PART III: SCREENING OF ALTERNATIVES

Chapter 21

GENERAL APPROACH TO SCREENING

In large policy analysis studies, the number of alternative policies is usually too large to consider each in detail. As a result, such studies often include a step in which a large number of alternatives are evaluated in terms of a small number of impacts to screen out the unattractive ones. The output of this screening step is a relatively small list of alternatives that appear to be "promising"--i.e., are sufficiently sensible and beneficial that they merit a more detailed and thorough evaluation.

In the screening stage of PAWN, the alternatives examined were called *tactics*. Each tactic is a change in the water management system that is designed to meet a particular objective (e.g., reduce agriculture losses from water shortage in the province of Drenthe). The essence of screening, then, is (1) to construct a list of tactics that might turn out to be promising, and (2) to determine which of these are promising by performing broad-brush assessments using a small number of selection criteria.

Our initial list of tactics came partly from prior studies and recommendations by Dutch experts, and partly from a needs assessment carried out by the PAWN team to identify problems with the existing water management system and locations where new tactics might be useful. The selection criteria were related to water management goals and objectives identified for the various regions of the country, and to the overall goals and objectives of the system. The criteria that we used in screening included administrative feasibility, cost-effectiveness, and dominance.

The PAWN study does not attempt to evaluate or screen out tactics on the basis of their political feasibility, even though some of the tactics considered are controversial. (A few exceptions were made where the PAWN guiding group believed that implementing the tactics was politically impossible.) PAWN generally operates under the principle that the degree of public acceptance for each tactic should be assessed by Dutch policymakers and then considered, along with each tactic's costs and benefits, when they compare the different alternatives to select a preferred policy.

Screening is more an art than a science. Since a limited number of tactics are considered and a limited number of selection criteria are used, it is conceivable that a tactic worthy of serious consideration will not even be considered or will be screened out, and that a tactic carried over to the final list will later be found to be unattractive. The results from screening rest to a considerable degree on insight, judgment, and knowledge about the water management system.

The entire process can be compared to the steps most people follow in buying a new house. There are generally too many houses for sale in the chosen city to visit each individually. However, a few basic criteria such as purchase price, neighborhood, and number of rooms will normally reduce the number of alternatives significantly. Then more detailed criteria, such as the heating system, layout of rooms, etc., can be considered for the remaining houses. If one follows this strategy, it is possible that one's "dream house" will be screened out in the first stage (e.g., because the price is slightly too high); but the result is usually quite satisfactory.

For purposes of screening, water management tactics were divided into two sets, each of which was analyzed separately:

- Technical and managerial tactics, which affect the movement and storage of water in the country, such as building a canal or changing the rule for flushing a lake.
- Price and regulation tactics, which affect the allocation of water among users by administrative or legal controls, such as taxing its use, controlling prices, or prohibiting certain activities.

The screening of technical and managerial tactics is described in Chap. 22; Chap. 23 treats the screening of price and regulation tactics.

Chapter 22

SCREENING OF TECHNICAL AND MANAGERIAL TACTICS

22.1. INTRODUCTION

A tactic is a change in the water management system that is designed to meet a particular objective. Technical tactics are those that add to or modify the existing water distribution infrastructure. They require the expansion of existing facilities or the construction of new ones--such as canals, pumping stations, and dikes. The Netherlands has three categories of waterways in the surface water (SW) distribution system:

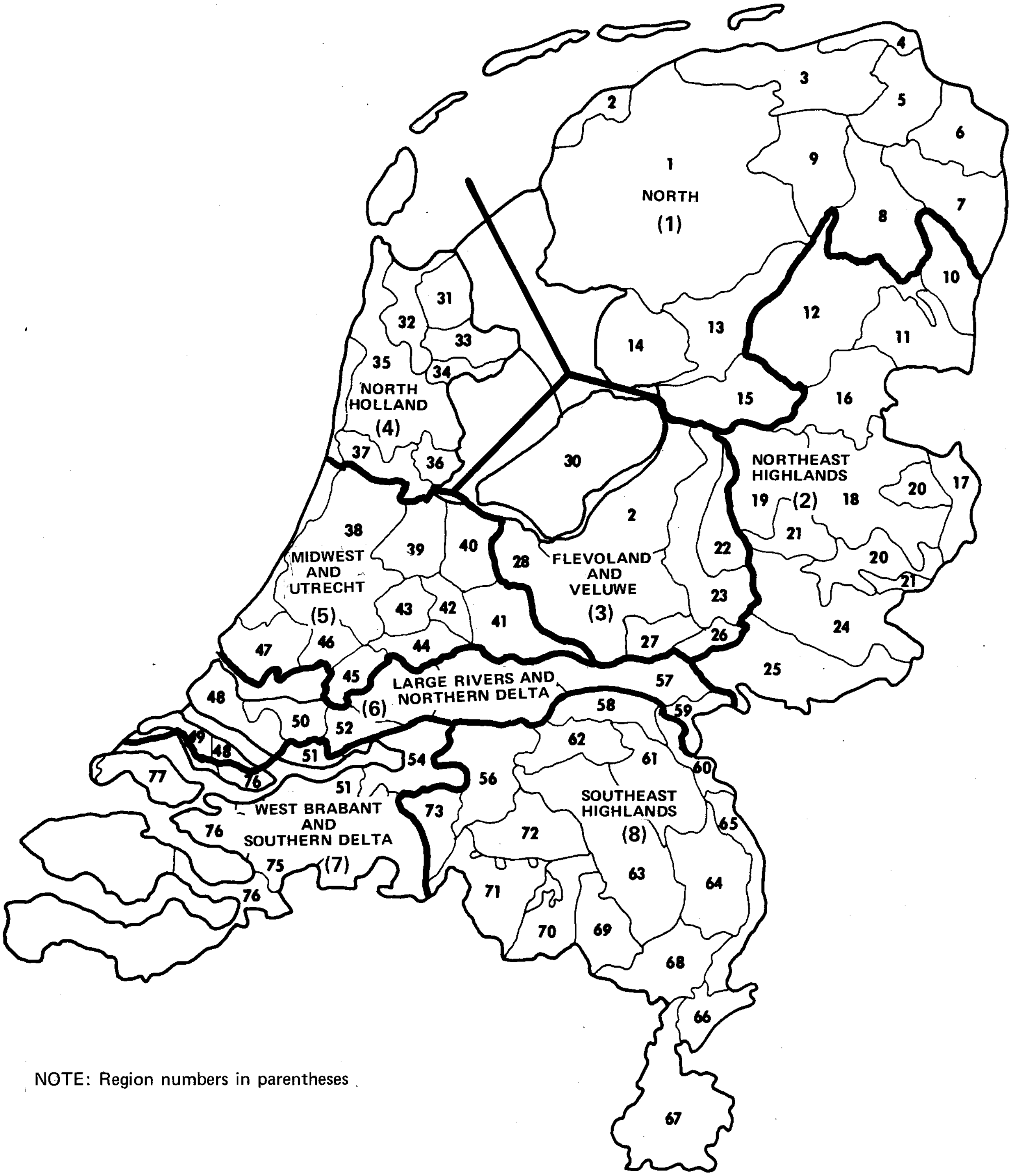
- The national system: large rivers, canals, and lakes.
- The regional system: smaller waterways that distribute water from the national system.
- The local system: the system of ditches that carry water from the regional system to individual farms. Technical tactics for improving the local system are combined in waterboard plans, developed by the local waterboard.

Managerial tactics change the rules that govern the operation of an infrastructure. Weir control strategies, lake level management rules, and flushing rules for lakes and boezems (systems of canals surrounding one or more polders) are all examples of managerial tactics.

The screening analysis concentrated on tactics designed to alleviate two of the country's most pressing water management problems: the shortage and salinity of the nation's SW supply. The significance of specific shortage and salinity problems and how they are manifested differ in different parts of the Netherlands. To identify and analyze tactics to alleviate these problems, we divided the Netherlands into eight regions (see Fig. 22.1). The regions, and the dominant water problem in each, are listed below:

1. North (shortage)
2. Northeast Highlands (shortage)
3. Flevoland and Veluwe (salinity)
4. North Holland (salinity)
5. Midwest and Utrecht (salinity)
6. Large Rivers and Northern Delta (neither)
7. West Brabant and Southern Delta (salinity)
8. Southeast Highlands (shortage)

The process of screening technical and managerial tactics involved the following five steps:



NOTE: Region numbers in parentheses

Fig. 22.1--PAWN districts and analysis regions

- Identification of tactics
- Estimation of the costs of the tactics
- Pre-screening of tactics
- Estimation of the benefits of the remaining tactics for different scenarios
- Comparison of the costs and benefits of the tactics; unpromising tactics are screened out and promising tactics are passed on for further analysis

Each of these steps is discussed below. A detailed description of the screening of technical and managerial tactics is contained in Vol. II.

