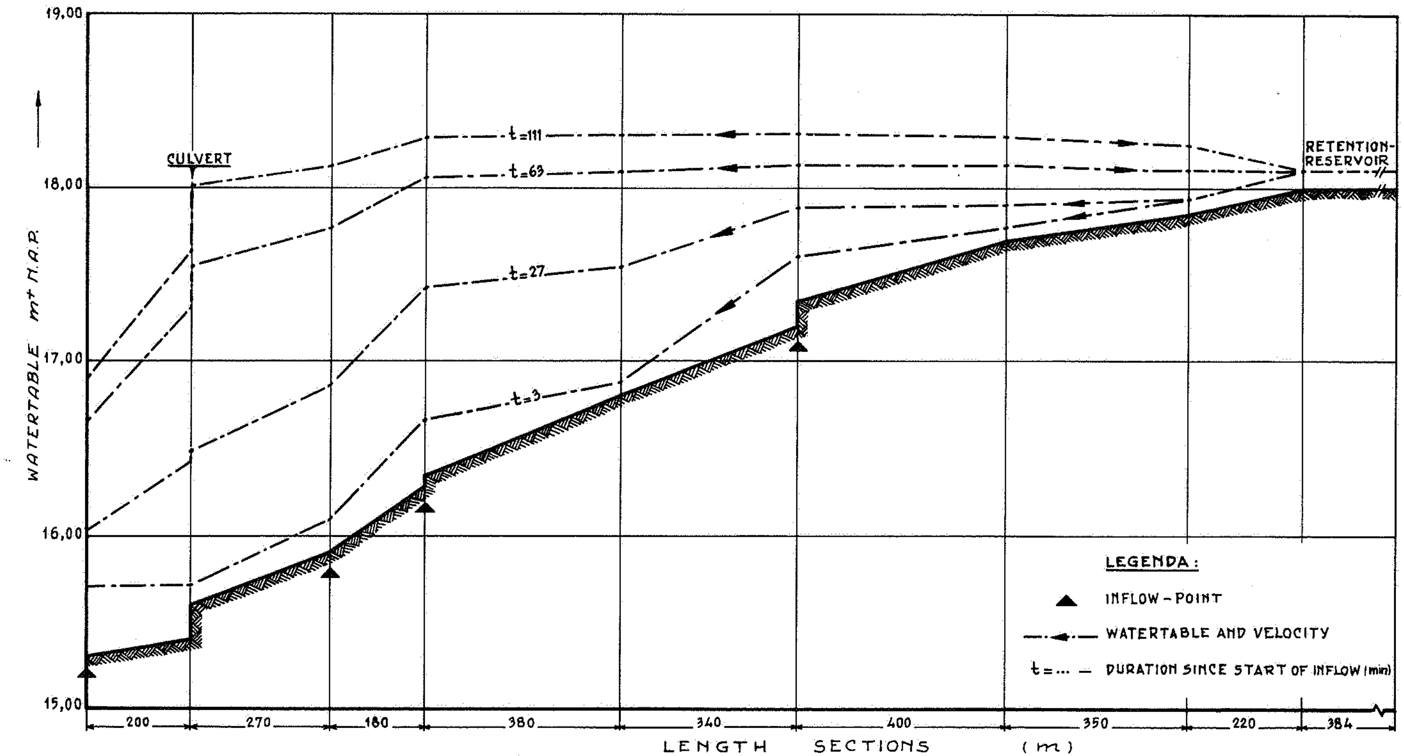

Table 1 Survey of measuring projects for urban hydrology in the Netherlands

Official body	Project
IJsselmeerpolders Develop-Authority (Rijksdienst voor de IJsselmeerplders = RIJP)	1. Lelystad: inlet-hydrograph of streets, squares and flat roofs, and the level of 2. Biddinghuizen: overflow frequency 3. Swifterbant: the same
University of Agriculture at Wageningen, Dept. of Hydraulics and Catchment Hydrology (LH-W)	1. discharge measurements of flat roofs and streets of different surfaces 2. discharge measurements in sewers of various residential quarters (Ede, Enschede)
Provincial Public Works of Gelderland (Provinciale Waterstaat van Gld. = PWS)	Groesbeek: discharge measurements of a sewered area, with combined sewerage system
Heidemij Nederland (HN)	Neede: measuring discharge from precipitation in combined sewerage system of a village of approx. 9.000 inhabitants on an impervious area of approx. 60 ha

With the help of some of the most important measuring results an impression is given of the progress of the investigations as far as it is known. More detailed information about the objectives of the investigations, the measuring program and the measuring equipment, the results, etc. are obtainable from the above-mentioned official bodies.

RIJP

With an empiric relation a "net" precipitation is deduced from the registered "gross" precipitation. The net precipitation is worked on with the reservoir model. With one and the same storage and overcapacity of the pumping plant, the calculated overflow frequency is for the net precipitation a factor of 2 to 2.5 lower than for the gross precipitation [1], [2] and [4].

LH-Wageningen (Dept. of Hydraulics and Catchment Hydrology)

The stress of the investigations lies on the formulation of a run-off model [10].

PWS-Gelderland

No results are available so far.

Heidemij Nederland

Primarily the investigations have been focused on the evaluation of the gauged area and the practical reliability of the equipment [7].

In view of the character of the sewering system the following two categories of registrations are worked out in succession: those preliminary result is that the discharge on dry days is dependent on:

- the time of the day;
- the day of the week (kind of day);
- level of the phreatic surface with respect to the position of the sewers.

5. CONCLUSIONS

1. The traditional models for the design and evaluation of sewerage systems in the Netherlands can be characterized as follows:
   - a pronounced schematization of reality,
   - the absence of practical testing and
   - a difference of at most a factor of 2 in the results of the calculation of similar models, if carried out by various advisory agencies and municipalities.

2. One gets the impression that, compared to practice, the above mentioned models predict a higher frequency of the occurrence of overflows and inundations of the sewering system. With respect to the overflow frequency, the preliminary results of measurements seem to confirm this statement [1].

6. RECOMMENDATIONS

The permanent flow model and the reservoir model can be improved by taking the discharge of precipitation in a sewered area into account.

As a result of the variety of factors affecting the discharge, a hydrologic approach to the entire area is significant for its sewerage system. The aim of the investigations should be focused on finding (possible parameters for) the descriptions of the way of discharging.

Then, time series of precipitations can be transformed into those of discharges, and next, a statistical analysis must follow. For an evaluation of the influence of overflow-water on the fluctuations of the open-water quality, the aspect of the quality of the overflow-water should also be included in the proposed measuring program for urban hydrology.

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IN WHAT WAY IS WATER POLLUTION INFLUENCED BY SEWERAGE SYSTEMS?

J.B.M. WIGGERS

SUMMARY

A sewerage system is defined and the sources of pollution are described. The relationship between the amount of pollution and the hydraulic design criteria is then outlined.

It is shown that in flat, to slightly undulating areas, the efficiency of sewer networks can be improved and their costs reduced without the need for detailed hydrological investigations.

A simulation model of the pollution discharge is presented and some of the results are discussed. One of the findings, which has to be verified by measurements, is that a combined sewer system can be as effective as a separate system in relation to surface water pollution.

It is stressed that it is of the utmost importance to define the quality of surface water required in a much more accurate way than is done at present, in order to be able to choose the optimal solutions for pollution abatement.

It is clear that more research is needed.

1. A sewerage system is made up of interconnected installations which have the function of making pollutants present in waste water harmless.

The operations involved can be classified as follows:

- collection (drainage of buildings and sewerage);
- transport (trunk sewers, pumps and rising mains);
- treatment (sewage treatment plant, retention and settling tanks);
- discharge (surface water).

The object of this report is to show how drainage systems influence the quality of surface water. In addition, it will be shown how far future hydrological investigations can increase the understanding of the mechanisms involved.

2. A drainage system pollutes surface water in the following ways:

- by the discharge of effluent;
- by overflows from combined sewerage systems;
- by direct discharge of rainwater from separate sewerage systems

Apart from the sewerage system, surface water is contaminated by other sources of pollution such as agriculture, diffuse discharges, certain ecological processes and, for example, natural loading with leaves, etc.

This contribution is confined to the effect of sewerage systems on the quality of surface water.

3. Drainage systems have as their aims:

- the removal of waste water from built-up areas, and
- the prevention of flooding by rainwater.

The community requires the following from drainage systems:

- the actual rainfall may exceed the design capacity of the drainage system a few times per year (frequency of street flooding);
- the water level must never lie above the ground floor level of dwellings (flooding of dwellings is not tolerated).

Because concern for the environment has received much attention in recent decades, a further requirement has been added:

- waste water must be treated.

Within the framework of these requirements, public bodies responsable for water quality control lay down regulations for the design and operation of drainage systems. The main elements of such regulations are:

- the overflow frequency ("o.f.") of combined sewerage systems may not exceed a given value (almost always included);
- future sewerage systems must be of the separate type (sometimes included).

4. Frequency of street flooding. Fig. 1 illustrates the results of the five minute rainfall analysis over a period of 12 years, on rainfall data from the KNMI (Royal Netherlands Meterological Institute) station at De Bilt [1]. The average rainfall intensity is plotted on the vertical axis. The horizontal axis represents the number of 5-minute periods in which a given intensity is exceeded.

The curves, reading from right to left, refer to the average intensities over periods of 5, 10, 15 and 20 minutes.

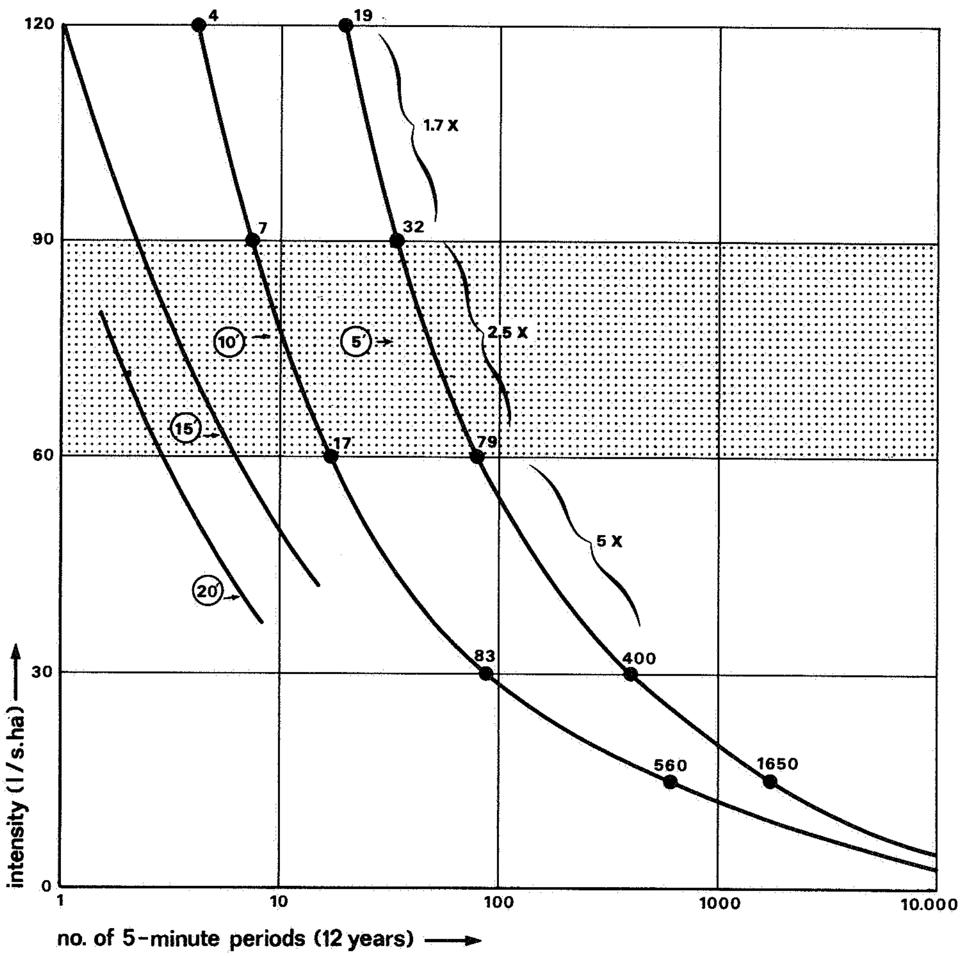
When the curve for an intensity averaged over 5 minutes is followed, it can be seen that an average intensity of 15 l/(s. ha) was exceeded 1650 times, 30 l/(s. ha) – 400 times, 90 l/(s. ha) – 32 times and 120 l/(s. ha) – 19 times.

The frequency drops dramatically up to an intensity of 60 l/(s. ha), but the decrease becomes less pronounced with any increase in intensity beyond 60 l/(s. ha). When we consider whether a design intensity of 60 or of 90 l/(s. ha) should be chosen, it is clear from Fig. 1 that a drainage system based on 90 l/(s. ha) offers very little extra security against street flooding. Certainly, especially in the flat areas of the Netherlands, a choice of 60 l/(s. ha) is justified.

When we look at the curve for the average intensity over 10 consecutive minutes we see that the frequency with which the value of 60 l/(s. ha) is exceeded falls from 79 to 17. This decrease is greater than the decrease given by the change from 60 to 90 l/(s. ha) averaged over 5 minutes.

The conclusion which can be drawn from this is that the time of concentration of a sewerage system is more significant for the frequency of street flooding than the design rainfall intensity.

Fig. 1



5. Experience with the situation in the Netherlands, which is a flat country, is that a drainage system based on a design intensity of 60 l/(s. ha) is satisfactory.

In the hillier areas of the Netherlands, problems can rise if in the detailed planning of city extensions, insufficient attention is paid to the fact that a drainage system is never designed to handle the maximum possible rainfall intensity. The layout and construction of the streets must be based on this fact. (The streets are a part of the drainage system.)

Occasionally the question arises – can a design intensity of less than 60 l/(s. ha) be used?

The reasoning behind this question is that a lower design intensity leads to lower construction costs, while the risk of flooding increases only marginally. In Fig. 2 the depth of street flooding is shown as a function of design intensity. The data are taken from five minute rainfall analysis over a 12 year period at De Bilt [1], and are based on rainfall time-depth relationships for return periods of 2, 5, 10 and 25 years.

The broken line applies for the situation in which the storage capacity of the sewerage system has been ignored. If we follow this line, which represents the relationship between street flooding and the design intensity (i) for a return period of 25 years, we can read off the corresponding values in column 2 of Table 1.

Table 1

design intensity (i)	street flooding (no storage in the system)	storage in the system[1]	street flooding (with storage in the system)
l/s. ha);	mm	mm	mm
1	2	3	4
2	47	1	46
10	29.5	2.5	27
30	21	4.5	16.5
60	17	7	10
90	14.5	9	3.5

[1] storage calculated with the aid of SRIODIM [2].

The expected maximum depth of water in the street decreases in proportion to the increase in the intensity which can be handled by the sewerage system. However, the values in column 2 do not take storage in the system into account.