22.2. IDENTIFICATION OF TACTICS

Our first task was to assess the major national and regional water management problems in the Netherlands. These efforts culminated in the description of the problems of shortage, flood, salinity, and quality (see Chap. 1). We then compiled a list of tactics designed to resolve the major shortage and salinity problems.[1] This task required an extensive review of proposed solutions. Several general RWS reports provided initial insights. We also consulted a large number of technical reports and documents dealing with tactics that were already being considered. We acquired an inventory of waterboard plans, based on a survey done in 1978 by the country's Unie van Waterschappen (Union of Waterboards).

Our most useful sources of suggestions were the discussions and meetings we had with Dutch water management experts. Early in the project a formal working group of such experts, called the Netherlands Support Group (NSG), was organized to provide information and guidance to the screening activities. It was composed of representatives of the various districts of WW (the Water Management and Movement Directorate of the RWS) and met on a regular basis. The NSG helped us to compile the list of tactics, supplied data needed to perform the analysis, and commented on our results as they were developed.

In a few cases our search for tactics to solve a specific problem did not reveal any previously proposed candidates. In these cases we designed tactics and asked the NSG to comment on their feasibility and reasonableness and to suggest improvements.

This step of the screening process produced a list of 65 waterboard plans[2] and 57 other tactics that were analyzed in succeeding steps. Information on the waterboard plans is given in App. B of Vol. II; the other tactics are listed in App. C of this volume.

Note that we sometimes refer to these other tactics as "major" technical and managerial tactics to distinguish them from more localized tactics such as waterboard plans or lock tactics.

22.3. ESTIMATION OF THE COSTS OF TACTICS

The survey of waterboard plans provided an estimate of the investment costs necessary to implement each plan. With no other cost information available, we assumed that the annual fixed cost of each plan was 10 percent of the total investment cost.[3] This amount is meant to include both fixed and variable operating costs. We assumed that the operating costs would be small. The costs of the waterboard plans are given in App. B of Vol. II.

For all of the other tactics, we made separate estimates of (1) investment costs (one-time outlays to build the required facilities), (2) fixed annual operating costs (the costs to staff and maintain the facilities), (3) and variable operating costs (the energy cost to operate the facility). Our general estimation approach in described in Chap. 3.

In comparing the costs and benefits of a tactic we generally used a tactic's annual fixed cost and ignored its variable operating costs. We did this because the operating costs (mainly the cost of electricity to run the pumps) were almost always very small relative to the fixed costs (10 percent or less). In the few cases in which operating costs represented a large proportion of a tactic's expected annual cost, we included the operating costs in the analysis.

We also generally ignored long-run costs other than the previously defined fixed costs because they were small. For example, the loss functions in our analysis consider only the short-run costs to shipping from implementation of the tactics, not the long-run costs that would result from the need to change the shipping fleet; a supplementary analysis of this assumption indicated that the shipping losses with and without the long-run costs are approximately the same.

The annual fixed costs of the 57 non-waterboard plan tactics evaluated in the screening analysis are given in App. C, along with information about their effect on capacity. A detailed description of how the cost of the tactics was determined is given in Vol. XVI.

22.4. PRE-SCREENING OF TACTICS

In screening, we generally used the reference assumptions for the rest of the scenario as described in Chap. 20, but we did some sensitivity analysis using alternative values mentioned there. In addition, we made several assumptions about demands for SW by drinking-water (DW) companies and demands for groundwater (GW) by industry and by DW companies that were used only for screening.[4]

The major analytic tool that we used in screening technical and managerial tactics was the DM, a detailed simulation model of the SW system of the Netherlands. This model is described in detail in Chap. 4. Since it is a costly tool to use, we sought to limit the number of tactics and combinations of tactics that would have to be tested using the model.

First, we focused on agriculture and shipping. Agriculture is the largest consumer of fresh SW; that sector uses nine times more water that do DW companies and 50 times more than is used by industry. (Industry and power plants use comparable or greater amounts of brackish water.) Thus agriculture suffers most from water shortages, and its salt-sensitive crops make it most vulnerable to salinity. Shipping, although it does not consume water, is also affected by low water levels on the nation's waterways.

Table 22.1 shows the estimated losses that agriculture and shipping suffer because of water shortages and salinity. The first column estimates the losses experienced in 1976, an extremely dry year. The second column shows the estimated losses in 1967, a year with average rainfall and river flows. The third column shows the losses in 1943, which, as argued in Sec. 5.5, approximate the expected losses averaged over all years. It is clear that the losses to agriculture from water shortage and salinity are orders of magnitude greater than losses to shipping and are considerable even in an average year. For this reason, most of the tactics we examined were designed to increase the quality or quantity of water supplied to agriculture.

The second way in which we limited the number of tactics to be tested was to use pre-screening procedures. These procedures allowed us to identify tactics that were clearly unpromising--i.e., tactics whose costs were clearly greater than their benefits.

Table 22.1

ESTIMATED AGRICULTURE AND SHIPPING LOSSES
(In Dflm)

Type of Loss	1976	Average Year	Expected Loss
Agriculture			
Shortage	6,218	532	1,424
Salinity	482	270	306
Shipping			
Low water	52	2	1
Lock delays	19	0	0

22.4.1. Pre-screening of Waterboard Plans

Agriculture accounts for more than 80 percent of the average demand for SW in the Netherlands. Demand on the national SW system can only come about if a given agricultural area has a local SW system that can be supplied from the national system. Hence, to determine present and future demand for agricultural water, one needs to know:

- The extent of the local SW systems that can be supplied from the national system

- What parts of the areas that can be supplied will have sprinkler equipment installed

The 65 waterboard plans in our inventory would affect the networks of ditches that carry water to individual farms and the inlet works and small waterways that connect the ditch network to the regional water distribution system. Plans actually implemented would increase the area that is eligible for SW sprinkling. Pre-screening was designed as a relatively inexpensive first pass through the waterboard plans, eliminating those whose costs were greater than the benefits. A final judgment on the remaining plans could be withheld until a more accurate assessment of their worth could be made in the regular screening process. Those plans that regular screening showed to be cost-effective would become part of the screening process for the other tactics: The area eligible for SW sprinkling is one of the components of the sprinkler scenario (see Sec. 22.4.3).

For each plan, the pre-screening process asked the following question: Over the long term, would the increased sprinkling made possible by the plan reduce crop losses sufficiently to offset the cost of the plan and the cost of the new sprinkling equipment? The key factor in determining both the reduction in crop losses and the cost of sprinkling is the sprinkler intensity--the proportion of the newly eligible area in which farmers actually install sprinkling equipment. Several different assumptions about sprinkler intensity were used in PAWN; for pre-screening, we assumed a high intensity of sprinkling (SPRHI). Assuming high intensity ensured that the estimate of benefits for a plan represented an upper bound.

Using the SPRHI assumption, we estimated the expected annual agricultural benefits, then compared the benefits to the plan's expected annual cost. If the expected benefits were less than the expected costs, the plan was eliminated from further consideration. Applying this procedure to the 65 plans resulted in a total of 46 promising waterboard plans. These plans were included in two of the sprinkler scenarios used to screen the non-waterboard tactics.

Figure 22.2 shows the approximate location of the 65 waterboard plans (their actual area is generally smaller) and the results of their pre-screening. About three-quarters of the plans (and of the promising plans) are located in the North, the Northeast Highlands, and the Southeast Highlands, since these are the regions that currently have the least access to SW for sprinkling. Implementing plans in regions 7 and 8 (West Brabant and Southern Delta and the Southeast Highlands) was particularly promising: Plans implemented in those areas alone provided twice the expected annual benefits of all the other promising plans combined.

Pre-screening was designed to reject clearly unpromising plans. When uncertainties arose, we made optimistic assumptions. We performed some analyses to test the sensitivity of the results to certain of these assumptions.