Until recently, the determination of the storage in the system, as a function of the chosen design intensity, was very costly. With the help of the optimising computer program SRIODIM [2] this relationship can now be determined at relatively low cost. An additonal advantage is that a cost-optimised system results for any selected design intensity. As a result, systems can be compared on the same basis. Storage as a function of design intensity (Table 1, column 3) is plotted in Fig. 2 (shaded zone) for a drainage system in a "typical" urban extension. From Table 1 (column 4) it follows that in the case considered, the amount of street flooding rapidly decreases when i is greater than about 30 l/(s. ha). The street surface covers about 20 to 40% of the total built-up area. If we assume that the effective storage between pavement edges is about 100 mm, this becomes 20 to 40 mm when distributed over the whole paved area. This means that rain-

Fig. 2

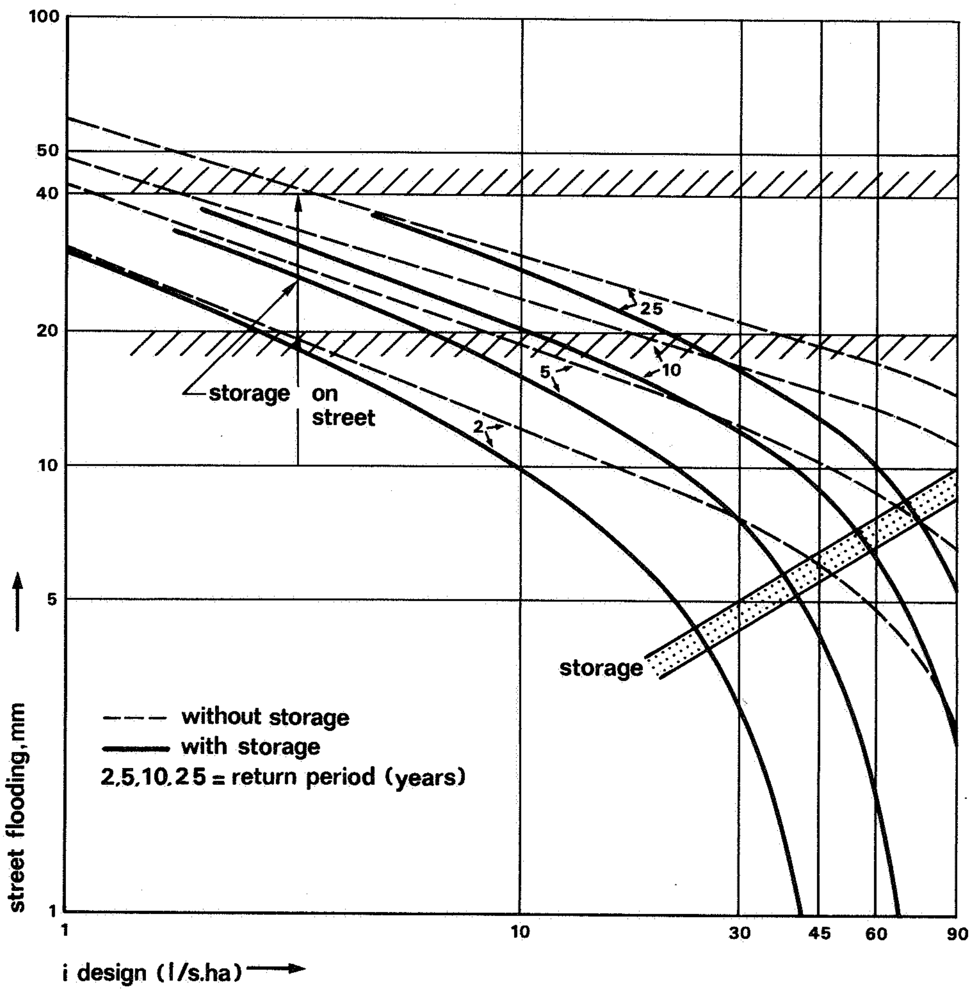
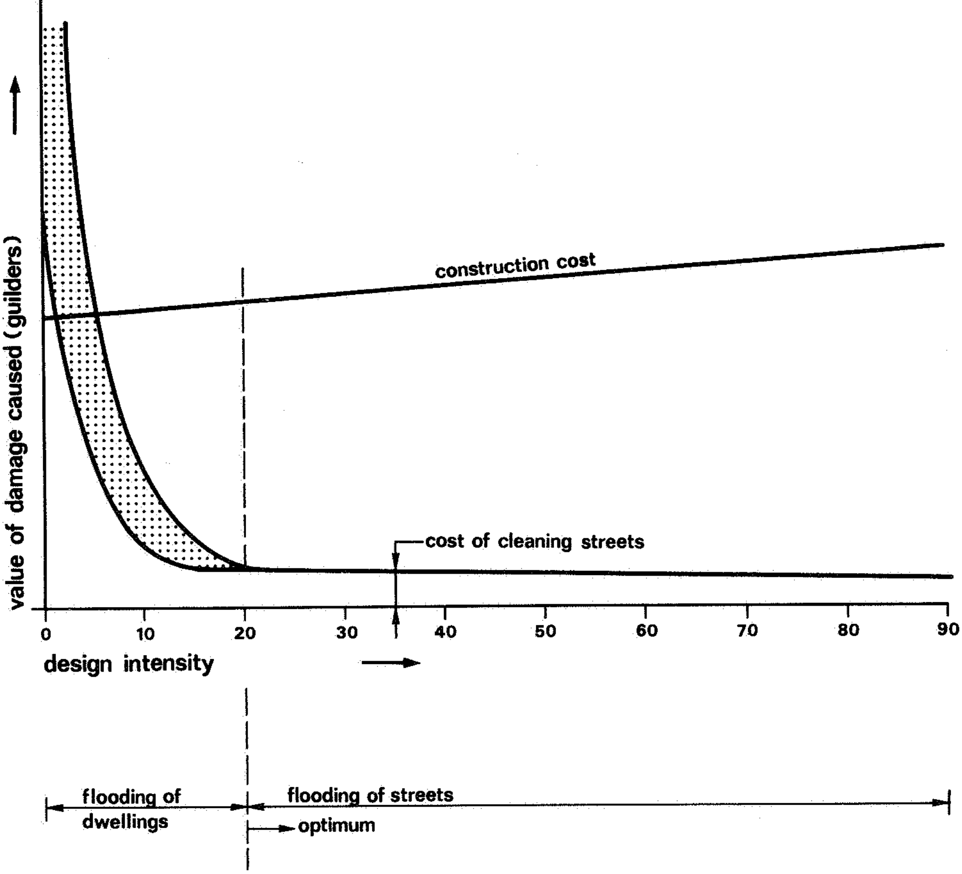


Fig. 3



fall which results in street flooding of 20 to 40 mm (calculated over the whole built-up area) can be accommodated between the pavement edges and cannot result in the flooding of dwellings.

From Fig. 2 we see that for T = 25 years a value of 40 mm for street flooding is reached when the intensity is about 3.5 l/(s. ha). However, if the storage capacity, based on the whole built-up area, is only 20 mm, an intensity of 20 l/(s. ha) can be used for the design.

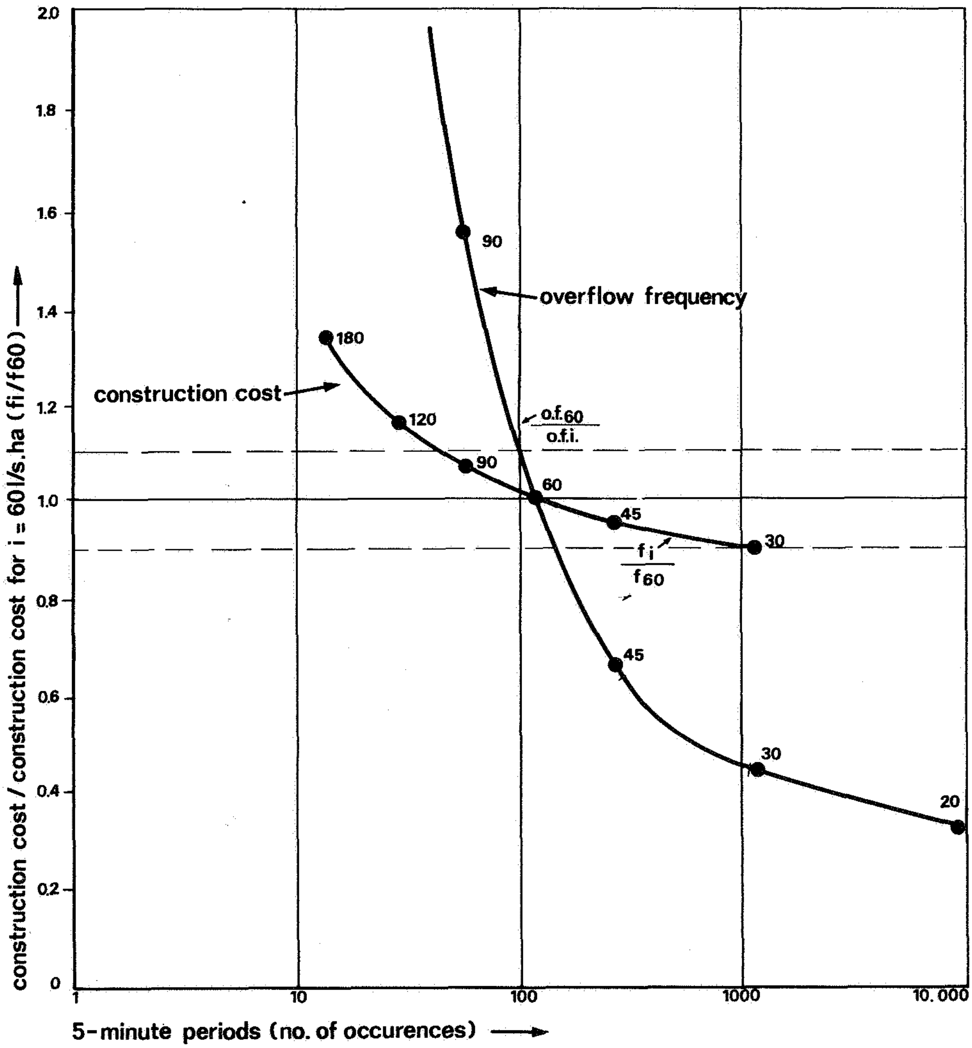
The above conclusions are valid if a return period of 25 years is regarded as the criterion, and this should not meet with any objection.

6. From the foregoing, it follows that a risk of damage to dwellings can arise if a design intensity of less than 20 l/(s. ha) is used. This is shown schematically in Fig. 3.

As the intensity is reduced from 20 l/(s. ha), the cost of damage progressively increases, since the frequency of calamities increases proportionally (see Fig. 1).

It follows that we can justifiably conclude that a design intensity of less than 60 l/(s. ha) can be used. With a great many reservations, the lower limit can be taken as 30 l/(s. ha). In practice, the lower limit must be determined by investigation. We can easily understand, however, that no municipal authority will ever be able to persuade the population to accept ground floor flooding several times a year, in order to fix the lowest allowable design intensity.

Fig. 4



There is evidence that the high cost of establishing this lower limit need not cause us too much concern. Fig. 3 includes the construction costs as a function of the design intensity. These costs have also been calculated with the aid of the SRIODIM program.

The conclusion is that lowering the design rainfall intensity from 60 to, for example, 30 l/(s. ha) yields no worthwhile savings. Moreover, it is not easy to prove that a design intensity of 30 l/(s. ha) does not involve excessive risks.

7. An aspect which has been ignored up till now is the required overflow frequency. Fig. 4 shows the relationship between the construction cost for various design intensities (fi/f60) with respect to the value of 60 l/(s. ha) and the occurrence during the 12-year period. The figure makes it clear that construction cost increases sharply when i becomes greater than about 90 l/(s. ha). (The horizontal scale is logarithmic.)

The same figure shows the relationship between the "o.f." at 60 l/s. ha) and other intensities as a function of the occurrence during the 12-year period. The "o.f." is determined on the basis of rainfall data from the meteorological station at De Bilt.

From the figure we can deduce that the "o.f." decreases sharply after i becomes greater than about 45 l/(s. ha). A decrease in i from 60 to 45 l/(s. ha) results in a decrease of approximately 4% in construction costs. The value of the "o.f." however, increases by about 50%.

If the "o.f." is a parameter indicating the effect of a combined system on the pollution of surface water, we must conclude that a decrease in the intensity used for the design to a value less than 45 l/(s. ha) may result in a major increase in the pollution of the surface water.

The annual average overflow frequency in the above sense is of doubtful value, however [4]. In fact, the overflow frequency is not a standard. All the same, it is regarded as a unit for calculation purposes.

8. To obtain an impression of the pollution discharge from drainage systems as a result of overflowing, we have built a mathematical pollution model. Information on this model and on a number of applications will shortly be published [3].

For the moment it is sufficient to present a number of results which are relevant to this present article.

Fig. 5 illustrates the relationship between the annual average discharge of pollution, the specific peak discharge means the average highest yearly peak discharge.

There appears to be a linear relationship between the specific peak discharge of pollution and the "o.f.". Therefore, it can be stated that the "o.f." is a parameter which qualitatively describes the annual average discharge of pollution. With the specific peak discharge, as a function of the "o.f." this is quite different. There is no linear relationship between them.

If peak discharge is taken as the significant parameter of surface water quality during and after loading, and this appears to be the case, we must conclude from Fig. 5, that the "o.f." is not a parameter which will allow us to estimate the effect of the overflows on the surface water.

Thus we must accept that from considerations of pollution discharge, a design intensity other than 60 l/(s. ha) cannot be justified. The required surface water quality is the determining factor. We will return to this point later.

9. Theoretical and actual overflow frequencies. Van den Berg and Ven produced a paper [5] on the occasion of the 34th Technical Meeting of the CHO-TNO (at which this paper was also discussed) which mentioned, among other topics, the difference between the theoretical and the actual overflow frequencies.