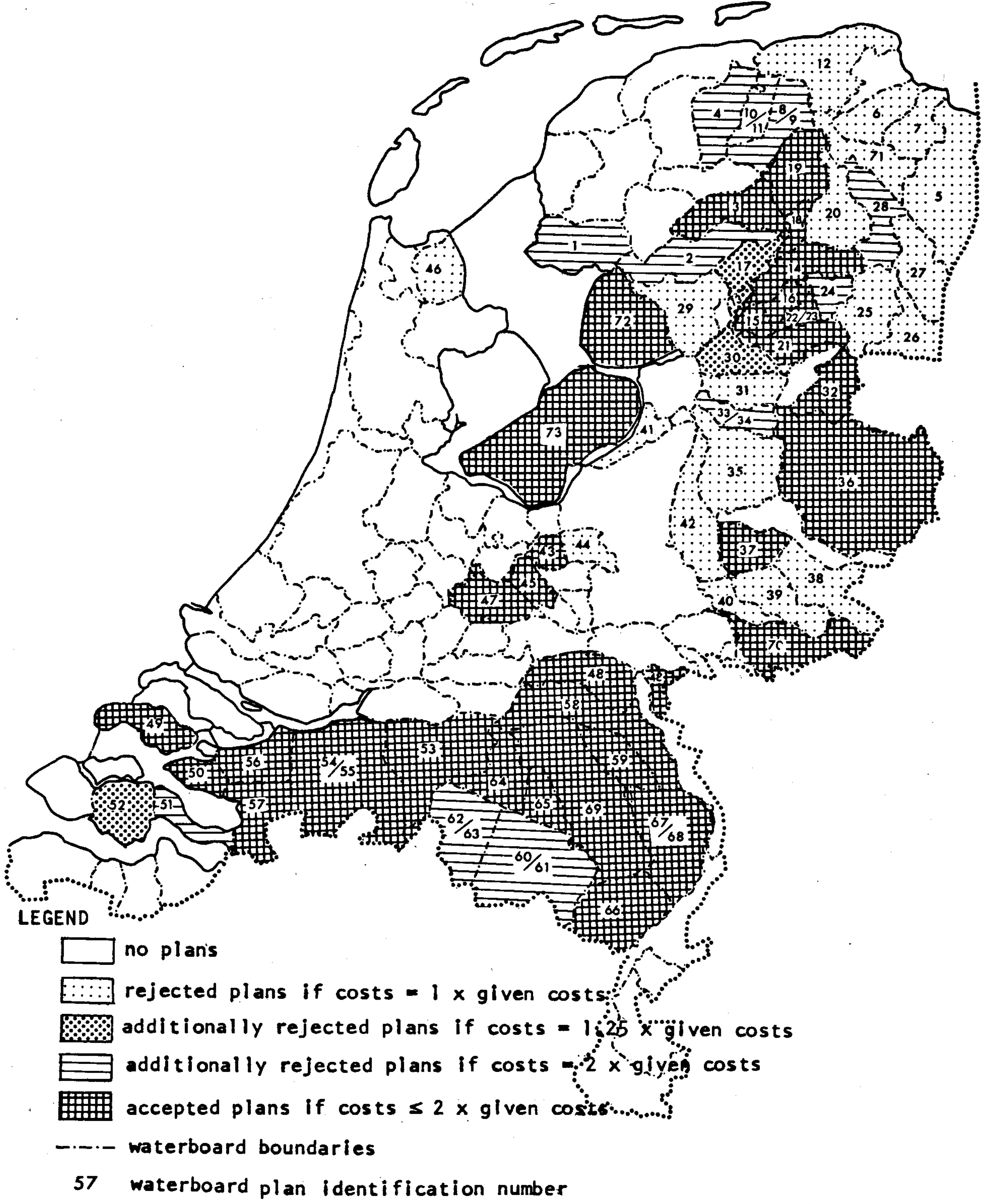


Fig. 22.2--Approximate location of waterboard plans and results of their pre-screening

Sensitivity to the Benefit Viewpoint. It could be argued that the benefits of the waterboard plans should be looked at from the point of view of the farmer, not the nation, since the farmers belonging to the waterboard may pay the cost of implementing a waterboard plan. We repeated the pre-screening, using this different benefit viewpoint. We included tax payments, deductions, and credits when calculating the expected annual benefits from sprinkling, and we assumed that farmers could deduct the annual investment cost of a waterboard plan from their income taxes.

This change in assumptions did not change the results of the analysis. The same plans were accepted as in the original pre-screening. (Reference 22.4 was specially prepared to summarize the costs and benefits of promising plans from both the farmers' and the nation's viewpoints.)

Sensitivity to Costs. We had reason to believe that the estimates of the costs of implementing the waterboard plans were low--perhaps as much as 50 percent. To investigate the effect of different cost estimates, we repeated the calculation of net plan benefits with costs that were inflated by a factor of 1.25 and 2, respectively. Figure 22.2 shows the results of the sensitivity analysis. Increasing the costs by 25 percent caused an additional four plans to be screened out. Doubling the costs dropped 10 additional plans, i.e., 14 more than in the base case.

These results indicate a sizable, but not extreme, sensitivity to the cost estimates.

Sensitivity to the Grass Multiplier. Benefits from sprinkling grass are highly affected by the introduction of the grass multiplier, which essentially doubles the gross benefits. Since grass is a very important crop in most plan areas, the pre-screening results are likely to be very sensitive to changes in assumptions about the grass multiplier. We calculated new optimal sprinkler intensities (lower than SPRHI) using the original crop values without the multiplier. We used these new intensities and the grass value without the multiplier to reestimate the benefits of the waterboard plans. Without the multiplier, only 20 waterboard plans remained promising.[5] Pre-screening results are extremely sensitive to assumptions about the grass multiplier. (These results were not reported in the December 1979 final briefing because the analysis was not completed until later.)

22.4.2. Benefits from Implementing Promising Waterboard Plans

The analysis that identified the 46 promising waterboard plans did not consider the limitations imposed on plan benefits by low river flows, lake levels, or supply capacity. We wanted to determine if the promising plans (as a group) would still be considered promising if cutbacks because of limited availability of water or limited supply capacity were taken into account. We therefore used the DM to estimate the benefits from implementing the promising waterboard plans under four external supply scenarios and for the low and high sprinkler intensities. (The external supply scenarios are discussed in detail in Chap. 5. DEX is an artificially constructed, worst-case "extremely dry" year; 1959 is a "very dry" year; 1943 is a "moderately dry" year; 1967 is an "average" year.) For each sprinkler intensity, we used the shortage loss probabilities associated with the external supply scenarios to obtain upper and lower bounds on expected annual net benefits from the waterboard plans. Net benefits = reduction in crop losses (gross benefits) minus the plans' investment costs and the investment and operating costs for the sprinkler equipment. Throughout screening, estimates of agricultural benefits were based solely on DM runs. We did not take into account the market effects used to calculate benefits with BENCOMP because we assumed that these effects would be too small to be relevant for screening. In impact assessment, we include market effects in our calculation of agricultural benefits (see Sec. 30.2).

The results of this analysis are presented in Table 22.2. The table shows that for either sprinkling scenario, implementing the promising waterboard plans would produce significant benefits for the country. The benefits increase as the sprinkler intensity increases.

Table 22.2

EXPECTED ANNUAL NET BENEFITS FROM IMPLEMENTING
PROMISING WATERBOARD PLANS
(In Dflm)

Sprinkler Intensity	DEX	1959	1943	1967	1965(a)	Benefits Upper Bound	Benefits Lower Bound
SPRLOW	298.0	222.9	49.5	-2.3	-34.5	72.0	10.3
SPRHI	545.5	453.5	102.2	4.7	-61.7	146.3	27.0

(a) Although we assumed that no reductions in agriculture shortage losses would be obtained from sprinkling in an extremely wet year, the investment costs must be amortized over all years, resulting in these negative net benefits in a wet year.

22.4.3. Pre-screening of National and Regional Tactics

Other than the waterboard plans, all of the tactics examined in the screening analysis involved changes to the national and regional water distribution systems. The pre-screening procedure that was used for these tactics was to estimate the maximum benefits that could be obtained from implementation of a tactic designed to reduce agriculture shortage losses in a particular part of the country. If the tactic's cost was greater than the maximum benefits that it could produce, it was not considered any further.

The benefits from a tactic are defined as the difference between the losses to agriculture and shipping without the implementation of the tactic and the losses to agriculture and shipping if the tactic is implemented. An increased supply brought about by a tactic means that in years with low rainfall, a smaller proportion of the crops will die due to an insufficient amount of water. The benefits from increased supply are therefore measured in terms of reduced shortage losses. A reduction in the salinity of water supplied to agriculture will result in a smaller proportion of the crops being damaged by salt. Thus, the benefits from reduced salinity are measured in terms of reduced crop losses due to salinity damage.

The benefits from a tactic vary from year to year depending on the rainfall and river flows. For example, tactics designed to reduce agriculture shortage losses will produce higher benefits in dry years than in wet years. Thus, since river flow and rainfall vary from year to year, the benefits of a tactic for any year are unpredictable. To compare a tactic's benefits to its cost, we need to estimate its expected benefits (the average over many years). Our approach, which is described below, produces upper and lower bounds on the expected annual benefits by taking weighted averages of the benefits in four external supply scenarios (DEX, 1959, 1943, and 1967). (The 1965 scenario, that for an "extremely wet" year, is not included because we assumed there would be no benefits from a tactic designed to reduce water shortage in any year wetter than 1967.)

For each region and several demand and supply scenarios, we used the DM to estimate the agriculture shortage losses that would occur (1) with the current water management infrastructure, and (2) if the infrastructure were expanded so that the SW sprinkling demand could be fully met. The difference between the two estimates of shortage losses would be the maximum amount of losses that the implementation of tactics would be able to prevent. We call this difference the preventable losses for the given region and set of scenario assumptions.