Fig. 5

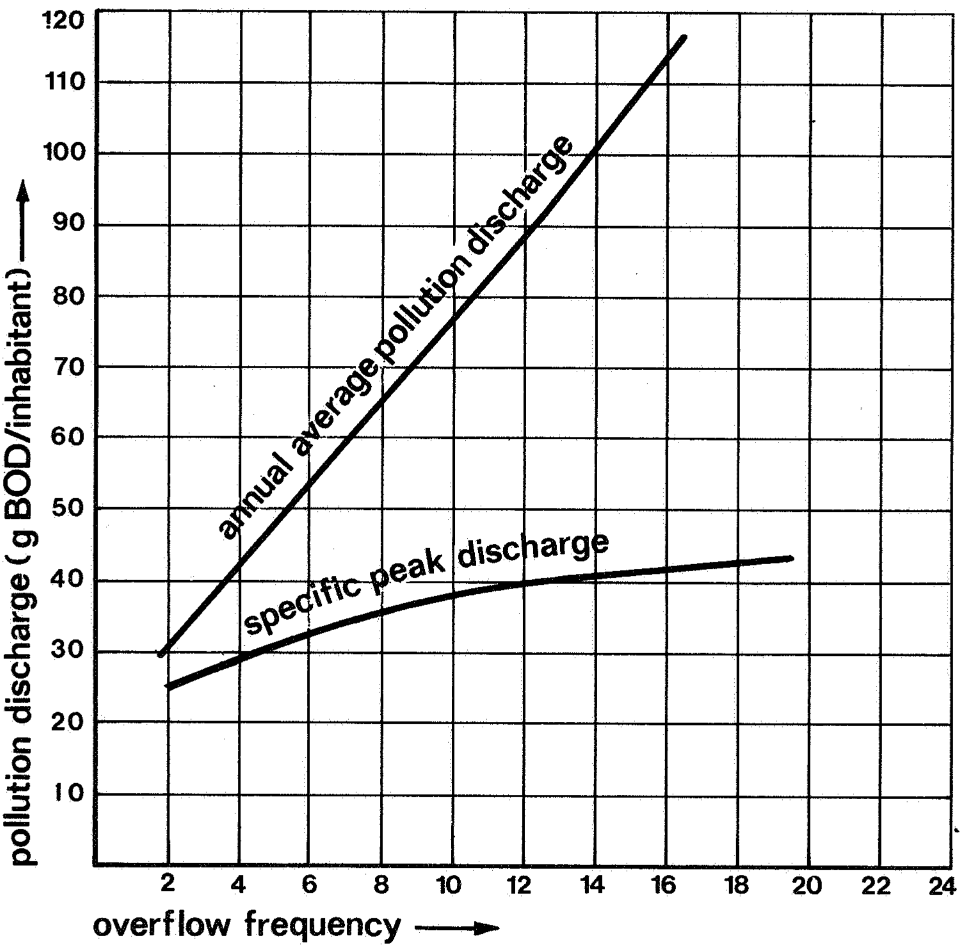
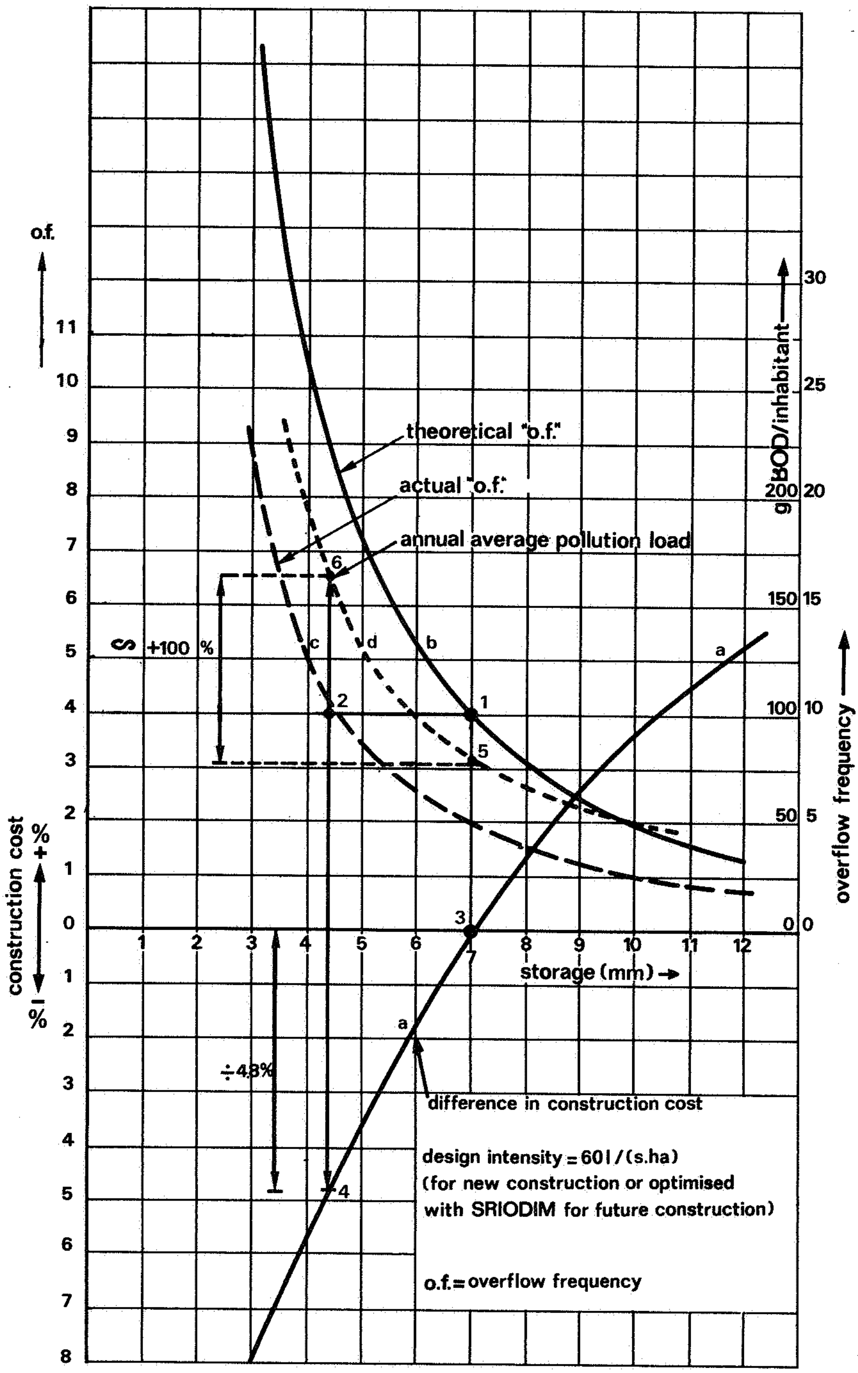
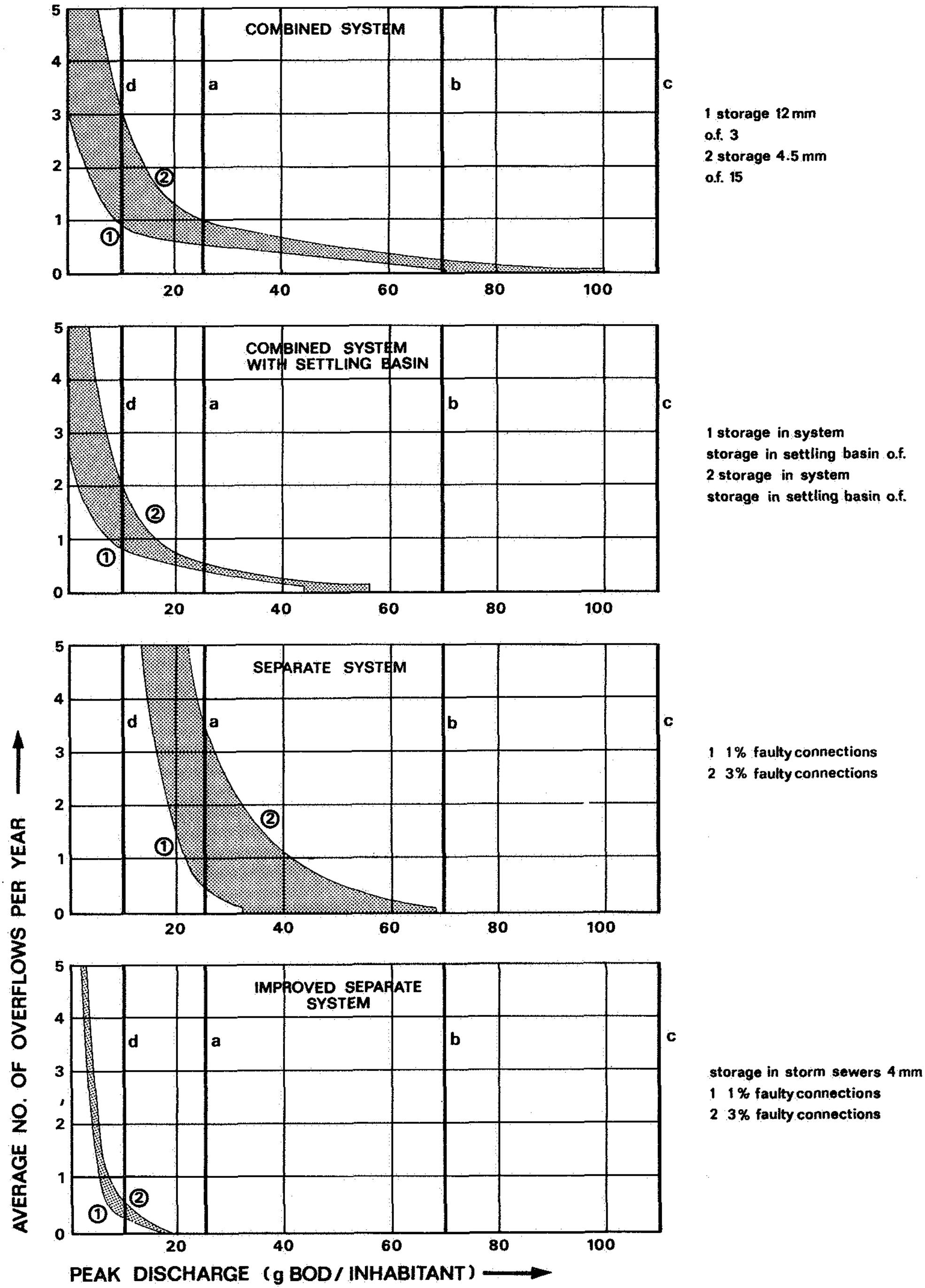


Fig. 6



o.f.
11
10
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
construction cost
+ %
% –
+100 %
÷48%
theoretical "o.f."
actual "o.f."
annual average pollution load
a
b
c
d
1
2
3
4
5
6
storage (mm) →
g BOD/inhabitant
overflow frequency
30
25
200 20
150 15
100 10
50 5
0 0
difference in construction cost
design intensity = 60 l / (s.ha)
(for new construction or optimised
with SRIODIM for future construction)
o.f. = overflow frequency

Fig. 7


COMBINED SYSTEM
1 storage 12 mm
o.f. 3
2 storage 4.5 mm
o.f. 15
COMBINED SYSTEM WITH SETTLING BASIN
1 storage in system
storage in settling basin o.f.
2 storage in system
storage in settling basin o.f.
SEPARATE SYSTEM
1 1% faulty connections
2 3% faulty connections
IMPROVED SEPARATE SYSTEM
storage in storm sewers 4 mm
1 1% faulty connections
2 3% faulty connections
d
a
b
c
AVERAGE NO. OF OVERFLOWS PER YEAR
PEAK DISCHARGE (g BOD / INHABITANT)

One of the conclusions drawn by these authors was:
"Inclusion of the precipitation loss seems to reduce the overflow frequency of a sewerage system, calculated from the pointplots of Kuipers (for De Bilt), by more than a half."

They deduced from this that the construction cost of drainage systems can be reduced by taking the lower overflow frequency into account.

In my opinion, this philosophy is incorrect.

In Fig. 6, the following parameters are plotted as a function of the storage capacity:

a. the difference in construction cost, compared with a storage capacity of 7 mm;
b. the theoretical overflow frequency (excess pumping capacity to the sewage treatment plant = 0.7 mm/h);
c. the actual overflow frequency (c = 0.5 times b);
d. the annual average pollution load in BOD/inhabitant.

As an example, let us consider a system with 7 mm storage capacity and a theoretical "o.f." of 10 (line b, point 1). The actual "o.f." would involve a storage capacity of only 4.5 mm (line c, point 2).

It appears that the construction cost (optimalised) could therefore be reduced by about 4% (line a, points 3 and 4). However, when we compare the corresponding annual average pollution loads (line d, points 5 and 6) we see an increase of about 100% due to the reduction of the storage capacity on the basis of the "actual" overflow frequency.

I do not believe that any water quality authority would regard this as an acceptable approach.

10. Combined as opposed to separate systems. As already mentioned a detailed article on the problem of system choice will shortly be published in H_2O [3]. It is within the scope of the subject of this meeting, however, to consider some aspects of this problem.

In Fig. 7 the horizontal axis represents the magnitude of a pollution load and the vertical axis the annual average occurrence. The shaded areas refer to values which are met in practice.

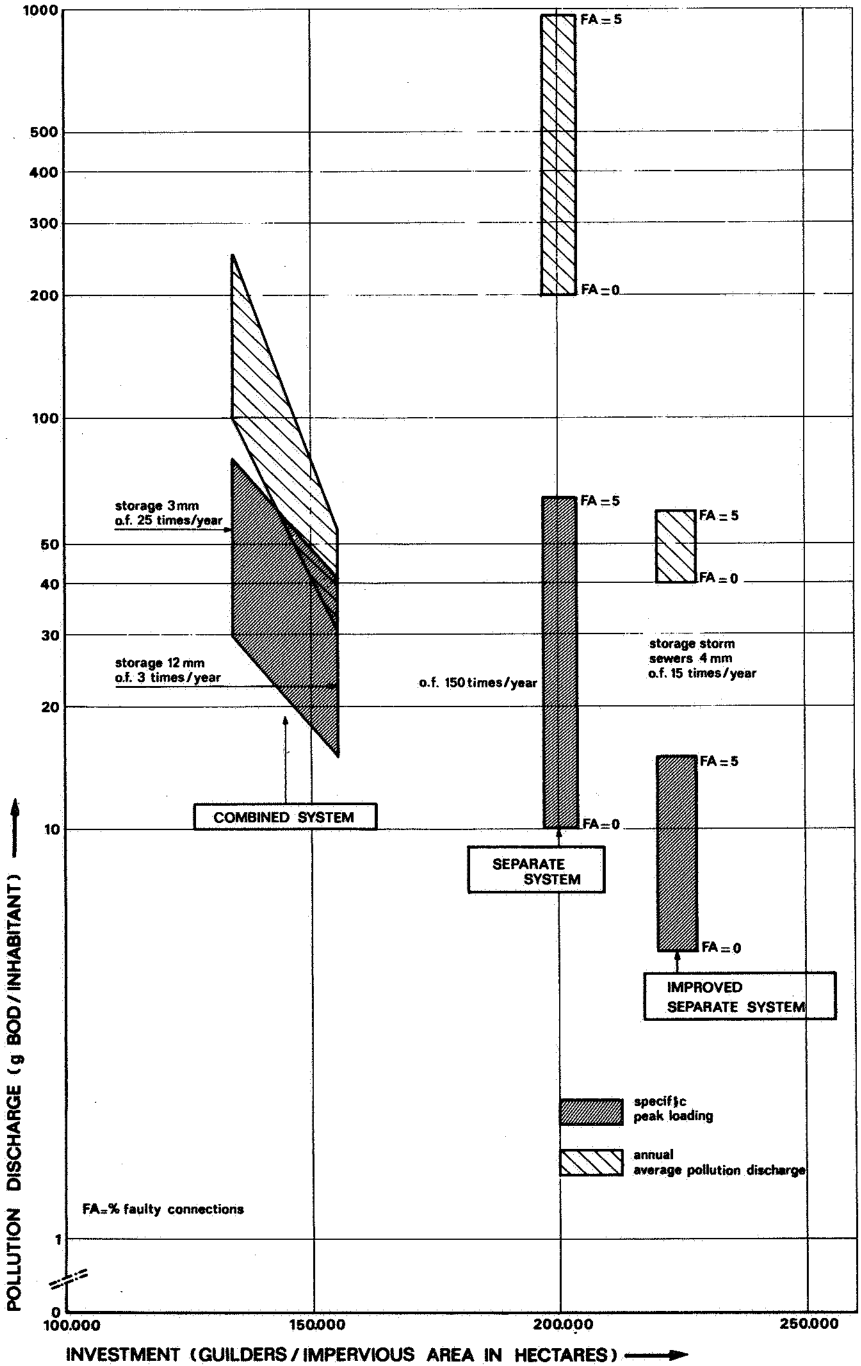
For example, a combined system usually has a storage capacity of less than 12 mm and more than 4.5 mm. The "o.f." then varies between 3 and 15.

When we consider the curves for the combined and the separate systems it appears that with the assumptions made (see [3]) the separate systems subjects the surface water to peak discharges more frequently than does the combined system.

The highest peaks of the combined system have a higher value than those of the separate system. In both cases, however, the return period is low (once in 10 years).

So far as peak discharges are concerned, when combined and separate systems are compared, the actual drawbacks of the combined system are probably less than is usually assumed. Indeed, on the basis of these provisional results with a pollution loading model,

Fig. 8



1000
500
400
300
200
100
50
40
30
20
10
1
0
FA = 5
FA = 0
storage 3 mm
o.f. 25 times/year
storage 12 mm
o.f. 3 times/year
COMBINED SYSTEM
o.f. 150 times/year
SEPARATE SYSTEM
storage storm sewers 4 mm
o.f. 15 times/year
IMPROVED SEPARATE SYSTEM
specific peak loading
annual average pollution discharge
FA = % faulty connections
POLLUTION DISCHARGE (g BOD / INHABITANT)
100.000
150.000
200.000
250.000
INVESTMENT (GUILDERS / IMPERVIOUS AREA IN HECTARES)

the combined system may well prove to be preferable. The crucial question is – what is the real pollution absorption capacity of the surface water?

If this is greater than 100 gBOD/inhabitant, for example, then any of the systems represented by Fig. 7 will be adequate. If the limit is below 20 gBOD/inhabitant, however, only the improved separate system will be satisfactory.

Cost considerations play an equally important role. In Fig. 8 investment is plotted against annual average pollution discharge or specific peak discharge, for systems which are typical in practice.

From the figure we can see that the separate system is about 50% more expensive and the improved separate system about 80% more expensive than the combined system. Moreover, it is clear that the annual average pollution load with the separate system is roughly 10 times greater than with the combined and improved separate systems. The peak discharges for the combined and the separate systems are of the same order of magnitude. The improved separate system is in this respect 4 times "better".

The above considerations give an indication that, in many situations, the combined system is an attractive possibility as a waste water transport system, from the points of view of both water pollution and costs.