Whether or not a tactic is promising depends on what the future demands for SW will be--and, in particular, on what agriculture's use of SW for the sprinkling of crops will be. We performed our pre-screening analysis using four of the six sprinkler scenarios originally defined in Sec. 20.4. In the order listed below, they imply increasingly large demands for SW.

- SPRLOW-RNONE, which approximates the current situation in the Netherlands.
- SPRLOW-RALL, which assumes that the promising waterboard plans are implemented and that sprinkling at current levels of intensity is carried out in all areas thus made eligible for SW sprinkling, as well as in those currently eligible.[6]
- SPRHI-RNONE, which assumes that the sprinkler intensity is increased to the high (optimal) sprinkler intensity in all areas currently eligible for SW sprinkling.
- SPRHI-RALL, which assumes that the eligible area is expanded by implementing the promising waterboard plans, and that the sprinkler intensity in the eligible area is increased to the high sprinkler intensity.

For any given sprinkler scenario, we used the drought damage probabilities in Table 5.1 associated with the external supply scenarios to obtain an upper bound on the expected annual agriculture shortage losses that could be prevented in the region by the implementation of technical tactics. Letting L(y) be the preventable losses in year y, the upper bound on the expected annual preventable losses (UB) can be obtained from the losses and drought damage probabilities by

$$UB = .07L(DEX) + .14L(1959) + .42L(1943) + .37L(1967).$$

This upper bound represents the maximum benefits that could be expected from any tactics designed to reduce water shortage in the region. If the maximum benefits for a case (a specific combination of region and sprinkler scenario) were small, we did not consider tactics for that case any further. Thus, we were able to screen out a large number of potential tactics without evaluating them explicitly.

Table 22.3 presents the maximum benefits by region for each of the four sprinkler scenarios. Two important conclusions can be drawn from the results in this table.

Conclusion 1. Preventable losses are generally greater with promising waterboard plans implemented (RALL) than without them (RNONE); and they are greater with a high sprinkler intensity (SPRHI) than with a low intensity (SPRLOW). The reason for this is as follows: If there are preventable losses under the SPRLOW-RNONE scenario, this implies that some agricultural areas sprinkled with SW cannot get all of the water they need to prevent crop damage. An increase in such an area's supply capacity after an increase in its amount of sprinkler equipment (as a result of expanding the eligible area or increasing the sprinkler intensity) leads to larger potential benefits than would occur without

Table 22.3

UPPER BOUND ON EXPECTED ANNUAL PREVENTABLE LOSSES
(In Dflm)

	SPRLOW		SPRHI	
Region	Without WB Plans	With WB Plans	Without WB Plans	With WB Plans
(1) North	0.0	0.0	2.8	7.5
(2) Northeast Highlands	0.2	0.6	6.8	19.9
(3) Flevoland and Veluwe	0.0	0.0	0.0	0.2
(4) North Holland	0.0	0.0	0.4	0.7
(5) Midwest and Utrecht	0.8	0.8	4.2	4.2
(6) Large Rivers and N. Delta	0.0	0.0	0.3	0.3
(7) W. Brabant and S. Delta	1.4	0.0	1.7	0.5
(8) Southeast Highlands	0.5	3.7	2.9	28.1
Total	2.9	5.1	19.1	61.4

the increase in sprinklers. These potential benefits are what we have called the preventable losses.

In region 7, the preventable losses decrease with the implementation of waterboard plans. The main purpose of the waterboard plans in that region is to create supply capacity to the eligible area from the fresh Zoommeer. Since that supply capacity can be made large enough to supply all the demands for Zoommeer water, preventable losses in the region are reduced to near zero in the RALL cases.

Conclusion 2. With the exception of regions 7 and 8, the potential benefits from technical tactics are almost nil under the low sprinkler intensity scenarios. Since the low sprinkler intensity was chosen to correspond roughly to the current level of sprinkling in the Netherlands, this result implies that few if any technical tactics are needed to alleviate agriculture shortage losses in the present situation. In the detailed screening of tactics we therefore limited our analysis to the high sprinkler intensity scenarios, except for tactics involving regions 7 and 8. Since the maximum benefit for regions 3 and 6 in all cases was very low, we did not analyze any technical tactics for reducing agriculture shortage losses in these two regions.

22.5. ESTIMATION OF BENEFITS FOR TACTICS THAT SURVIVED PRE-SCREENING

We used the DM to estimate the expected annual benefits for the tactics that passed pre-screening. The DM calculates the water flow in the major rivers and canals, the levels of the lakes, and the concentration of salt in these waters, and uses this information to determine the agriculture shortage and salinity losses, and losses to shipping from low water flows and lock delays.

To obtain the upper bound for expected annual benefits, we assumed that the benefits in DEX would be obtained in all years drier than 1959; the benefits in 1959 would be obtained in all years between 1959 and 1943 in dryness; etc. Treating a tactic as promising if its annual fixed cost is less than the upper bound on expected annual benefits is therefore very conservative. This is risk-averse behavior--as if we expect a year as bad as DEX to occur once every 11 or 14 years instead of once every 50 years. For the lower bound we assumed that the DEX benefits would be obtained in all years drier than DEX; 1959 benefits would be obtained in a year between DEX and 1959 in dryness, etc.; we also assumed that there would be no benefits from the tactics in any year wetter than 1967.

Letting B(y) be the benefits obtained in year y from implementing a tactic, the formulas for upper and lower bounds on the expected annual benefits (EAB) are:

For shortage losses:

$$
\begin{aligned}
&.02B(DEX) + .05B(1959) + .14B(1943)\\
&+ .42B(1967) < EAB < .07B(DEX) + .14B(1959)\\
&+ .42B(1943) + .37B(1967)
\end{aligned}
$$

For salinity and shipping losses:

$$.02B(DEX) + .07B(1959) + .04B(1943) + .44B(1967) < EAB < .09B(DEX) + .04B(1959) + .44B(1943) + .43B(1967)$$

22.6. COMPARISON OF COSTS AND BENEFITS

22.6.1. The General Procedure

The final step in the screening process is to compare the annual fixed cost of a tactic with the upper and lower bounds on the expected annual benefits. If the fixed cost exceeds the upper bound, the tactic is clearly not promising. We have chosen to consider a tactic promising if the annual fixed cost is less than the upper bound; however, we recognize that unless the cost is less than the lower bound, the expected annual benefits may in fact be less than the annual fixed cost. A decisionmaker who was concerned only with the expected annual benefits of a tactic would be inclined to reject the tactic if its costs were between the upper and lower benefit bounds. However, a decisionmaker who is risk-averse (i.e., is willing to pay more than the expected annual benefits to avoid a large loss in a very dry year) might still want to accept the tactic under those conditions. Thus, the list of promising tactics includes all tactics whose upper bounds on expected annual benefits exceed their annual fixed cost, and this might include some whose expected annual benefits would actually be somewhat less than their annual fixed cost.

22.6.2. An Illustration: The Krimpenerwaardkanaal

To illustrate how we compared costs and benefits, we summarize the analysis of one of the technical tactics--building a canal through the Krimpenerwaard to reduce agriculture salinity losses in region 5 (Midwest and Utrecht).

Some of the country's most valuable crops are grown in this region--the world renowned Dutch bulbs (tulips, hyacinths, etc.), vegetables under glass (mainly tomatoes, cucumbers, and lettuce), and flowers under glass (mainly roses, carnations, and chrysanthemums). All are quite sensitive to salt. The principal inlet point for the region's boezems is located along the Hollandsche IJssel at Gouda.

Salinity in the region's SW system is a major problem. The high salinity is due mainly to the upward seepage of saline GW. In some years low Rijn flows allow the Rotterdam salt wedge (see Chap. 11) to reach the mouth of the Hollandsche IJssel, whence it is carried through the Gouda inlet and into the region's boezems. This further increases the salinity of the boezems and causes considerable damage to the region's crops. There are some alternative supply routes that can be used to transport Rijn-salinity water to the Midwest boezems during such emergencies, but their capacity is insufficient to supply all of the region's demands.

Building a canal through the Krimpenerwaard is one of the tactics that has been proposed for alleviating this problem. Its possible usefulness was mentioned in a 1967 RWS report, and a number of specific designs were examined by an RWS working group studying alternatives to the Gouda inlet. The design we evaluated in the screening analysis was the one favored by this working group. It has a capacity of 40 m^3/s and follows the route shown in Fig. 22.3. Using cost estimates prepared by the working group, we found that the annual investment cost of the canal (in 1976 guilders) was 5.2 Dflm, and its fixed annual operating cost was 0.5 Dflm, resulting in an annual fixed cost of 5.7 Dflm.

The benefits from the canal were measured by the reduction in agriculture salinity losses in the Midwest and Utrecht. These benefits are partially offset by increases in shipping losses caused by reduced flows on the Waal. The Krimpenerwaardkanaal would require transportation of additional water from the Waal to the Lek through the Amsterdam-Rijnkanaal because there would not always be enough water available on the Lek in the section along which the extraction point for the new canal is located. Extraction of this additional water from the Waal at Tiel would increase low-water shipping losses during periods of low flow on the Waal (which are the periods when the new canal is needed most).

DM runs were made with and without the Krimpenerwaardkanaal using the SPRHI-RALL sprinkler scenario for the DEX, 1959, and 1943 external supply scenarios. (No year wetter than 1943 was run because it was clear that the canal would not be needed in such years.) The differences between the salinity and shipping losses in the two sets of runs (with and without the canal) were used as the benefits to be derived from building the canal. Table 22.4 presents the results obtained from these runs, as well as the upper and lower bounds obtained by applying the formulas given in Sec. 22.5 to these results.

The numbers in Table 22.4 provide several important insights. First, the salt wedge is a serious problem only in an extremely dry year such as DEX. Second, the increased losses to shipping on the Waal from this tactic are significant. In fact, in 1959 and 1943 they outweigh the reductions in salinity losses that the tactic achieves. Finally,

Table 22.4

COMPARISON OF BENEFITS AND COSTS OF BUILDING A KRIMPENERWAARDKANAAL (HIGH SPRINKLER INTENSITY, WITH WATERBOARD PLANS)
(In Dflm)

	External Supply Scenario				Expected Annual Benefits		Annualized
Type of Benefit	DEX	1959	1943	1967	Upper Bound	Lower Bound	Fixed Cost
Salinity	41.5	0.2	0.0	0.0			
Shipping	(6.9)	(2.4)	(0.3)	0.0			
Net	34.7	(2.2)	(0.3)	0.0	2.9	0.5	5.7

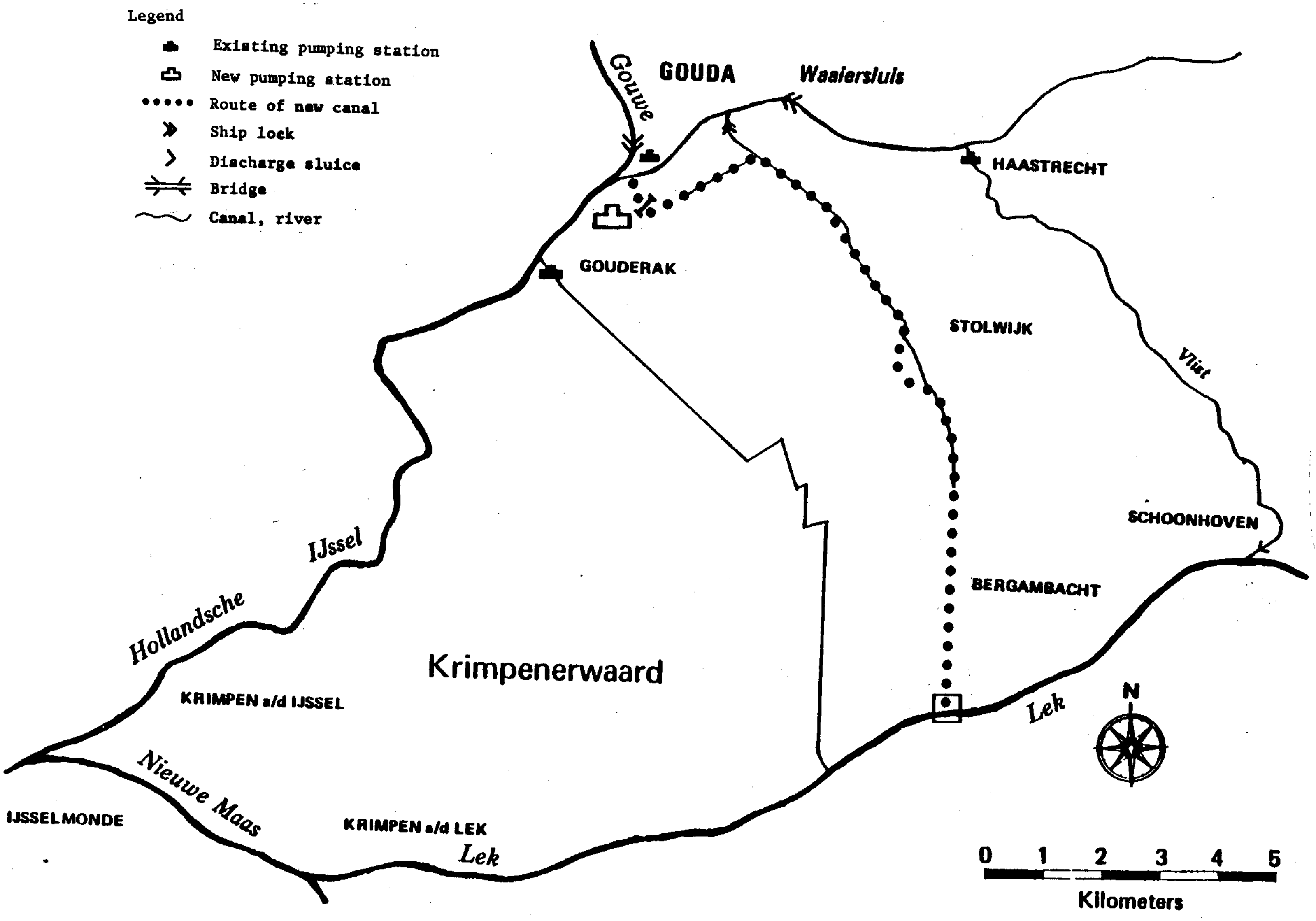


Fig. 22.3--Krimpenerwaardkanaal route

a comparison of the tactic's expected annual benefits with its annual fixed cost shows that it is not a promising tactic. It was therefore set aside--i.e., not examined further in later stages of PAWN.

22.7. SUMMARY OF SCREENING RESULTS

The purpose of the screening phase of PAWN was to select from the large number of potential tactics a reasonably small number that merited more detailed evaluation. In this section we discuss these promising tactics and draw some general conclusions.

The SPRHI-RALL scenario produces the highest demand for SW, which leads to the highest agricultural losses from shortage and salinity, and the highest shipping losses from low water levels. As a result, the benefits from implementing technical and managerial tactics are the greatest for this scenario and the list of promising tactics is longest. However, in every case, we were able to identify one of the alternatives as dominant--more attractive than the other promising tactics.

There were few tactics that were worth considering further under the SPRLOW-RNONE scenario. Most of the tactics we identified as promising are promising only if the system is stressed by the high demands represented by the SPRHI-RALL scenario.

Included in our study were several large and very costly tactics, some of which had total investment costs of well over 200 Dflm and have been under consideration by the RWS for many years. We found only one such expensive tactic to be promising (tactic 9 in Sec. 22.7.3). All the other promising tactics had investment costs of less than 80 Dflm, and most were considerably below this amount.

Except for a few very inexpensive national tactics, most of the promising tactics primarily affect a single region. This suggests that the national water management infrastructure is functioning rather well, and that future water management analysis and policymaking should be focused more on regional water management problems.

In the remainder of this section we shall summarize the screening results. First we identify a new policy for flushing the Markermeer, one of the few inexpensive national tactics found promising. Then we identify the dominant promising tactics in turn for different sprinkler scenarios. By <u>dominant</u> we mean the following: In many instances there were several alternative solutions to a given water management problem. (For example, there were five alternatives evaluated for expanding the supply capacity to the Northeast Highlands.) Sometimes more than one of these alternatives was found to be promising. However, in every case we were able to identify one of the alternatives as dominant--that is, more attractive than the other promising alternatives for some reason, usually because it had a higher benefit/cost ratio.

22.7.1. A New Policy for Flushing the Markermeer

The current managerial strategy is the current set of managerial rules used by the RWS to manage the infrastructure. It includes a policy to reduce the salinity of the Markermeer by flushing it with large quantities of water (up to 70 m^3/s) from the IJsselmeer (see Sec. 1.4). In the early stages of our analysis, we discovered that such flushing creates some serious problems. In dry years, heavy flushing early in the summer leads to cutbacks in extractions from the IJsselmeer and Markermeer later in the summer, causing large agriculture shortage losses. We decided to evaluate a change in this strategy--to flush more than 10 m^3/s only when the lakes were at their target level. This change would decrease shortage losses in all areas extracting from the IJsselmeer and the Markermeer in any year in which the current flushing policy would have made the lakes so low that sprinkling water extractions would have been reduced. The change would also increase the salinity losses in North Holland in such years.

We used the DM to ascertain whether the reduction in shortage losses would be greater than the increase in salinity losses. The results showed that in very dry years the new flushing rules would considerably reduce the shortage losses and only slightly increase the salinity losses. The upper bound for the expected annual benefits is 2.5 Dflm; the lower bound is .7 Dflm. Since the net benefit was positive and could be implemented at essentially no cost, we assumed that this tactic would be implemented. We therefore designed a new managerial strategy, called the RWS managerial strategy, that embodied the new flushing rule. We used this new strategy in the rest of the screening exercise.