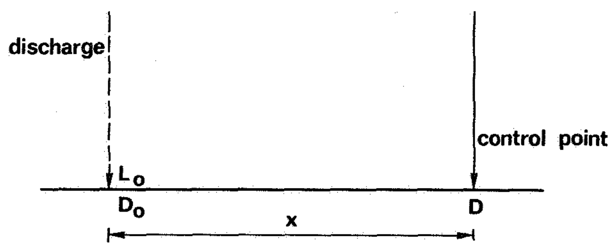
11. It follows that the pollution absorption capacity of the surface water must be known if a completely well-founded choice of system is to be made.

In the following section this question is considered again, but with a different approach.

Fig. 9 represents a flowing stream. At a given point, polluted water from a sewerage system is discharged into the stream. After mixing with the stream, the oxygen deficit is Do (= $c_s - c_o$) and the BOD is L_o. At a distance x from the point of discharge the O_2 concentration can be calculated from the following expression:

$$D = Do \exp(-K_2 \cdot x/v) + \left[\frac{K_1}{K_2 - K_1}\right] \cdot L_o \left[\exp(-K_1 \cdot x/v) - \exp(-K_2 \cdot x/v)\right]$$

Fig. 9



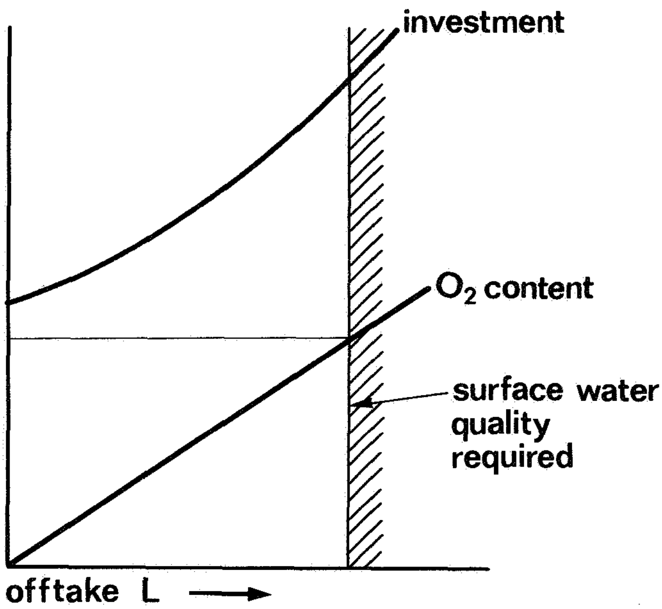
in which:

K_2 = BOD breakdown constant
K_1 = aeration constant
v = average stream velocity

For x = constant
D = α Do + β L_o

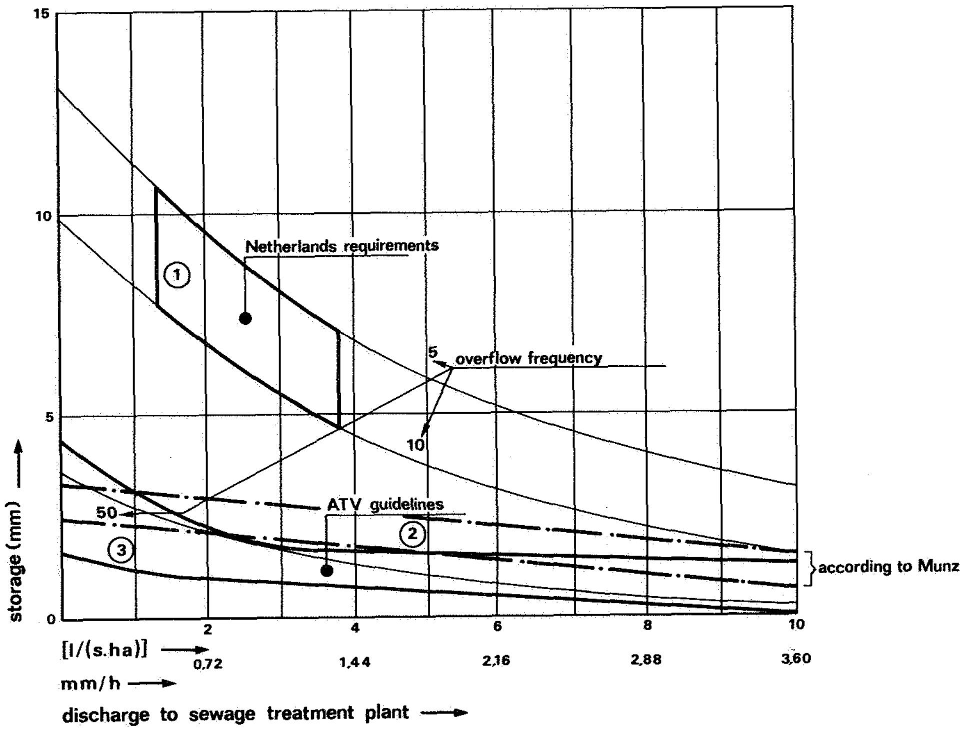
Thus, the decrease in O_2 content is affected by the linear BOD-term after mixing. If the point in the stream, at a distance x from the point of discharge is the determining point, then with gross simplification the situation at that point can be characterized as shown in Fig. 10.

Fig. 10



With a further decrease in β (BOD at the point) the O_2 content increases linearly. The probable investment necessary to achieve this, however, increases exponentially. There is no question of optimising. The amount of investment necessary will almost always be determined by the water quality which is considered to be required. In this example, the water quality to be attained would have to be typefied by the BOD.

Fig. 11



12. It is known that detailed specifications for the achievement of water quality do not yet exist. Specification of the water quality is a difficult problem and one for which no solution is to be expected in the near future.

Other countries are struggling with the same problem – how to arrive at satisfactory standards. This is applicable just as much to surface water as to sewerage systems.

Discharges to the sewage treatment plant are plotted against storage capacity of the sewerage system in Fig. 11. In the Netherlands, the "o.f." requirement lies between 5 and 10 times per year. Besides, the discharge to the treatment plant is limited.

Similar areas in the figure reflect German (ATV) and Swiss (Munz) guidelines [6]. It is obvious that the latter differ significantly from requirements in the Netherlands. These differences cannot be explained on the grounds of the national situation but reflect the national tradition. The Germans and the Swiss debate the areas in which storage and discharge have to be located. From the "high and dry" position adopted in the Netherlands such disputes seem pointless. This pointlessness cannot, however, be proved.

I hope that the above statements will illustrate how little is known anywhere about the effect of sewerage systems on surface water.

13. CONCLUSIONS

- For the development of effective sewerage systems, further knowledge of urban hydrology in the Netherlands' situation is unnecessary.
- Simulation models give a good qualitative impression of the effects of water quality improvement measures.
- A better understanding of the relationship between the measures to be taken and the reduction in pollution is urgently needed. In this connection, integrated water quality models must be constructed, tested and used. "Integrated" in this sense means the inclusion of several disciplines such as hydrology, hydraulics, ecology, economics, civil engineering, etc., all having equal importance.

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URBAN GROUNDWATER: USAGE, IMPEDIMENTS AND ADMINISTRATION

R.H.J. KREMER and E. SCHULTZ

SUMMARY

The influence of urbanization on the groundwater regime presents itself in several ways.

In this article the aspects will be discussed which are important in:

a. polder areas with controlled open water- and groundwater-tables. In these areas there are semi-permeable layers in the profile,
b. areas with free discharge. Here the soil is permeable down to a considerable depth. Shallow and deep groundwater are not separated.

Essential are the consequences which may be expected as a result of different activities during the process of urbanization, and the conditions to which the groundwater in an urban area has to come up to.

Finally will be discussed to what extent we can speak of an adequate administration of groundwater.

1. INTRODUCTION

There is a well-known saying: "He whom the water harms stems the flood". But in the case of groundwater, it should be: "That which the eye does not see, cannot cause harm". The conception that the open water is not merely our enemy, but also a primary life source, has clearly penetrated. The groundwater has never been a spectacular enemy, even though it can be an appreciable obstacle. Here, too, it is gradually realized that groundwater is an important raw material. In order, on the one hand, to make its use safe, and on the other hand to keep the impediments within acceptable limits, good administration of the groundwater is just as essential as that of the open water.

During the consecutive stages of urbanization, usage, impediments and administration of the groundwater come to the fore in varying ways. In this article, an impression will be given at the outset of the initial situation, i.e. the circumstances as they exist in the Netherlands. Then an examination will be made of the groundwater aspects in conjunction with the opening up of the land for development. And finally, groundwater in the town will be discussed. After this stocktaking, we shall show where the bottlenecks are situated and where improvements can be introduced.

2. THE INITIAL SITUATION

If we examine its hydrology, its water management and its geology, then it is possible in the Netherlands to distinguish two main groups. In the west and north and locally along the rivers, there are the polder areas. In the east and in the south of the country there are mainly sandy soils. Along the coast we also have the dunes. But these are only indirectly of interest owing to their function for drinking-water supplies.

The polder areas are characterised in particular by artificial control of the water. By means of a system of trenches or drains, ditches and canals, the superfluous rainwater is carried away by the pumping stations. We thus have an artificially controlled groundwater level, this level varying between rather narrow limits. Another less obvious, but certainly nonetheless important, hydrological aspect of the polder areas lies in the fact that, in these parts, semi permeable strata occur, as a result of which there is an indirect relationship between the shallow and the deep groundwater. In the case of the deep groundwater, there is consequently frequent mention of overpressure or underpressure, and this gives rise to seepage or infiltration. One aspect of groundwater quality here provides the phenomenon that the deep groundwater is frequently salt, as a result of which it constitutes in the seepage areas an impediment for the surface water. Thus annual chloride charge in the Central Western part of the Netherlands as a result of seepage, gas wells and industrial groundwater extraction amounts to 180,000 tons per annum [1].

In addition to these hydrological and water management characteristics, there are also

Fig. 1 **Profile structure in the Netherlands.**

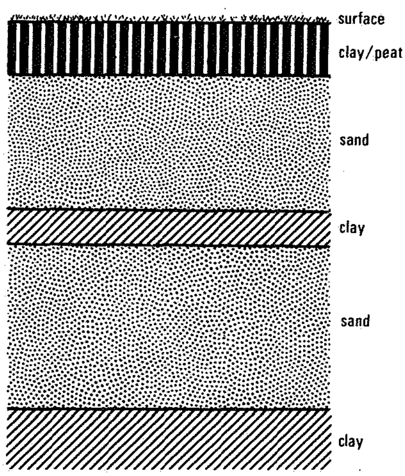

Fig. 1a Polder areas in the western and northern part of the country and locally along the rivers.

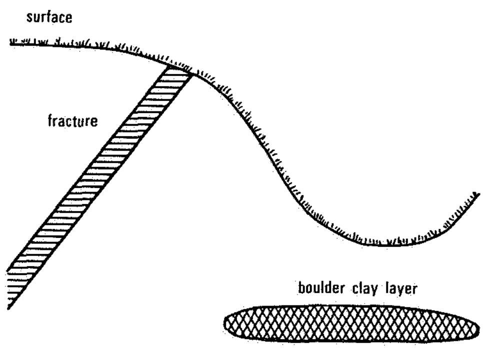

Fig. 1b Sandy soils in the eastern and southern part of the country.

a number of geological aspects which are of importance in relation to the groundwater. In polder areas, there is the upper stratum, the Holocene, mainly consisting of clay and/or of peat. The upper stratum is semi-permeable and peat in particular is highly compressible. The thickness of this layer varies from a few metres to some twenty metres. Beneath the Holocene there lies the Pleistocene. The Pleistocene is made up for one or more aquifers, separated by semi permeable strata. As regards the calculation of groundwater flow, it is generally assumed that he impervious basis is located in the Pleistocene at 200–300 m-sea level [2]. The soil surface in the polder areas is generally level and the logical stratification is horizontal.

For the sandy soils, an important feature as regards hydrology and water management is the fact that we here find free drainage through brooks and small rivers. Seeing that in these areas the intervention of man has also been a factor, the brooks and small rivers are frequently dammed in the summer in order thereby, where this is possible, to produce such groundwater level that drying out of the crops is prevented. In order to realise a satisfactory level of drainage and discharge, many brooks have been improved and this as a rule has led to deeper groundwater levels in the basin. Moreover, in the sandy soils, there are also areas where the groundwater level is located several metres beneath the soil surface and accordingly does not influence the vegetation.

Generally it may be stated of the sandy soils that fluctuations occur in the groundwater level within fairly wide limits. Here we frequently find a vulnerable geohydrological situation, when local intervention in the groundwater level can produce repercussions over a wide area. Frequently, in these parts we find a direct relationship between the shallow and the deep groundwater, and there is a single aquifer. Boulder clay strata and fractures can however, affect the flow of the groundwater when, especially in the case of fractures, differences in groundwater levels may occur of several metres over short distances. The quality of the groundwater is good and even such that, at the present time, we obtain more than half our drinking water supplies from this groundwater [3].

In the case of the sandy soils, the main geological feature of the groundwater is the fact that it shows a single aquifer. Locally, distortions may occur, both steep, as in fractures, and horizontally, as in boulder clay strata. As a rule, we are there concerned with inclined areas.

Taking this initial situation, which has been described very generally, it is interesting to see in which parts of the country the urbanization is concentrated. A glance at the report on urbanization in the Netherlands will show that, of the fourteen growth centres twelve are situated in the polder areas [4]. In the Atlas of the Netherlands, it will be seen from the map showing groundwater levels in the winter that these, in the case of the growth centres, frequently lie between the soil surface and forty centimetres beneath the soil surface [5]. When drawing up the report on urbanization, it is thus clear that no thought was given to geohydrological or geological aspects. The resultant costs of land reclamation and laying foundations are accepted in principle as being necessary. An endeavour is frequently made to economise on these costs, as a result of which, either from the hydrological viewpoint or as regards the facilities for using the urban area, a less favourable situation arises.

In those districts which are not designated as growth centres but where, albeit on a smaller scale, building work is proceeding, parts which are good from the drainage aspect are frequently already developed, and as regards newbuilding one is restricted to the lower-lying and poorly drained areas. Whereas in the polder areas and especially in the major towns, it was customary for measures to have to be taken in order to prevent interference with the groundwater, for the smaller local authorities and those for which building in this sort of territory is new, the groundwater will frequently have unpleasant surprises in store. It is then also important that, before undertaking urban expansion of any magnitude, a soil and geohydrological investigation should be undertaken. On the basis of this, it is then possible to gain an insight into the drainage measures which will be involved.

A number of data regarding the groundwater are frequently available. For example:

- the data contained in TNO's files of groundwater levels (Groundwater Survey – TNO);
- TNO's groundwater maps on scale 1 : 50,000; only some of these are ready;
- the data in the pump-testing files of the National Institute for Water Supply (Rijksinstituut voor Drinkwatervoorziening);
- the geological maps on scale 1 : 50,000 of the Geological Survey of the Netherlands (Rijks Geologische Dienst);
- the soil maps on scale 1 : 50,000 of the Soil Survey Institute (Stichting voor Bodemkartering);
- the water engineering maps on scale 1 : 50,000 of the Topographic Service (Topografische Dienst);
- data from the municipal authority and water-authority archives, or the drinking water supply organizations.

Frequently little is as yet known regarding the quality of the groundwater. Regarding the presence of fresh or salt groundwater, the reports of the geo-electrical measurements of the Service for Water Management (Rijkswaterstaat) contain a considerable amount of information [6]. The regional studies of the Institute for Land and Water Management also contain considerable information relating to the quality of the groundwater [1].

3. OPENING-UP FOR DEVELOPMENT (LAND RECLAMATION)

When developing new residential areas, it is necessary to carry out a number of civil engineering and land use development engineering works in which groundwater in its various manifestations plays an important role. In this context one may think of the digging of municipal canals, the laying down of sewers and supply pipes, and the provisions to be made for building-pits, drainage and land improvement. At this stage, inconvenience is especially experienced from the groundwater. Use is seldom made of the groundwater.