22.7.2. Dominant Promising Tactics for All Sprinkler Scenarios

A few tactics are promising candidates no matter what the sprinkler scenario. For example, when designing policies for impact assessment, it would clearly be worthwhile to consider the 46 waterboard plans that the pre-screening analysis identified as promising.

Our analysis of technical and managerial tactics identified six that deserved to be explored in more detail no matter which of the four sprinkler scenarios was assumed for the future. The six are:

1. Change the policy for flushing the Markermeer. (See Sec. 22.7.1.)

2. Use portable pumps during periods of low flows on the Julianakanaal to recycle water at the Maasbracht lock. This tactic, which has already been implemented by the RWS, reduces shipping losses on the canal due to delays at the Maasbracht lock when there is not enough flow to lock ships through quickly. It enables what water there is to be reused. Portable pumps are mounted on a barge, which is placed in one of the lock chambers.

3. Construct a groin[7] in the Nieuwe Waterweg. According to our analysis, this tactic, by reducing the intrusion of the Rotterdam salt wedge, would eliminate approximately 75 percent of the agriculture salinity losses in the Midwest.

4. Redirect Wieringermeerpolder discharges to the Waddenzee. The discharges of the Wieringermeerpolder are the most saline of any of the polder discharges entering the IJssel lakes. This tactic would divert these discharges to the Waddenzee, resulting in significant decreases in agriculture salinity losses in North Holland.

5. Dredge the Waal below Tiel. This very inexpensive tactic would allow water to be extracted at Tiel for transport along the Amsterdam-Rijnkanaal without the associated shipping losses due to the build-up of sediment in the Waal below Tiel.

6. Raise the Flevoland dike. This tactic was found to be the least expensive and most worthwhile way to provide Flevoland with adequate protection from floods that would occur if the Markerwaard is not built and the Markermeer overtops the current dike.

These six tactics include two designed to reduce agriculture losses from salinity; one that will reduce agriculture shortage losses; two that will reduce shipping losses from low water; and one that is designed to reduce the chance of flooding. The last tactic is the most costly, having an annual fixed cost of 5.3 Dflm. The combined annual fixed cost of the other five tactics is only 2.2 Dflm.

22.7.3. Dominant Promising Tactics for Scenario with High Sprinkler Intensity and Promising Waterboard Plans

We used the SPRHI-RALL scenario to produce the highest demands for SW that can reasonably be expected in the future. This scenario represents a tripling of the percentage of cultivated area with sprinkling equipment. The existing SW distribution network does not have adequate capacity to meet the demands that would occur in dry periods. As a result, the preventable agriculture shortage losses are very high, and considerable benefits could be realized from implementing tactics. We identified eight more tactics that merited more detailed analysis.

7. Expand the throughput capacity of the Van Starkenborghkanaal by 9 m^3/s. SW for Groningen is transported from the IJsselmeer through a series of canals. The bottleneck in the route occurs on the Van Starkenborghkanaal at Gaarkeuken, where the current throughput capacity at the shiplock is 16 m^3/s. Expanding this capacity to 25 m^3/s

would eliminate about 60 percent of the preventable shortage losses in Groningen in an extremely dry year.[8]

8. Expand supply capacity to the Northeast Highlands by 15 m^3/s. Agriculture shortage losses in this region are high even in average years. This tactic would expand the capacity of the supply route from the IJssel River, through the Twenthekanaal and Overijsselsch Kanaal, to Drenthe. It would eliminate almost 80 percent of the preventable shortage losses in the region in an extremely dry year.

9. Build a water supply pipeline from the Maas to Delfland. This tactic would enable up to 8 m^3/s of low salinity Maas water to be transported to Delfland, an area in the Midwest in which the most valuable crops in the country are grown. Implementation of the tactic would significantly decrease agriculture salinity losses in all years.

10. Make the Grevelingen a freshwater lake. This tactic would enable farmers in areas adjoining this large (currently saltwater) lake to obtain fresh water for sprinkling on their crops. It requires construction of an inlet to the lake to allow fresh water to continually flush it, and implementation of a waterboard plan to make the water accessible to the farmers.

11. Increase the throughput capacity on the Lozen-Nederweert section of the Zuid-Willemsvaart to 9 m^3/s, expand the syphon capacity to the Noordervaart by 5 m^3/s, and increase the pumping capacity at Panheel by 10 m^3/s. This tactic would reduce the preventable shortage losses in the region in an extremely dry year by about 75 percent.

12. Expand thethroughput capacity of the Rijn-Schiekanaal at Leidschendam by 12 m^3/s. Currently all of Delfland's water is transported from Rijnland along the Rijn-Schiekanaal. Midway along this route (at Leidschendam) there is a pumping station with a capacity of 8 m^3/s. During dry periods, the demand for SW in Delfland often exceeds this capacity. The resulting cutbacks in sprinkling produce high agriculture shortage losses. Expanding the capacity of the pumping station to 20 m^3/s would eliminate these losses.

13. Modify groins around Tiel. Under the SPRHI-RALL scenario, large extractions into the Amsterdam-Rijnkanaal are made from the Waal at Tiel, thereby decreasing the depth of the Waal, which leads to increased shipping losses. This tactic, by narrowing the river around Tiel, would increase the river's depth by between 10 cm and 20 cm, which would eliminate most such losses caused by the extractions.

14. Increase the summer target level of the IJsselmeer and Markermeer to NAP - 0.10 m. During the summer half-year, the level of the water in these lakes is allowed to vary between two limits. The upper limit is currently set at NAP - 0.20 m for the IJsselmeer and NAP - 0.25 m for the Markermeer. This tactic would substantially increase the stored fresh water available to the northern half of the country.

These eight tactics include six that are aimed at reducing agriculture shortage losses, one that will reduce agriculture salinity losses, and one that will reduce shipping losses from low water. Seven of these tactics are relatively inexpensive--the highest annual cost is about 3.5 Dflm. The remaining tactic, the Delfland pipeline, has a cost of 37.9 Dflm, including the expected energy cost. The upper bound on the expected annual benefits of these eight tactics is 107.1 Dflm.

The fourteen tactics discussed in the preceding two sections make up the set of dominant promising tactics for the SPRHI-RALL scenario. For this scenario there were eleven promising tactics in addition to the fourteen dominant promising tactics noted above. This volume presents the dominant promising tactics only. Volume II presents information on all promising tactics.

22.7.4. Dominant Promising Tactics for Scenario with Low Sprinkler Intensity

Without implementation of the promising waterboard plans, we found no promising tactics aside from those that were promising under all scenarios (see Section 22.7.2).

There are two promising tactics if the promising waterboard plans are implemented:

15. Make the Grevelingen a freshwater lake. This is the same as tactic 10 above.

16. Increase the throughput capacity along the Zuid-Willemsvaart between Lozen and Nederweert to 9 m^3/s and expand the syphon capacity to the Noordervaart by 5 m^3/s. This tactic would increase the supply capacity to the Southeast Highlands by 5 m^3/s. Although it would eliminate only about 14 percent of the preventable losses in the region, its cost is low enough to make it worth examining in more detail.

22.7.5. Dominant Promising Tactics for Scenario with High Sprinkler Intensity and No Waterboard Plans

If farmers expand their sprinkler capacity to enable them to sprinkle whenever the expected benefits outweigh the expected costs, the demand for SW will exceed the capacity of the existing water management system, leading to high preventable losses in some parts of the country. Even without the implementation of the promising waterboard plans, there are three dominant promising tactics, all of which would expand the capacity of the water distribution system to supply SW to farmers:

17. Expand the throughput capacity of the Van Starkenborghkanaal by 9 m^3/s. This is the same as tactic 7 above.
18. Expand the supply capacity to the Northeast Highlands by 10 m^3/s. This is similar to tactic 8 above, with the same route but different facilities.[9]
19. Increase the throughput capacity along the Zuid-Willemsvaart between Lozen and Nederweert to 9 m^3/s and expand the syphon capacity to the Noordervaart by 5 m^3/s. This is the same as tactic 16 above.

The combined annual fixed costs of these three tactics is 2.5 Dflm; the upper bound on their expected annual benefits is 7.3 Dflm.

22.7.6. MAXTACS

The tactics discussed above are consistent with the discussion of technical and managerial tactics found in Vol. II. The analyses on which these tactics were based took advantage of updated cost estimates and additional specifications on the various tactics--information not available to us at the final PAWN briefing (December 1979). For this reason, the tactics that we have just described differ somewhat from those presented as promising at the final briefing.

At the briefing, we wanted to present a set of dominant tactics under the scenario that made the most severe demands on the SW supply system--the SPRHI-RALL sprinkler scenario. We presented a list of nine tactics, which we called MAXTACS (for Maximum Tactics). In the impact assessment stage of PAWN, MAXTACS were evaluated using a large number of impact measures. It is MAXTACS that are used in the rest of the analysis reported in this volume. (Readers wishing to know the detailed results of the additional Dutch screening analysis and impact assessment should consult the Nota Waterhuishouding. Some summary results are presented in Chap. 33.)