In the polder areas, the areas suitable for development are mainly located at low levels, with the groundwater levels in the winter in or only a few centimetres below the soil surface. In order to be able to build in such areas, the following measures are possible in principle:

- the filling of the area with a layer of sand;
- the lowering of the groundwater level by lowering the water level of the polder, possibly in combination with the laying of a drainage system;
- filling the area in combination with a lowering of the groundwater level.

These measures will have different effects on the groundwater level as this occurred in the initial stage. Where the area is raised, the groundwater level will in any event not fall. As a result of the filling, there may well be settlement owing to the groundwater being pressed out of the semi-permeable strata. A lowering of the groundwater level, in areas with seepage, may well result in an increase in the seepage. In areas with infiltration, the infiltration will decrease and may well change to seepage. Three disadvantageous features may be found:

- settlement may occur; in peat areas, additionally also oxidation and shrinkage, as a result of which the lowering of the soil surface may well be equal to the lowering of the groundwater level;
- an increase in seepage resulting in a lowering of the piezometric head of the deep groundwater, as a consequence of which extra settlement may take place in the upper stratum;
- the seepage water is frequently salt, as a consequence of which the usefulness of the surface water is adversely affected.

This latter point in particular is frequently unacceptable to the administrative authorities of the surface water in the surrounding countryside. As a rule, this results in conditions being laid down in particular as regards the chloride content of the water coming from the town. A lowering of the groundwater level alone is therefore for the most part not possible. With a combination of a lowering of the groundwater level and filling of the land, the consequences will in theory be the same as with a lowering of the groundwater alone, though with the combination it is possible to regulate the changes in seepage or infiltration. The problem, however, is frequently that, though the formulae for calculating the groundwater flow or any changes therein are well known, knowledge of the ground constants (permeability (kD) and hydraulic resistance (c)) is such that it is difficult to state what precisely will happen. Special circumstances will be present when the upper groundwater is fresh and the groundwater located below it is salt. A lowering of the groundwater wil then lead to raise of the fresh/salt interface, as a consequence of which the seepage may become salt over a period of time [7].

In addition to the inconvenience which may be experienced from the groundwater during building, there are also a number of other aspects where groundwater plays a part. Thus, during urbanization, there is an enlargement of the trench or drainage ditch distances, and this will in particular affect the fluctuation in the groundwater level. Where excavation and land filling takes place, stability problems are frequently encountered.

Finally, mention must be made of the fact that a two-soils system then arises. The gardens and conduits, and as a rule also the roads and squares, lie on or in the Holocene. Houses, buildings and bridges have their foundations in the Pleistocene sand. In order to retain problems of subsidence within reasonable limits, a certain amount of time will have to elapse before a start can be made on the building work, once the land has been raised or the groundwater level lowered. For the two-soils system, a state of equilibrium in the groundwater is always of considerable importance. Any subsequent intervention will lead to further subsidence and subsidence problems.

In the sandy areas, the causes of the problems are mostly different from those in the polder areas; but the measures to be taken will be the same. Owing to the vulnerable geohydrological situation, a lowering of the groundwater level will lead to a fall in the groundwater levels in the surrounding area. Since in these areas, changes in the geohydrological system can have far-reaching consequences, especially for the vegetation, falls in groundwater levels are completely unacceptable. As a result, it will frequently be necessary to consider raising the ground. As a result of the frequently capricious geological structure of the land, it will be necessary to be prepared for unpleasant surprises. Fractures and boulder clay strata can give rise to a capricious sytem of groundwater levels. With suitable arrangements, however, these areas afford greater possibilities for adjusting the grouping of the project according to the natural aspects. As a rule in these areas, problems with subsidence play a less important part than in the polder areas.

The measures which have to be taken in connection with reclamation have to result in sufficient drainage depth. The extent to which this requires to be achieved during the building phase is not legally prescribed, while at the same time there are also no generally accepted criteria. Two basic principles are possible:

- The local authority takes the measures which are necessary to enable a well drained site to be handed over to the builder and the future residents. On a well-drained site, it must be possible to use the appropriate transport vehicles, to lay or repair supply pipes and sewers, and to store building materials, all this without excessive inconvenience from water. The standard applied frequently for this purpose is a drainage depth of at least 70 cm beneath the soil surface, with an excess frequency of once or twice a year [8].
- The municipal authority takes steps to ensure that the building sites are accessible and also supervises compliance with the building code with regard to the groundwater. Actually, this amounts to the builder himself having to comply as best he can and the resident being given a degree of security against inconvenience from water in the form of the building code.

A subsequent phase in the development process consists of the digging of town canals, sewerage runs and building pits. In all these operations, inconvenience may be experienced from the shallow groundwater. In the polder areas, there is always the danger that, owing to overpressure in the Pleistocene, the Holocene bases of canals or building pits will burst. These disturbances may result in an appreciable increase in what is mainly salt seepage water and a lowering of the overpressure.

A good example of this kind of problem is to be found with the laying of canals when Almere was being constructed. The initial nucleus of Almere, Almere-Haven, was constructed directly behind the Gooimeerdijk. The Holocene here is five metres thick and the strata are hardly consolidated (pore volume 70–80%). The area is covered with one metre of sand, as a consequence of which the surface is at present approximately at –2,50 m sea level. The canals ends up at –6 m sea level. The target level in the Gooimeer is on average –0,30 m sea level. As a result of the location immediately behind the dyke, the piezometric head of the groundwater in the Pleistocene is in or above the soil surface.

If the canals are laid out without special precautions, a lowering of the piezometric head could take place up to, or somewhat above, the level of the canals. This is tantamount to a lowering of the overpressure of the deep groundwater by some 2,50 m. Owing to the high pore volume of the Holocene stratum, this lowering of the piezometric head alone would lead to a settlement of the order of one metre. There was also a fear of falls in the level of the groundwater in the Gooi area. This kind of problem has led to the canals in Almere-Haven being supplied with an enclosure of the base consisting of a layer of clay 3 m thick, ballasted by a 2 m thick layer of sand.

This enclosure of the base gives rise to extra cost. For the following nuclei, an investigation has been made to see hwat extent a sealing off of the base is necessary. With the coming of computers, we are now in a position to describe both the stationary and the non-stationary groundwater flow in the area. The use of models of this kind is taking place increasingly for the purpose of calculating the effects of groundwater extraction [9]. In order to be able to determine the influence of the town canals to be dug, the Almere area has been built into a model with the aid of which it is possible to simulate the stationary groundwater flow. With this, it became clear in particular that the distance from the dyke is important. The second nucleus of Almere, Almere City, lies at least two

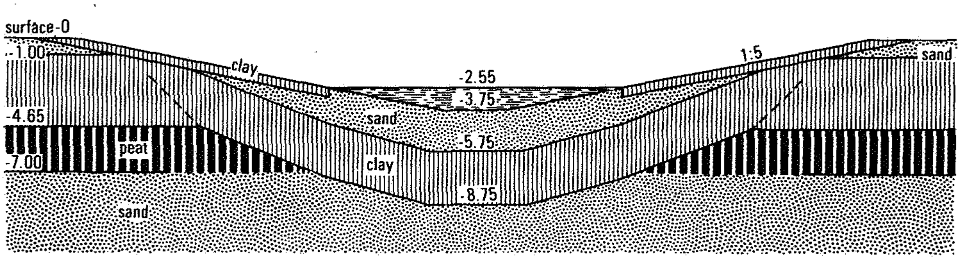

Fig. 2 Cross-section of the canals in Almere-Haven.

kilometres within the dyke. It was now possible, using the model, to calculate that, as a consequence of the laying of the canals in this nucleus, a decrease of the piezometric head could be expected of the order of 10 cm. This lowering was so slight that it was possible to dispense with any sealing of the base of the canals here.

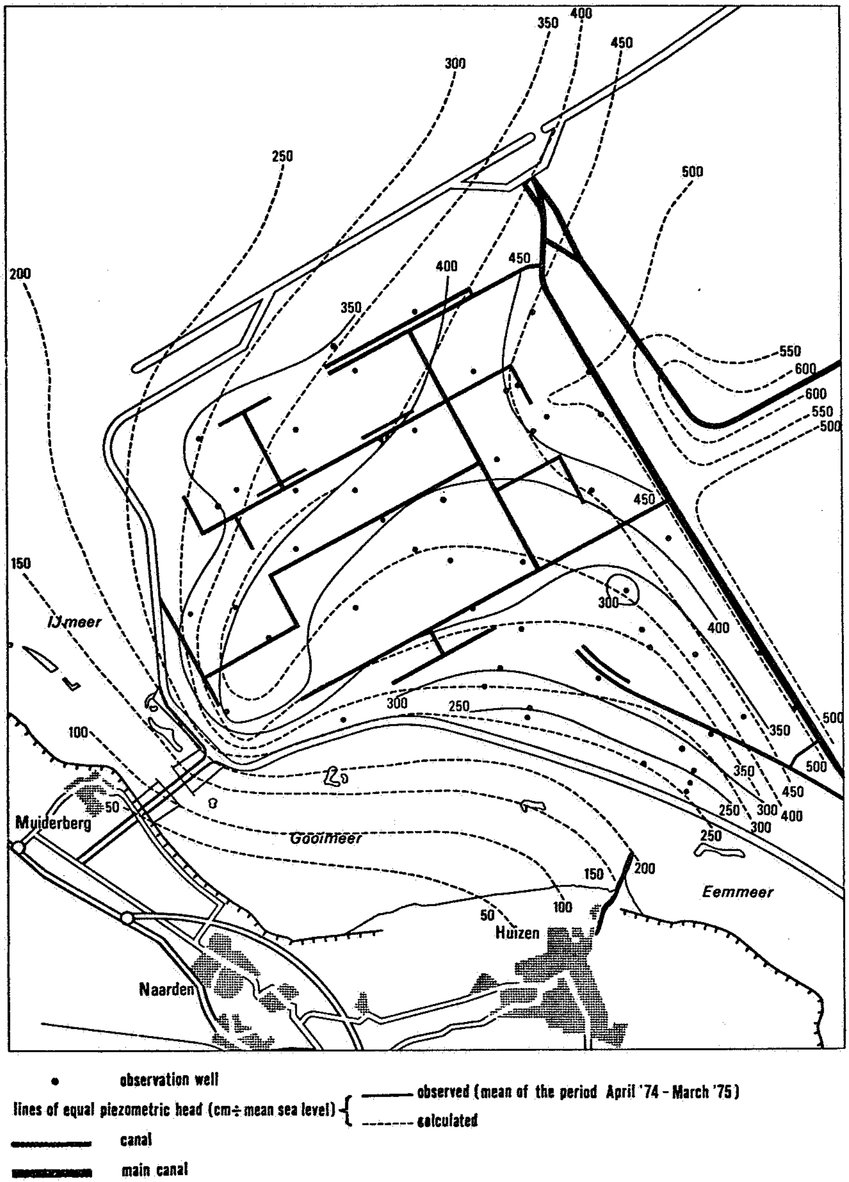

Fig. 3 Lines of equal pieazometric head for the Almere area in the present situation.

4. THE URBANIZED PHASE

In the course of urbanization, some 50% of the surface is covered. The proportion of the precipitation falling upon the impervious surface does not infiltrate, but is carried away through the sewers to the water-courses. In polder areas, this may inter alia result locally in excessive drying-out of parklands and plant-holes. With building pits and well-point dewatering of the soil, it may take a long time before the groundwater fills up again. On the sandy soils, owing to the direct relationship between the shallow and the deep groundwater, there is a direct effect on the hydrological system and problems may arise therefore with supplies of moisture, also for the surrounding area. In addition to the quantitative aspect, various activities in the town may have a deleterious influence on the quality of the groundwater. We need only think of leaking oil or petrol tanks, or sewers. In the polder areas, when there is pollution, as a rule only the phreatic groundwater is affected when, with the partitioning which is adopted in these areas, the risk of spreading

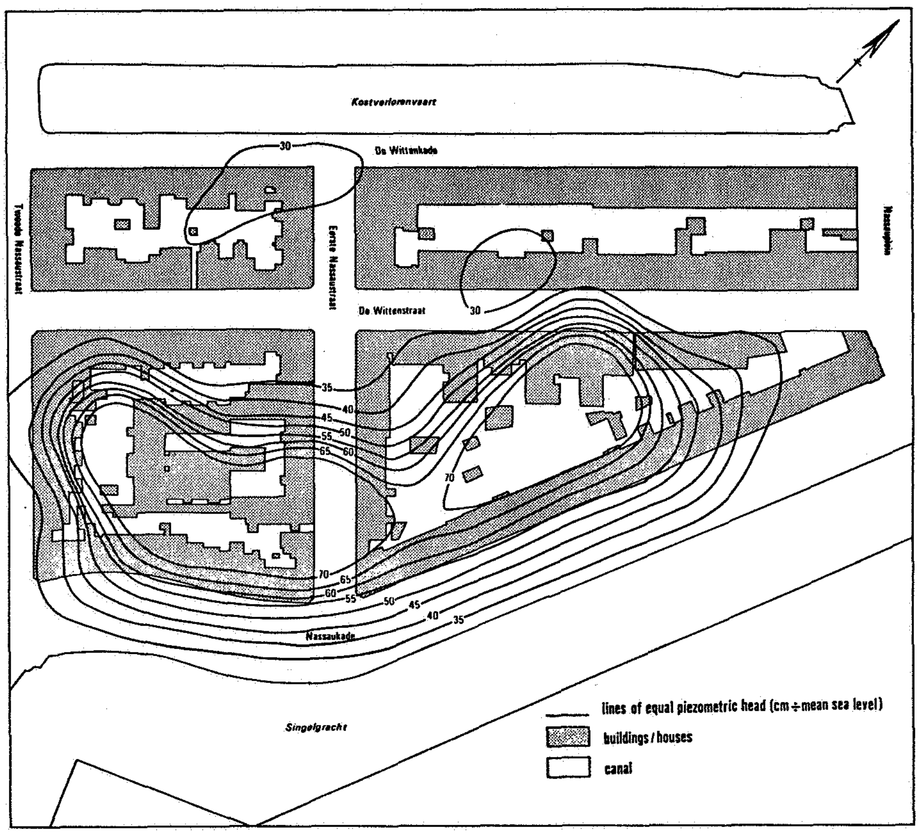

Fig. 4 Lines of equal piezometric head of the upper aquifer of the "Staatslieden" district of Amsterdam.

is also restricted. In the sandy soils, there is considerable risk of spreading when pollution occurs. From the various papers published on this subject, it is very evident that comparatively little is known regarding this quality aspect.

4.1. *Use of the groundwater*

With the use of the shallow groundwater, there are some three main possibilities. Almost everyone will be aware that this groundwater can be used for providing moisture for gardens and plantations, and in addition also for the conservation of timber structures, especially wooden piles. But the shallow groundwater is also used for supporting the level of roads, gardens, squares and conduits. The latter fact is nowhere mentioned in the many published documents on the distribution and control of groundwater.

From the deep aquifers it is possible to draw water for the purposes of drinking-water supplies, factory water supplies, cooling water or water for fire-fighting. In the polder areas, the groundwater pressure is also, though this is far from being generally known, used for supporting foundation sandy strata. The following consequences of the use of the deep groundwater are of significance. Groundwater extraction leads to a lowering of the piezometric head as a result of which subsidence can appear in the strata in which foundations have been laid.

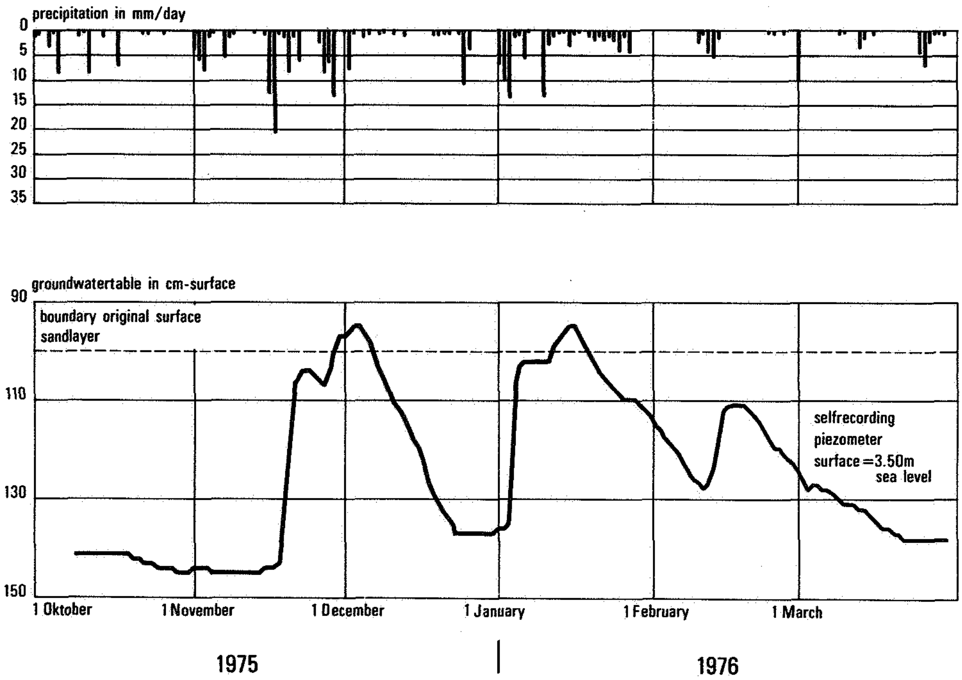

Fig. 5 Continuously recorded precipitation and the course of the groundwater table in a residential district in Lelystad.

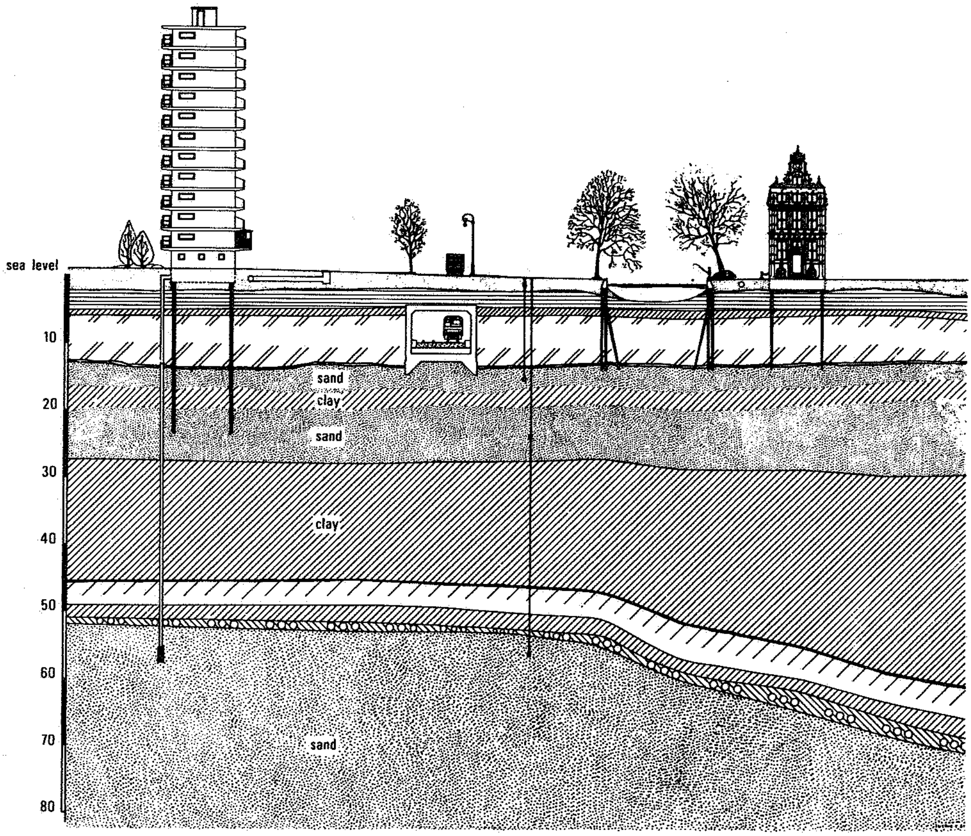

Fig. 6 The situation in Amsterdam.

When groundwater is pumped up and then is released again into the surface water after use, this can lead to silting. A striking example of this is the discharge from the yeast and spirits factory at Delft into the catchment basin ("boezem") water of Delfland. As a consequence, the chloride contents have locally mounted up to above 1,000 $mgCl^-/l$. Where groundwater is extracted, there is also the danger that the extraction of fresh water will result in salt groundwater being drawn up, with a consequential loss of opportunities for its use.

4.2. *Inconvenience from groundwater*

With regard to the shallow groundwater, it is above all of importance that the groundwater should not cause any inconvenience for the residents. Manholes and their underground footpaths, etc. need to be dry. Good drainage is also important for the hard surfaces of roads, for the laying of foundations on steel, and it must be possible to carry out the laying or repair of cables without inconvenience from the water.

A less well-known aspect is the fact that there is a direct relationship between a damp dwelling and the occurrence of diseases such as asthma, bronchitis and rheumatism. Following a systematic investigation in the inner city at Leiden, it was found that, in a district with damp housing, the percentage of juveniles suffering from asthma was almost two and a half times as high as in a district with dry housing. This connection has also been demonstrated in other places, albeit less systematically. Though the quality of housing has now been improved, dampness among housing which is otherwise good can still be the cause of the occurrence of the above-mentioned diseases. On the basis of these results, it wil be necessary to ensure, especially where a town is being renovated, that any existing inconvenience from the groundwater is remedied [10].

Inconvenience from the deep groundwater is experienced above all in the case of building pits which frequently have to be well pointed in order to keep them dry or to prevent the surging up. The consequences for the deep groundwater are essentially the same here as the consequences of the use of deep groundwater, with this difference that, in the case of building pits, we usually find that the situation is only a temporary one. In the case of those pits, however, the shallow groundwater is often extracted too.

4.3. *Control of the groundwater*

The idea that control over the groundwater is necessary has been given statutory form for the first time in the Groundwater Act relating to Water Works 1954. This Act is specifically directed to the extraction of groundwater for drinking-water supplies [11]. Only around 1970 did provincial groundwater regulations gradually become operative and only in 1975/1976 was a Groundwater Bill introduced into Parliament, and this has recently been before the Second Chamber [12]. In Act. 1 (3) of this Bill, however, it is stated, inter alia: "This Act shall not apply to the withdrawal of groundwater: (a) for the purpose of drying out or draining land".

Admittedly, the Explanatory Note to the Bill shows that it is recognised that these works affect the groundwater level, but since they are not directed towards removing groundwater, they are kept outside the scope of the legislation. There is thus no integral statutory philosophy as regards groundwater. Still more noteworthy is the fact that the typical urban interests in connection with groundwater are not mentioned in the Explanatory Note.

During the past ten years, publications have been appearing regularly on the threat to, and the protection and control of, groundwater [13]. These pracitcally all relate to the quantity of groundwater available for water supplies and the threats thereto, both as regards shortages and as regards pollution. The problems confronting urban groundwater, and the interests connected therewith, have not come to the fore. But in the urban areas, groundwater has an important part to play, both actively as regards vegetation and extraction, and also passively for maintaining the height of roads, squares and foundations and keeping foundation piles moist. There are no statutory regulations stating who is to control the groundwater in the towns. Accordingly, active control of groundwater, i.e. determination of the correct groundwater levels for the shallow and the deep groundwater, controlling actual groundwater levels and extracting or introducing water in order to maintain the levels thus ascertained, is not provided for. For our surface water, on the other hand, this has for centuries been the most customary task in the world.

A number of things, though, are done:

(1) In certain municipal districts, groundwater levels are regularly measured in measurement shafts. The data are filed and in some cases included in TNO's archive of groundwater levels.

(2) On the basis of the Nuisance Act and the Building Code, it is possible to prohibit the removal of groundwater or to make its removal subject to certain conditions. When a permit is granted, however, no consideration is given as to whether such removal fits into a fair distribution of the groundwater available. The quality aspects too of such removal are left out of account.

(3) On the basis of a number of provincial groundwater regulations, it is possible to grant or refuse permits for the removal of groundwater; consideration of all interests then takes place. There is however certainly no uniformity in this field, so that in Rotterdam for example the granting of permits is so regulated, whereas in Amsterdam, with its vulenerable old brickwork houses, a permit of this kind is still not necessary. The South Holland provincial groundwater order, in particular, makes the whole of the provincial territory subject to the granting of a permit, whereas the North Holland order only recognizes a general obligation to register, and only designates Velsen and the Gooi district as a compulsary area for the purposes of permits. And yet each year in Amsterdam, between 15 and 20 million m^3 of groundwater are being extracted.

(4) In many cases, especially during the construction of major engineering works or buildings, proper account is taken of the groundwater. This occurs either by selecting such a method of execution that the groundwater is not affected, as for example the sinking method and the pneumatic caisson method for the building of the Rotterdam and the Amsterdam underground railways respectively, or by means of special provisions, such for example as sheet piling screens or return pumping.

When the Groundwater Act now under consideration comes into operation, it will be possible to regulate the extraction of groundwater by means of permits. Seeing that geohydrological knowledge and experience are directed in particular to the extraction of water, the conditions for granting permits in that field can then be sufficiently underpinned.

For the drafting of proper conditions for protecting urban development, the available knowledge and experience are too fragmentary and investigation is therefore necessary. Whether the development if the control of groundwater will go so far that a level-controlling system complete with infiltration arrangements will be laid down, cannot as yet be foreseen. Infiltrating water into an urban district has however been suggested in order to influence the groundwater as a possible solution towards increasing the carrying power of the timber pile foundations.

And, finally, a practical example of the threat to urban groundwater and the risks connected therewith. In Amsterdam West, a garage business had been established on an inner plot in a block of flats. Complaints were received at a certain moment from the neighbourhood regarding petrol and oil laden air in the flats. An examination showed that a pipe to one of the petrol storage tanks had presumably been leaking for some time. The petrol in the meantime had flowed out over the groundwater under the adjoining houses, as a result of which the fire service considered temporary evacuation necessary for some of those premises. An attempt was made to remove the petrol by pumping away the shallow groundwater under the garage. This was not very successful since, as the groundwater level was lowered, the petrol adhered to the particles of earth. Tackling the problem with chemical substances, introduced through the manholes, also produced little results. The solution was discovered by infiltrating water in the garage and thus driving away the petrol. Directly in front of the flats, it was possible to collect the petrol with groundwater, at first in a groove and later in a drainpipe. Good control of groundwater can thus be of vital importance from the qualitative point of view.

5. RECOMMENDATIONS

(1) An investigation into how to arrive at an optimalization of the system of urban layout in relation to initial situations.

(2) An investigation into the preparation of standards relating to drying-out of land and controlling the groundwater as a basis for the directives to be issued.

(3) The appointment of a controller of groundwater for urban areas.

(4) An investigation into how to achieve quantity and quality control over groundwater, especially for urban areas and allowing for urban requirements.

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THE RELATIONSHIP BETWEEN URBANIZATION AND WATER ECONOMY FROM THE MUNICIPAL AUTHORITY POINT OF VIEW IN THE LIGHT OF THE SITUATION IN AMSTERDAM

J.H. VAN DER VLIET

SUMMARY

Its location in a former swampy area has given rise to particular problems for Amsterdam.

In order to maintain Amsterdam's polder-based situation, it has been customary until ca. 1950 to raise building sites up to the level of the "boezem" (system of reservoirs for superfluous polder water) and, later, to slightly below that level.

A great number of pumping stations drain the superfluous water from these areas into the "boezem" water in and around Amsterdam. Over a hundred kilometers of weirs protect the low lying areas from flooding. These dikes, etc. need attention, especially when cables and pipes are to be conducted through them.

Between 1960 and 1970, urbanization of the polders in Amsterdam led to administratively dissolving a number of water authorities. Since 1970, preparations have been made to merge some water boards in the Province of North Holland, and they partly also reach into Amsterdam.

Some of Amsterdam's sewerage systems are "combined", others "separate". Plans have been made for a great sewerage purification plant, and that because the effluent water of a part of Amsterdam's ancient city centre flows to the IJsselmeer in inpurified condition.

The Amsterdam local authority has set out points of departure for pertinent environmental hygiene. Unfortunately, the Act relative to the Pollution of Surface Water has not left the administration of water purification to the local authority of Amsterdam. The exploration of purification plants, though has been delegated to the city.

1. HISTORY

Its location in a former swampy area has given rise to particular problems for the growth of Amsterdam. In the Middle Ages, it was customary to raise building sites artificially. Until the second half of the 20th century, it was customary to raise up to 70 cm above NAP in order to prevent flooding. In this manner, even in the 19th century, residential districts were formed in an area which lies in a shorse-shoe shape around the network of canals. In these districts, the roads follow the direction of the former polder ditches.

Since the 2nd World War, municipal extensions into the surrouding, and frequently deeper polders, have no longer been realised on land raised above the level of the "boezem" (system of reservoirs for superfluous polder water), but elevations were carried out in part, frequently to a permanent height of some 1.30 m above the level of the polder. This is why in these newly-built areas (garden towns) the polder situation has been maintained as such.

2. PRESENT-DAY HYDROLGOICAL SITUATION

Amsterdam possesses within its boundaries some 50 or so smaller and bigger districts in which the water level is maintained artificially (i.e. polder areas). The depth is from 1–6 m below NAP.

All the water drawn up from these low-lying areas finds its way into the "boezem" waters surrounding and traversing the City. The North Sea Canal "boezem" forms the last reservoir for superfluous water coming from the remote periphery. From this "boezem" (average level NAP –0.40 m), all this water is conveyed to IJmuiden via the sluices and the newly raised pumping station into the sea.

This colossal pumping engine (capacity 150 m^3/sec.) was officially brought into operation on 16th October last year by Holland's first dike-reeve, Mr. Westerterp, and is also able, in the event of high North Sea levels, to release the superfluous water from the North Sea Canal "boezem".

This pumping station will also be playing an important part in connection with the struggle against silting on the North Sea Canal "boezem".

The Amsterdam city "boezem" flows out by means of free flow into the North Sea Canal "boezem". The same applies in the case of the Amstelland "boezem", which flows away freely via the municipal waterway and then round via the Amsterdam-Rhine Canal, to the North Sea Canal and the IJ. In the West, Amsterdam borders on Rhineland's "boezem", with an average level of NAP –0.60 m. The superfluous water from the polders draining into this "boezem" cannot flow away freely into the North Sea Canal "boezem". Rhineland's "boezem" is pumped up in 4 places, namely Gouda, Katwijk, Spaarndam and Halfweg. From these pumping stations, those in Spaarndam and in Halfweg flow out into the North Sea Canal.

There is also the "boezem" of Waterland, with an average level of NAP –1.45 m.

Of the 3 Waterland pumping stations, two discharge into the North Sea Canal "boezem" and one into the IJsselmeer.

3. THE WEIRS

When it is remembered that the Amsterdam local authority administers inter alia some 125 km of waterways, some 60 polder pumping stations, 100 or so inlets and approximately 120 km of polder and "boezem" embankments, it is clear that the authority, in repsect of its hydrological tasks, is comparable to a large-scale water authority.

First of all, let us consider the weirs. Following the breach in the dike at Zijkanaal (= side canal) H in 1960, when the Oostzaan garden village was submerged, a report was prepared in which all the important Amsterdam dikes were examined and any improvements considered necessary were highlighted. Since then, the authority has had a number of dikes which were considered insufficiently robust, strengthened. More recently, for this purpose grateful use has been made of the systematical dike investigation of the Weirs Investigation Centre at the Hague.

A special position is occupied by the weirs on Amsterdam territory which are of particular importance for the safety of residential and work districts, but which are under the administration of statutory water authorities.