The 9 tactics in MAXTACS are:

- Change the policy for flushing the Markermeer (tactic 1 above).

- Use portable pumps on the Julianakanaal at Maasbracht (tactic 2 above).

- Construct a groin in the Nieuwe Waterweg (tactic 3 above).

- Expand the throughput capacity of the Van Starkenborghkanaal by 9 m^3/s (tactic 7 above).

- Expand supply capacity to the Northeast Highlands by 15 m^3/s (tactic 8 above).

- Build a water supply pipeline to Delfland (tactic 9 above).

- Make the Grevelingen a freshwater lake (tactic 10 above).

- Increase the throughput capacity on the Lozen-Nederweert section of the Zuid-Willemsvaart to 9 m^3/s, expand the syphon capacity to the Noordervaart by 5 m^3/s, increase the pumping capacity at Panheel by 10 m^3/s, and build pumping stations along the Wilhelminakanaal with capacities of 5 m^3/s. This tactic would increase the supply capacity to the Southeast Highlands by 15 m^3/s. It would reduce the preventable shortage losses in the region in an extremely dry year by more than 85 percent (equivalent to about 170 Dflm). (The same as tactic 11 above except for the construction of the pumping stations, the costs of which are high.)

- Decrease the minimum level of the IJsselmeer and Markermeer to NAP - 0.50 m. This tactic would involve dredging the shipping lanes and building some new pumping stations around the lakes to enable the minimum level to be reduced to NAP - 0.50 m. It would increase the storage capacity of the lakes by about 200 mcm (million cubic meters)--about a 50 percent increase--and would eliminate agriculture shortage loss caused by cutbacks in extractions from the lakes in extremely dry years. (Provides about the same increase in the storage capacity of the lakes as tactic 14 above, but at a higher cost.)

22.8. QUALIFICATIONS ON RESULTS

As discussed previously, this volume and the other PAWN volumes document the methodology and results presented in the PAWN final briefing on December 11 and 12, 1979. These results were considered tentative because (1) some of the methodology had not become available until late in the analysis, and (2) the RWS planned to perform additional analysis.

Thus the results presented in the preceding sections on the screening of technical and managerial tactics are subject to a number of qualifications.[10] A detailed discussion of the qualifications is contained in Chap. 12 of Vol. II. Generally, they suggest that benefits may have been underestimated for certain of the tactics. This implies that some tactics found to be promising are likely to be even more worthwhile than we have shown. It also means that there may be other promising tactics that were screened out in the analysis. In addition, since preventable losses were underestimated in some of the regions, it is possible that the initial screening step led us to not even consider some tactics that would have turned out to be promising.

We should point out, however, that a very conservative standard was used for identifying promising tactics: the upper bound on expected annual benefits. Taking into account all of the qualifications on the results, it is likely that most, if not all tactics whose expected annual benefits are greater than their annual fixed costs are included in the set of tactics that we identified as promising.

NOTES

1. Tactics designed to reduce pollutants in the water supply are discussed in Chaps. 16, 17, 26, and 27.

2. The waterboard plans varied enormously in completeness and specificity. Some plans were well thought out and developed in great detail. Others were only sketches. Some waterboards had no specific plans at all but suggested some ideas when we talked to them. Because the various waterboard plans are not really comparable, the estimates for the areas to be affected by the plans and the costs of implementing the plans are very uncertain.

3. We calculated the annual fixed cost of a plan by applying a capital recovery factor of 0.10 to its total investment cost. A capital recovery factor of 0.10 reflects a useful life of approximately 50 years and a discount rate of 10 percent.

4. DW companies extracted 306 million m^3 of SW in 1976. We based our projections of 1990 demands on predictions by VEWIN (a trade association of the DW companies in the Netherlands). We calculated the breakdown of these extractions by PAWN node and district, as shown in Table 2.7 of Vol. II.

   Our estimates of 1976 GW extractions by industry were based on CBS data, which provide industrial GW extractions and quantities used for cooling by Economic Geographical Region (EGR). We allocated these EGR extractions to PAWN districts by using correspondence tables that relate EGRs to municipalities and municipalities to PAWN districts. We obtained the 1990 projections by multiplying the 1976 values by a factor dependent on the province within which the district lies. [22.1], [22.2].

We obtained estimates of GW extractions by DW companies from REGWAT data, which provide information on GW extractions by water company and municipality. We matched the municipalities with PAWN agricultural districts, then assigned their extractions to the corresponding district. We obtained the 1990 estimates by multiplying the 1976 values by a factor obtained from the VEWIN Ten Year Plan. [22.3]

5. The 20 waterboard plans that survived screening without the grass multiplier are numbers 43, 45, 47, 48, 49, 50, 51, 52, 53, 54, 56, 57, 58, 59, 64, 66, 68, 69, 72, and 73.

6. One of the surviving waterboard plans assumes that the Grevelingen has been made a freshwater lake. When we are considering that tactic, we include that waterboard plan in RALL; otherwise, it is excluded.

7. A groin is a low dam built out from the shore of a waterway that can be used to direct a current or serve as a mixing device.

8. Subsequent analysis by the RWS found some additional costs for this tactic and screened it out.

9. The Twenthekanaal route (Route 1) was found to be the dominant promising alternative for this demand scenario. However, there are four alternative routes that are also promising (see Vol. II, Table 12.5).

10. Because of common assumptions and data, many of these qualifications also apply to the results of managerial strategy design and impact assessment.

REFERENCES

22.1. MR-282A (unpublished PAWN memorandum), "Industrial and Drinking-Water Company Demand Scenarios," July 1979.

22.2. MR-272 (unpublished PAWN memorandum), "Procedure for Developing Scenarios for Surface Water and Groundwater Extractions by Industry and by Drinking-Water Companies by District," April 1979.

22.3. VEWIN, Tienjarenplan '78--vereniging van exploitanten van waterleidingbedrijven in Nederland: samenvatting (Ten Year Plan 1978, Including the Operation of Waterworks (infrastructures) already in the Netherlands: Summary Report), Rijswijk, June 1978.

22.4. MR-374 (unpublished PAWN memorandum), "Overview of Waterboard Plan Screening Results," November 1982.

Chapter 23

SCREENING OF PRICE AND REGULATION TACTICS

As defined previously, screening is the process of identifying promising tactics and retaining them for further consideration, while setting the remainder aside. This chapter briefly summarizes our screening of price and regulation (P/R) tactics. During PAWN, three lengthy internal documents describing these screening activities in detail were published, submitted to experts in the Netherlands and the United States for comment, and then thoroughly revised. Readers interested in more than this brief overview should consult those documents.[23.1-23.3] Here we begin with a general description of P/R tactics, briefly describe our screening methodology, and then summarize the conclusions of the P/R screening process.

23.1. INTRODUCTION

Price and regulation tactics are government directives that affect the allocation of water among users by altering its cost or availability. P/R tactics may specify prices, impose taxes or subsidies, or set quotas and usage restrictions. In contrast to technical and managerial tactics, P/R tactics directly affect the demand for water rather than its physical supply. They usually affect the allocation of water among sectors such as agriculture or industry and among individual users within a sector. Often they are carried out by a local authority, such as a waterboard, a water quality board, or a DW company, following rules established by the state or local governments.

P/R tactics can be applied to the discharge of pollutants as well as to the extraction and use of intake water, and we originally intended to fully screen water-discharge as well as water-intake tactics. In fact, we published a detailed qualitative analysis of current water pollution activities and controls early in the PAWN study.[23.1] Most nonaccidental discharges of pollutants into surface waters of the Netherlands are now governed by quotas and prices, but we eventually discovered that the available data were too scanty to allow us to examine either the effectiveness of the current regulations or the practicality, effects, and costs of alternative ones. Large amounts of discharge data were made available to us near the end of the PAWN study, but by then we had completed screening and most PAWN analyses. Consequently, P/R screening covers only water withdrawal and use; it specifically does not deal with subsequent water discharges by the users or the effects of those discharges on the public and environmental health of the Netherlands.

PAWN considers how P/R tactics would affect the allocation of water within the Netherlands. We look at several different types of allocations. Economic efficiency is often a major goal. An allocation is efficient if no other allocation can improve the economic condition of the total group of users. Marginal-cost-based prices and freely functioning markets promote economic efficiency. Regulations and licenses can also be used to implement efficient allocations if information on the desired allocation is available ahead of time.

We also investigate a number of interesting allocations that are based on goals other than economic efficiency. Often, not all of the benefits (or costs) of a particular allocation can be quantified in monetary terms, e.g., environmental protection (or degradation). And, at times, certain socioeconomic groupings of households or businesses require special consideration. In these cases an "efficient" allocation of water is not desired, and prices (or simple forms of taxes) may be of little help. Regulations and licenses, on the other hand, are especially useful in allocating water when nonmonetary factors must be taken into account.