The establishment of the Bijlmer water board (under Amsterdam), in which inter alia the oft-mentioned Bijlmermeer is located, is actually a direct consequence of the urbanization of the territory in question. The Weesperkarspel (later Amsterdam), Diemen and Ouder-Amstel local authorities originally prepared their municipal expansion in an area in which 9 small water boards were situated. By the combination of these small water boards to form the Bijlmer water board in 1967, the Province reduced the number of permit-granting authorities to one. The new water board, moreover, on its constitution, was allocated a very important task, namely the strengthening of the waterretaining ring in conjunction with the urbanization of the area in question. It was laid down that the three local authorities, as "originators", should together bear 90% of the cost. Later, when the reinforcement of the dikes was being prepared and it was found that the local authorities did not have their share available, the same cost distribution again came up for discussion. It was pointed out on behalf of the local authorities that urbanization is a social phenomenon and that it is hardly right to think in terms of "originators" in this connection; at the same time, the appearance of municipal development signifies rising income for the water board, and from this the whole of the strengthening of the dikes ought to be paid. To date, there is talk of pre-financing by the water board; but no final decision has been taken regarding the distribution of the cost.

With urbanization, Amsterdam is being increasingly faced with an alternative method of residence, namely the houseboat. Without going into the urban aspect of municipal canals sliding to a halt with houseboats and their unpurified discharges on the surface water, it must be stated that the administration of the dikes too does not become any simpler with the arrival of these floating residences. On a "good" day, they lie, unasked and unasking, alongside an important weir. Having regard to the housing situation in the City, they are tolerated, and then are frequently supplied with gas, light and water. The necessary connections form a potential danger to the waterretaining dikes. Strict conditions are accordingly attached by the weirs administrator to permits for the laying of these connections in the dikes.

Connections of larger diameters, the conveyer pipes for gas, water and oil, supply the City with the necessary fuels and provisions. Whereas conveyance by pipelines affords considerable advantages on the one hand, the obvious disadvantage is that they inevitably have to cross weirs.

Pipe crossing for weirs, designed for sinking or for traversing, must be carried out to the satisfaction of the weirs administrator, or in this case the local authority in such a manner that the safety margin appearing on paper is also there and will remain in practice. This applies particularly in the case of high-pressure gas and oil conduits, and also water conveyance pipes.

4. AMSTERDAM AND THE WATER BOARDS

Between 1960 and 1970, the Province of North Holland administratively disbanded some 13 regulated polders where the territory was being increasingly taken over by the urban development of Amsterdam ("depolderization"). In the process, the local authority was given their allotted tasks.

This related in general to smaller water boards whose financial position was not particularly rosy and which were watching and increasing proportion of the ownership of their territory passing into the hands of the municipal authority. As a consequence, the number of agrarian landowners and users declined rapidly and it was becoming increasingly difficult for these water boards to form an administration in accordance with the regulations.

Also, in connection with the urbanization of the polders, different requirements are being made in regard to the water management. The regulation of the water levels is not only related to an optimal crop production, but rather directed towards the security of timber foundations and the prevention of any weakening of roadways, embankments, etc.

The capacity of the pumping engines has to be adjusted to the increase in the speed of the outflow of rainwater as a result of the increase in the hard surface in the polder. As a rule, an expansion of the pumping capacity is required.

The weirs require to afford a much greater degree of safety since they now have to protect whole municipal districts full of people, houses, roads, factories, etc. against flooding.

But a number of (only partially urbanized) polders inside Amsterdam have remained under regulated water boards. Some of these until recently have been on the list for depolderization as well.

During the past few years, however, the tide of depolderization has been turning. Around 1970, the Province of North Holland became very active in the field of water board concentration. In the area of Rijnland, North Holland, the Province has been striving towards the formation of a single large water board into which it will possibly draw the water boards in Amsterdam West.

In 1967, to the North of the IJ, the High Water Authority (Hoogheemraadschap)

"Buikslotermeer" was abolished. Around this time, discussions were conducted between Amsterdam and the High Water Authority (Hoogheemraadschap) ' Waterland regarding the depolderization of the urban district of Amsterdam North situated in Waterland. These came to nothing owing to a difference of opinion regarding the amount of the redemption monies for the water board's charges. Preparations are now going ahead for a concentration of water boards in the area of Waterland also and this will probably include the depolderized and urbanized *Buikslotermeer.*

Amsterdam is not very happy at this development. The City has tradionally fulfilled a large number of tasks in the field of water control and is well equipped for this both technically and administratively. The abolished, urbanized polders call for water management, specifically directed to the interests of these (low-lying) municipal areas, and to the interests of these areas as part of the City as a whole. The considerable complexity of interests in which urban areas in my opinion calls for their being handled by a general administration, namely that of the local authority; and here an identical treatment of the citizens plays an important part. Moreover, concern for the municipal weirs in Amsterdam enjoys high priority and this is not surprising, having regard to the high density of the population and the value of the City's investments.

The old saying "He whom the water harms stems the flood" and also the famous striptych "interest-payment-control" no longer apply in these urban areas that are still in the polder state.

In short, I am of the opinion that those areas of a large city which are located in polders form a single unit with that city to such an extent that partial administration by a second, co-ordinative, public-law body alongside the municipal administration, i.e. a water board, is out of place.

5. QUALITY OF CONTROL

The ancient inner city of Amsterdam and the 19th century districts surrounding it are drained, apart from the girdle of canals, in accordance with the combined system.

A large conveyer conduit carries this water to a point in the IJsselmeer where biological self-purification sees to the breaking-down of the effluent arriving (approximately 100,000 m^3 per day).

Encouraged also by the central Government, Amsterdam has made a start with preparations for the construction of a sewerage water purification plant in Amsterdam East (on the island of Zeeburg) where some 700,000 inhabitant equivalents will be able to be purified.

Once this plant is ready, evacuation into the IJsselmeer, which has been going on since 1913, will be halted. The oldest purification plant is in Amsterdam West where the sewerage district is organized according to the combined system.

The southern part of Amsterdam is also organized separately for sewerage purposes. This sewerage district also covers the Bijlmermeer, and Gaasperdam, at present being developed, both being situated within the Bijlmer water board. The purification plant for this area is situated near the Amstel.

In Amsterdam North, both separately and combined sewerage systems are to be found, all draining off into the North purification plant, situated on the North Holland Canal.

Then in the western port area there are a few other districts organized for sewerage purposes, hitherto drained off into a number of inlet harbours. In future, another sewerage water plant will also be constructed here in order to purify the increasing flow of effluent from this factory area.

Returning to the heart of the City, I would direct your attention to the much praised girdle of canals, which is not yet connected to a sewerage system. The effluent is discharged here direct into the city canals. So as not to be confronted with unacceptable situations in this, the most beautiful, part of Amsterdam, these canals are flushed through each day. The Zeeburg pumping station in Amsterdam East, situated at the end of the discharge canal, pumps water out of the IJsselmeer and into the City. If, all except for one or two, the sluices between the city "boezem" and Amstelland are closed, and also those between the city "boezem" and the IJ, then a more or less direct flushing of the city canals is brought about in the direction east-west, flowing out into the western part of the IJ. So as to hinder navigation, and at the present time in particular the round passenger trips, as little as possible, this refreshing of the waters takes place during the night, between 22.15 and 05.30 hours.

Despite this effective flushing system, the Amsterdam city authority is striving for the abolition of the somewhat outmoded manner in which the girdle of canals gets rid of its effluent. In 1968, the first local authority Memorandum on Environmental Hygiene appeared, comparable to the present-day combat plans of the purification water board (zuiveringsschappen). This Memorandum announced a plan for the sewerage arrangements for the city's canals, and execution of this plan has now been taken up.

Since the appearance of the first Memorandum on Environmental Hygiene in 1968, modern environmental hygiene legislation has been envolved whereby in particular the duties and position of the local authority administrations in this matter have been changed; consequently a new approach to problems in this field is now necessary.

Also in connection with this, the Amsterdam city authority has reformulated the points of departure for administration in the coming years and set them out in a Second Memorandum on Environmental Hygiene published at the beginning of this year. In this, criteria are laid down in the matter of water quality which are requried to support the basic principle of policy that the existing water quality may not decline, and that the aim of an improvement in quality shall be pursued.

Concrete form is given to this by the plans for increasing the pumping capacity of the sewerage pumping stations and the salvage capacity of the combined sewerage system, whereby the number of times that the overflows will be brought into operation will gradually be reduced to 7–10 times a year.

The Amsterdam local authority, as far as I am aware, occupies a special position as regards quality control, in the sense that the Provincial delegation order, within the scope of the Law relating to the Pollution of Surface Waters, has left the administration and exploitation of its purification water plant with the local authority.

In addition to the traditional tasks connected with sewerage, other quality tasks such as renewal of the water in the city "boezem" and dealing with calamities, have remained with the local authority.

Passive quality control in and around Amsterdam is distributed among a total of 4 quality administrators. These are two High Water Authorities ("Hoogheemraadschap Rijnland" and "Hoogheemraadschap van Uitwarende Sluizen van Kennemerland en West Friesland"), the Government and the Amstelland and Gooiland purification boards. This latter board covers the whole of the city "boezem".

Initially, Amsterdam made considerable efforts to keep quality control within the local authority boundaries for itself, since four quality controllers within a single local authority is probably rather too much of a good thing.

This view has not been accepted however by the local authority with any great gratitude, as witness the delegation earlier referred to of purification administration.

6. CONCLUSION

From the foregoing, it should be clear that Amsterdam's concern with water is many-sided and intensive, and will remain so.

It has not been possible to devote any attention to groundwater; but it must be stated that Amsterdam literally stands or falls by a careful administration of groundwater levels, especially in the older city districts.

An extensive network of plumbing shafts, especially along the conveyer drains, gives us overall information regarding groundwater levels within the city. When works are being undertaken, however, it is repeatedly the experience that the state of the groundwater level is completely unpredictable and can vary in this city sometimes from metre to metre.

By arrangement with the Province, the local authority is now seeking for a form for organizing an effective groundwater control. Here it will be necessary to bring the uncontrolled removal of groundwater for various purposes under control.

The influence of urbanization on the water economy is nowhere better demonstrated than in the huge "Central Government" works now under construction in Amsterdam, especially the ring-way round Amsterdam (Rijksweg 10) and the Hem railway-line plus tunnel. The realization of these projects and the radical consequences thereof for the water economy in the municipal polder areas which are traversed, constitute sufficient material for a number of separate lectures.

Returning to the commencement of my paper, and following the route of the merchant ships of the Middle Ages on their way to the far-off East Indies, we pass the island of Zeeburg and sail across the former Zuider Zee.

Here, directly to the east of the city, between Schellingwoude and Muiden, and before reaching the shoals at Pampus, the Uilenbos designation plan which is still to be drawn up will eventually be realized. A Land of Cockaigne for the civil engineer, in view of the many relationships which will require to be realized in this area, between the city itself and the new town-in-formation, Almere, in particular the north/south fresh-water conveyer system in the interests of joining up the main systems in Holland's water economy; discharge towards IJmuiden of the brackish percolating water from the IJsselmeerpolders; operation of the flushing of Amsterdam's city "boezem"; cooling water for the Diemen electric power station; rail and road communications; shipping communications; the removal of refuse; and recreation.

I would suggest that, as you continue your voyage, unhindered by a drained Markerwaard, you should turn round to took at the city and its surroundings as they grow smaller: an interplay of land and water, which invites attention and possibly respect.

WATER BOARDS AND URBAN DEVELOPMENT AREAS

J.S.J. DRAGT

SUMMARY

Water management in the Netherlands is held by the Government, the Province, the Water Boards and a few Municipalities.

The Government has entrusted the water boards the care of one or more of her special interests in water management. These interests extend over a larger area and often encompass the territories of more than one municipality.

When an urban development plan is being prepared, it is the water boards's duty to check the influence of growing peak-drainage on the open drainage system in the entire area. Both quantitative and qualitative aspects are of importance.

It is desirable that structured premeditation between water boards and municipalities becomes the general rule, so that it will be possible to recognize problems early and to look for optimal solutions.

A "wet development plan" should be one of the appendices of the complete area development plan. In this "wet development plan" it will also be possible to determine who will realise the various plans and who is going to finance them.

1. INTRODUCTION

In the Netherlands there are some 800 municipal authorities and some 800 water boards "waterschappen". If the man in the street is asked what a municipal authority is and does, a reasonably good answer will be forthcoming. If, however, he is asked what a water board is and does, there is a considerable likelihood that this dual question will be received with a completely blank expression.

This is strange, for the tasks which the water boards undertake in the sphere of protection against the sea and the rivers, and in the field of water economy, concern as it were the primary conditions for the country's very existence. Apparently, the interests at stake are less concern to present-day urbanized people. However, in recent days there has been an increasing interest shown for water boards. The points of contact between the sphere of the water boards and those of the government, such as a spatial order, regional development, environmental hygiene, etc., are also increasing.

To the same time the waste water treatment has particularly brought the water boards into contact with the inhabitants who until quite recently were completely unaware of the existence of any water board. I propose today to consider in particular one of the points of contact with which the water boards are becoming increasingly concerned, namely urbanization.

Before proceeding, however, it woujld seem to be desirable to enumerate the various authorities in the Netherlands which are concerned with water control.

2. THE ORGANIZATION OF WATER CONTROL IN THE NETHERLANDS

Water control, as part of the overall concern for water supplies etc. in the Netherlands – and this relates to the administration of the open water – is mainly distributed between the Government, the Provinces and the Water Boards. But whereas the Government and the Province have many other tasks to fulfil besides concerning themselves with water supplies etc., the Water Boards have as their sole aim that of looking after one or interests connected with the country water.

Sometimes, municipal authorities too have concern for those water-matters among their responsibilities. An example of this is the complicated water management system in Amsterdam, where the municipal authority itself appears as the administrator of the polder.

In general, however, it may be stated that the Water Board after the Government and the Province, is the regulating body charged with looking after water-matters at the lowest, decentralised level within the Dutch policy, which, as you may well have noticed, is a complex of administrative relations which it is not always easy to appreciate and comprehend. I shall not go any further into this. If you wish to know more, then the report of the Study Commission of the Water Board will provide you with full information on the subject [1].

Within the purview of my paper, I should however like to stress that water boards and municipal authorities in the exercise of their tasks stand in a co-ordinative relationship towards each other. Both occupy a subordinate position vis-a-vis the Government and the Province. I shall be returning to this point shortly.

I spoke just now of concern for water supplies. It is, however, difficult to define exactly what that phrase covers. In any event, this concern deals with the quantity, the level, course and quality of the water, or, briefly, concern for the hydrosphere. This concern can be separated into a quantitative and qualitative exercise of tasks. Little has changed during recent decades in the organization of the quantitative administration. Over the period there has been a concentration of water boards and the specification of their tasks has been expanded in the case of many water boards. It is general now for "the advancement of a good water management" to be one of the tasks of the water boards.

An important change has however taken place in the field of concern for water quality.

Before the Law relating to the Pollution of Surface Waters (W.V.O.) came into force in 1970, the position was that the quality aspect of the surface water was looked after rather by river regulations of the central government, provincial orders or water board by-laws.

In the Province of North Brabant, the water authorities were already in the fifties allotted waste water treatment within the scope of the provincial regulations.

With the W.V.O., in particular, active administration of quality has now got well off the ground. It is regrettable that the relationship between quantity and quality has fallen down in a number of cases owing to the fact that the two types of contról are not always assinged to one and the same authority.

As a result, concern for water matters has not become any clearer or simpler. Also, alongside the "all in" water boards there are purification water boards ("zuiveringsschappen") which are only charged with the qualitative surface water control, while certain provinces have retained the qualitative control for themselves.

3. MANAGEMENT STRUCTURE LAWS INFLUENCING WATER ADMINISTRATION

Urbanization of rural areas is always accompanied by influences on the water management of those areas. Atmospheric precipitation and waste materials require to be removed from the area in altered quantities. The water board has inter alia the task of ensuring that the water management throughout the area over which is responsibility extends and which as a rule covers various municipal authorities, is not disturbed.

The water board is able in this connection to regulate matters through waving its by-laws, thus exercising control.

But there is also clearly an active form of control reserved for the water board. Constantly increasing urban effluents frequently call for an adjustment of the hydrological situation outside the urban areas.

But, also, the municipal authorities must see to it that works which the water board is required to undertake within the scope of its tasks fit in with the policy of the municipal authority. I here have particularly in mind certain aspects of spatial development.

It is clear that where two co-ordinative public-law bodies work within each other's spheres of influence, rules will be necessary in order to safeguard their mutual interests. And these exist. Thus the By-Laws Act obliges the water boards to submit their draft by-laws to the councils of the municipal authorities which are then in a position to signify their approval or disapproval.

At the same time, art. 8 of the Decree relating to Spatial Development specifies that, when preparing their designation and structure plans, municipal authority councils must consult any water boards which in their view are concerned. The latter can then raise any objections they may have. Meanwhile, I would draw your attention to the difference between the By-Laws Act and the Decree relating to Spatial Development: for the water board, a categorical obligation, hwereas the municipal authority is not clearly placed under any obligation.

For our purpose, it is significant that, through the By-Laws Act and the Decree relating to Spatial Development, the water boards and the municipal authorities are given an opportunity to consult and thereby in mutual consultation to seek for the best solutions.

The further administrative determination of the results of such consultation in the form of planning permits, exemptions from the by-laws, permits under the water pollution legislation, etc., is then, apart from any necessity of submitting certain documents, etc. for inspection, a mere formality.

4. PRESENT-DAY PRACTICE IN REGARD TO CONSULTATION AND DESIRABLE ALTERATIONS

What is the present practice in regard to the development of designation plans, especially for residential areas?

Enquiry of colleagues with other water boards has taught me that there is considerable differentiation in the manner of approach.

On the one hand, we find water boards – and I have in mind here especially the water boards in the lower parts of the Netherlands – which for centuries have had strong ties with the municipal authorities, and on the other hand we find relatively young water boards on the higher sandy soils for which contact with the municipal authorities is of much more recent date. Here, as it were, it is a process of habituation.

Fortunately, it is noticeable that even between these latter water boards and the municipal authorities, there is increasing interest in each other's activities, comings and goings.

In general, however, we find in practice today that the designation plan in connection with urbanization only appears with the water boards when this is considered necessary within the scope of art. 8 of the Decree relating to Spatial Development. Unfortunately, we find that, in practice, this consultation is arranged too late for any optimum adjustment to be effected between the designation plan and the provisions concerning water management, either qualitatively or quantitatively. In order to achieve a balanced hydrological arrangement for an urbanized area and the outer area over which it exercises influence, in my view, plans should be developed together with the water boards from the earliest possible stage. This is all the more necessary, now that the water boards frequently, within the scope of water quality control, also have responsibility for waste water treatment. The water boards are not primarily concerned with the content of the plan in terms of physical or spatial planning: they willingly leave this approach to the "Working Group 2000". Rather, their concern is with testing a plan in its development phases at suitable times in connection with aspects concerning water management. The need for consultation with the water board regarding hydrological aspects of the municipal authority's designation plan is becoming increasingly clear.

In order to be able to conduct this consultation fruitfully, it is desirable for the water boards, for their part, to have a water management plan (both qualitative and quantitative).

The hydrological aspects of the designation plan can then be tested against this water management plan. I consider it desirable for a "wet structure plan" for the urban area to be drawn up in this manner in consultation between the water board and the municipal authority.

In my view, it is of the utmost importance for regulations to be evolved over the short term whereby the relationship discussed here between hydrological and spatial development can be administratively determined during urbanization. For this, it will be necessary for consultation between the municipal authorities and the water boards in regard to the structure and designation plan to be made into a categorical obligation.

The Union of Water Boards stressed this point last year on the occasion of the Urbanization Memorandum. Unfortunately, the Government decided not to comply with this request in the memorandum in its final form. I have however heard that the Union attaches great importance to this point and will definitely be reverting to it.

5. QUANTITATIVE AND QUALITATIVE CONSEQUENCES OF AN ABSENCE OF PROMPT CONSULTATION

If there is no prompt consultation, the major and minor consequences, as already suggested, will soon manifest themselves: at the outset, quantitatively, in terms of concern for water management.

In the low-lying areas of the Netherlands, people will know the paths to follow in order to remain dry-shod. I would point here, for example, to the "building development enquiry" of the IJsselmeerpolders Development Authority, in conjunction with the Civil Engineering Department of the University of Technology, Delft [2]. But I doubt whether people in the higherlying areas always sufficiently recognize how it is possible to remain dry-shod.

In my experience of water board practice in North Brabant, examples of this are well known. In the last resource, I am not referring to calamities, but to defects in the plan. What is one to think of the bungalow park laid out in an old fen, where the plots were sold during a dry summer? The consequences in wet periods can be imagined.

Even the realization of a large desination plan, prior to the closing of a river embankment system, brought the water to the front doors when high levels occurred, which however are only to be expected once in x years (where x is certainly greater than 10). These, and countless other occurrences, small or great, can be avoided in the majority of cases if the consultation which I have advocated in the foregoing is undertaken. From case to case, it will then be possible to see how the hydrological and spatial aspects of the urbanization plan can then be adjusted to suit one another.

In the case of structure plans for the whole of the territory of the municipal authority, I have in mind more particularly the water courses plan and/or the water quality plan. In the case of designation plans, especially those for residential areas I have in mind the main lay-out for sewers, with the places for overflows, storage ponds, effluent ditches, etc.

If now consultations are commenced in good time on these aspects, it will be possible to avoid finding in the relative designation plan that these provisions cannot be realized or if they can, then only at very high cost. The exploitation calculations will then be under attack and controversy will be born. An example of this is the designation plan, where the water board was only able to react when it was tabled for inspection: it was found that 2.5 ha. of pond surface was required, as a result of which both the designation plan and the exploitation arrangements had to be drastically altered.

In order to avoid misfortunes of this nature, structured consultation has already been introduced by a number of water boards and municipal authorities on their own initiative. In particular, a report was drawn up by the High Water Authority (Hoogheemraadschap) of "Uitwaterende sluizen in Kennemerland en West-Friesland", in joint consultation with the relative municipal authority on the provisions required for water management. This report is at the same time the bais for the granting of permits by the said Hoogheemraadschap. In my own water board, too, the aim is to achieve a similar degree of consultation. On the other hand, it is obvious that the water boards must allow in their plans for the consequences of these plans for urban development. Was there, not so long ago, not a water authority which had to alter its plans for lowering the level of the polder water because, inter alia, others were concerned at the consequences for the foundation of houses?

Finally, it is a sad example of unco-ordinated policy that the discharge of waste water from the area covered by a new designation plan still temporarily has to take place into the surface water because the treatment engineering (conveying or treatment) is not yet reday, or because a connecting main sewer from the municipal authority is not yet ready, even though the treatment plant is functioning efficiently. In this connection, the Crown's declaration of 3rd December 1976 is of interest, when approval was withheld from part of the designation plan of the Oud- en Nieuw Gastel municipal authority, since as a consequence the discharge of waste water into a ditch would increase unacceptably.

6. FINANCING AND EXECUTION OF ADAPTATION WORKS

In the above, a number of critical marginal notes has been included regarding the preparation of a designation plan. The water boards are not always the ones to point a finger at the municipal authorities. An active and far-sighted water board can avoid many of the above problems by sounding the alarm early.

If the water board is involved at an early stage in the preparation of the designation plan, questions will automatically arise regarding the financing of the works of adaptation required. These questions can only be answered if the task of the water authorities can be clearly defined.

This is clearest in the case of works which are essential for the purpose of rendering effluent harmless through sewerage treatment plants. The water board (or purification board) here has a obvious task and is able to pass the cost on to the polluters (over the whole of the administrative area). The fact that horizontal and vertical delivery points may lead to extensive correspondence regarding the commencement and ending of this task is mentioned here in passing.

It becomes more difficult when the financial and technical consequences of discharging diluted sewerage water through the overflows of combined sewerage systems come to be considered. We shall then find that we are primarily concerned with the views of the local water controller.

These may extend from no overflowing and thus a separate system, to permissable overflow frequencies of 2 to 10–15 times per annum.

It is clear that local circumstances play an important part here. The complex problem of the effects of overflowing water on the quality of surface water leads to here being considerable differences in acceptable overflow frequencies.

It is then also understandable that, as regards the adaptation of older sewerage systems to the desired overflow frequency, there should be some hesitation on the part of quality controllers. The financial consequences are enormous.

With regard to any combatting of negative effects experienced from discharging "overflow water" from a combined sewerage system on the quality of surface water, I take the view that this is the responsibility of the quality controller.

Still dealing with the general acceptation of a combined sewerage system, it is not merely a question of the water quality controller at one end of the sewers only wishing to receive a restricted outflow in order to keep the cost of purification as low as possible, and shifting the consequences of receiving the discharge load over to the municipal authority. The sewerage system will then of course require to be laid out in accordance with generally acceptable principles.

It should be noted that we are here considering future, as yet unforeseeable, consequences of discharging overflow water.

If it is found necessary, during the prescribed consultation on the sewerage plan, to make increased demands of the sewerage plan as a consequence of foreseeable complaints, then this must be considered as a technical sewerage matter and therefore one to be financed by the municipal authority, by means of passing on amounts concerned in the land charges.

It may also be that consultations leads to the only possible choice, namely no discharging of effluent and "therefore" a separate system. In this case, too, the costs of this system should be brought into the designation plan.

In my view, the consequences of inadequate knowledge of the effects of effluent discharge on surface water should be borne by the person responsible for qualitative water control, the more so since the local set of problems may be a consequence of a lack or failure of regulation up-stream.

And it is the water board in particular (and also the responsible Provincial Authorities) which can assess the consequences of quality control over the region. Possibly this view accords with the interpretation of art. 9.3 of the Act relating to the Pollution of Surface Waters (W.V.O.), which refers to compensation for a permit-holder if the consequences of altering or withdrawing a permit cannot *reasonably* be attributed to this fault.

With regard to the quantitive aspect, matters are much more difficult. Each designation plan leads eventually to an accelerated disposal of rainwater. Have the water boards a responsibility in regard to the collection and further disposal of these quantities of urban water?

It has already been stated that the water boards have the task of looding after one or more water control interests. These interests are thus withdrawn from the general task which rests upon the municipal authority. But this does not mean that everything connected with water is withdrawn from the municipal authority's purview. The drawing of dividing lines is however a difficult task.

In a concrete case, namely that of the water board "Regge and Dinkel", the "Dolk Commission" in 1963 gave its verdict regarding the cost distribution of the Hengelo Brooks Plan [3]. It would take us too far to quote all the points in their report, but I would just mention here a couple of their findings since these can be a point of departure valid for all water boards.

On the strength of a number of consideration, the Commission came inter alia to the conclusion that "insofar as the works relate to control of the problem of rapid drainage from urban areas, it is reasonable to see therein a task for a water authority". But again: "Insofar as special interests have to be respected when regulating drainage, or works or measures of third parties call for extra provisions, the increased costs incurred as a result thereof should not have to be borne by the water board, but by the third parties concerned."

The above findings could also serve as a guide to other water boards as to the policy they should pursue.

The fact too that most water boards have a rating system on buildings suggests that there is room for water board initiatives where the disposal of water from urban areas is concerned.

At the initiative of the Union of Water Boards, following the holding of an enquiry, a report appeared in 1974 from which it can be concluded then that the mutual differences between the water boards as regards a conception of their tasks are still considerable.

The reporting commission concerned, on the basis of the results of the enquiry, arrives at a number of recommendations. The most important recommendation, underlining the conclusion of the Dolk Commission, reads as follows:

"In principle, regulation of rapid urban disposal of water is the responsibility of the water board. The extent to which the water authority ought to undertake this task actively, i.e. not solely through its permits policy, but also by making provisions itself or making some contribution thereto, is largely determined by an examination of the building foundations and a quantifying of the effects of drainage from the hardened surfaced on the waterways. From considerations of the responsibilities of water boards the efficiency and uniformity of the administration of justice and the levying of imposts, the water board ought to approach an active conception of its tasks as positively as possible."

The Union's Commission on Water Economy has aligned itself behind the relative report and the recommendations. It will probably be some time before a generally acceptable view will be able to be submitted to the autonomous water boards by the Union Council for the processing of the now faster drained urban water.

Nor can it yet be stated that, where water boards operate a rating of built-up areas, there is also room for the execution of works connected with the realization of expansion plans. This will vary from water board to water board and also depend on the manner in which the rating system is supported and can if necessary be increased.

I am of the opinion that the unity of legal administration calls for the technical opportunities which a water board has for collecting an accelerated outflow of rainwater from urban areas to be distributed of necessity fairly among all interested parties and all who are likely to feel aggrieved. Likewise, extra costs in a specific case should be borne by all. There then arises a parallel with the manner in which costs of waste water treatment are assessed. The following case may help to illustrate this.

A large municipality located on a medium-sized river applies for exemption for the discharging of overflow water into the river. Global studies show that the rises in the level of the river remain within permissible limits. The municipal authority is given permission to discharge into the river without further provisions. Five years later another, albeit small, municipality, just down stream from the first municipality, also applies for exemption for discharging large quantities of rainwater in connection with the development of this community into a growth city. The water board now comes to the conclusion that new peak discharges can no longer be allowed into the river and (indirectly) prescribes storage ponds.

Viewed in the light of the above-mentioned unity of administration of justice, this would definitely appear to be unreasonable. It is desirable that as soon as ever possible more clarity should be provided from the water boards.

7. FUTURE TECHNICAL TRENDS AND QUANTITATIVE AND QUALITATIVE WATER CONTROL

The above clarity is all the more desirable when we turn our attention to future developments.

In many designation plans, the phenomenon of open water is included as a factor, even where, from the point of view of water control, this is not directly necessary.

In all cases, but certainly where open water is used as a catchment for polluted rainwater, these waterways require to be flushed through. In the low-lying areas of the

Netherlands, this generally does not cause any considerable problems, though the problem of silting requires continous attention. The 1976 drought has taught us where, also in those low-lying areas, the bottle-necks occur.

The position in the country's higher areas is different, since there reliance is mainly placed on natural rivulet off-take, and this, precisely in the periods when the waterways require it most, has practically no water to carry.

In addition to water supplies for agriculture (rainfall), the water boards in the higher parts of the Netherlands will also have to include in their policy aspects of flushing surface waters charged with urban effluents.

In the structure plans to be evolved in future for the water management in the Netherlands, considerable thought will require to be directed to this problem in the higher areas. Then too these water boards will be able to draw up a structure plan for the water management, whereby in particular it will be possible to test the qualitative policy.

Nevertheless, in many instances it will not be possible to realize the above opportunities for flushing. In such instances, it will have to be anticipated that consideration will have to be given to reducing the pollution load still accepted today.

In order to increase the appreciation of this "pollution load" and its effects on the environment, STORA has been undertaking an investigation on an ambitious scale. The total cost of this investigation is estimated at N.fls. 3,500,000. The 1st phase has now been started (approximately N.fls. 300,000). At the same time, the Union of Water Boards has taken the initiative in setting up a working group intended to draw up guidelines for a uniform approach to drainage from the hardened surface and for opportunities for processing effluent in the waterways. The working group has not yet commenced its activities. All this should leas to a better insight being gained into the functioning of sewerage systems and their influence on the surface water, both quantitatively and qualitatively.

Only then will it be possible to speak more pertinently on separate systems, improved separate systems, improved combined systems, etc.

In the meantime, it will be necessary to draw up the designation plans for urban development in such a manner that future measures in the sphere of improved quantitative and qualitative control are not excluded in advance.

With this assertion, I find myself once again back at the commencement of my story, where I stated that already at an early stage in the drafting of the designation plan for developed areas, the structures of urban drainage through sewers and open water are required to be known, if the opportunities for future developments are also to be provided for.

It is therefore desirable through team work – this is a topical catch-phrase, I willingly admit it – to accompany the preparation of a new designation plan, with reservation of course of the responsibilities of each of the authorities taking part.

It is well known that "all rain comes from above", but the time when God's water could be allowed to stream over God's fields is past since long.

And finally, I would thank all those who have provided this paper with critical marginal notes, as a result of which it has been possible to interpret the water board concepts in the Netherlands as well as possible. Without support as this, even an author is powerless.

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