We consider both short-run and long-run tactics. Short-run tactics operate over periods of days or a few weeks. Long-run tactics operate continuously over longer time periods, perhaps one to 20 years. In special cases we also touch upon very short-run tactics, targeted for crisis situations of several days' duration.

The following section contains a short description of the criteria we used in P/R screening. Then we summarize, as briefly as possible, the results of our screening process. The chapter ends by recapitulating the conclusions of P/R screening.

23.2. CRITERIA FOR P/R SCREENING

Screening begins with the specification of a set of desirable characteristics for the tactics. Tactics should promote the efficient allocation of water or other specific social goals. To accomplish this, and to do it as cheaply as possible, tactics should meet a set of criteria: A promising tactic should be feasible; it should either be cost-effective in the aggregate, or at least provide significant benefits to some major interest group; and it must not be dominated by any other feasible tactic. These criteria will be discussed in turn.

A tactic should be technically, administratively, and politically <u>feasible</u>. It should not prevent any part of the water management system from working well. It should not be difficult to administer. And it should be politically viable; that is, it should not be manifestly unacceptable to the voters or decisionmakers who must ultimately rule on its adoption.

A promising tactic should be <u>cost-effective</u> in the narrow sense. Its aggregate direct benefits should outweigh its direct costs. As many types of benefits as possible should be expressed in monetary terms, but those that cannot must nonetheless be estimated and considered in some manner. Sometimes, however, a tactic with benefits equal to or even slightly less than its costs may qualify as promising during screening, since we seldom have complete or accurate estimates of benefits and costs at this point. If increased benefits (or reduced direct costs) do not turn up after further study, however, these tactics should be dropped.

A promising tactic should provide significant benefits for some major interest group. For example, it might increase water availability or quality for agriculture in a particular region of the country; or it might promote the preservation of a threatened environmental area. This criterion must hold if the previous one does not. A promising tactic should either be strictly cost-effective or it should provide major benefits for some particular group. For political or social reasons, a tactic that provides significant benefits for a particular group may at times be preferred to competing tactics that provide more total benefits but do not target them specifically to the needy sectors and regions. We therefore retain such tactics for further consideration.

Finally, a promising tactic is never dominated by another competing tactic. If two (or more) tactics for the same purpose produce the same benefits, the least costly tactic is the promising one. Or if two (or more) competing tactics cost the same amount, the one that produces larger benefits is the single promising tactic.

P/R screening differs in both kind and degree from technical and managerial (T/M) screening. T/M screening develops detailed estimates of costs and benefits for a large, but limited, number of potential tactics. P/R screening, in contrast, takes a broad approach to a virtually limitless set of possible tactics.[1] In P/R screening we used qualitative assessments (e.g., will a tactic be hard to administer?) in combination with rough estimates of a tactic's potential effects (e.g., can it save a great deal of water?). Furthermore, we generally used information from existing sources. We did not develop our own detailed estimates of costs and benefits until the policy design and impact assessment stages of analysis, when the number of P/R tactics to be considered had been greatly reduced.

23.3. SUMMARY OF P/R SCREENING RESULTS

During the early stages of the PAWN study, hundreds of potential P/R tactics were brought to our attention during interviews with government, industry, and academic experts. Other possible tactics were discovered in our readings and in-house discussions. In screening, we applied the above criteria in order to identify promising tactics and set aside the remainder. To systematize our search, we adopted a three-tier screening procedure. First we determined where a price or regulation tactic, of any type, might be worthwhile; that is, we screened over user groups. Then we determined where the actions of those selected users might best be controlled; that is, we screened over control points. Finally, we attempted to determine what particular form of tax or quota would be most appropriate for each surviving user and control combination; that is, we screened over policy instruments.

23.3.1. Users

Table 23.1 gives a rough indication of the major uses of water in the Netherlands. The table shows estimates of water withdrawals in 1976 by the major user groups.

Table 23.1

WATER WITHDRAWALS IN THE NETHERLANDS--1976
(In mcm/yr; includes nonconsumptive uses)

Demand Group	SW	GW	DW
Agriculture	2700(a)	200	
			300
Commercial	(b)	50	
Households	(b)	(b)	500
Industries(c)	3000	350	200
Power plants(c)	8600	(b)	(b)
DW companies	400	700	100
Shipping	(d)	(b)	(b)

SOURCE: Agricultural estimates from Vol. II, Tables 1.1 and 1.3. Others directly from Statistiek van de watervoorziening in Nederland 1976, Centraal Bureau voor de Statistiek, Table 2.

(a) Includes water for sprinkling and level control but does not include 950 mcm used to reduce salinity in boezems and polders by flushing.

(b) This demand group usually does not use this type of water.

(c) SW estimates include brackish as well as fresh water, but not seawater.

(d) Shipping "uses" but does not withdraw SW.

Surface Water. Industrial firms and power plants withdraw the most SW, but investigation proves them to be relatively unimportant user groups. This is because most of their withdrawals consist of low-quality, brackish water withdrawn from surface sources near the North Sea. Furthermore, they "consume" little of the nonbrackish SW they withdraw; most of it is used and then returned to the inland water system. Thus, tactics designed to control industrial and power plant uses of SW would probably have little effect on total SW consumption. The costs of reducing these SW uses would almost certainly be large compared with the benefits.

Commercial firms, households, and shipping consume insignificant amounts of SW. Tactics designed to control these uses would certainly be of little value.

On the other hand, DW companies and agriculture use significant amounts of SW, and these applications are specific enough that it seems worthwhile to consider tactics for their control.

Groundwater. The table also shows the major users of GW. DW companies use as much GW as all other users combined. GW is especially desirable in producing DW because it is both purer than SW and better tasting. Farmers and commercial and industrial firms also use substantial amounts of GW in their production processes.

It is practical to control GW extractions throughout the Netherlands. Large industrial extractors are now licensed; and the proposed GW law includes provisions for controlling all (or almost all) GW extractions. Since the supply of GW is limited, and since demand has been growing rapidly in recent years, it seems worthwhile to consider controlling some of the GW uses. Agriculture, industrial firms, and (especially) DW companies use substantial amounts of GW at present, and we expect that the farms and DW firms, at least, will desire to increase their consumption in the future.

Drinking Water. DW is, by definition, water of high quality. It is used for human consumption, hygiene, and sanitation. It is also used in the production and processing of foods and other consumption and health items. Smaller amounts are used in other industrial processes and in external applications in farming.

DW use is monitored throughout the Netherlands. Commercial, industrial, agricultural, and most household withdrawals are metered. Control, and especially restriction, however, may not be politically or socially acceptable in many situations. For example, public health requirements probably forbid any substantial reductions in the personal or food-processing uses of DW. In some situations, however, it would be possible to control certain industrial uses that consume large amounts of DW. For example, given sufficient incentives, industrial firms might substantially reduce their processing and cooling uses of DW.

23.3.2. Control Points

The amount of water taken from the various sources could be controlled in several ways. Potentially, the government can control the water use of individual users (and thus aggregate water consumption) by monitoring and controlling withdrawals; by indirect controls on water usage; or by controlling access to water.

Technical and economic efficiency considerations suggest that direct monitoring and control of withdrawals is usually the most effective and efficient means of control. Unfortunately, this requires monitoring each user, which is often not practical. We call tactics targeted directly at monitoring and controlling individual water withdrawals withdrawal tactics. Residential water meters are an example.

Indirect usage controls include restrictions on the use or ownership of water extracting/using equipment (such as pumps or sprinklers), controls on the types of crops planted, prohibitions on the production of DW from SW, and limits on the size and number of farms in certain regions. Indirect controls are less efficient and usually less effective than direct controls, and they often have undesirable side effects.

A third alternative is not to attempt to control the amount used by individual users, but to control the total amount withdrawn by limiting the number of users. We call tactics of this type (such as a permit system for new wells) access tactics. When the number of users is large, access tactics may provide as much control over total withdrawals as withdrawal tactics would, yet be easier to implement.

Surface Water. DW companies and farmers use significant amounts of SW and it seems worthwhile to investigate how reductions in their withdrawals might affect other sectors and the total welfare of the Netherlands. DW companies, when they use SW, usually extract planned amounts from well-known locations. Direct controls--that is, withdrawal tactics--should be feasible and appropriate for controlling the long-run SW use by DW companies. Since most SW use by DW companies is via large facilities (pipelines, reservoirs) and requires time-consuming processes (aeration, filtration), we see little need for short-run controls.

Agricultural withdrawals of SW are different. Farm demands for SW depend heavily on the amount of local rainfall, and it is probably not possible to control all of the SW withdrawals of farmers. Farmers withdraw SW directly from ditches, and since the ditches are ubiquitous in the Lowlands, monitoring withdrawals would be quite difficult and extremely costly there. In the Highlands, control would be a much less severe problem because relatively few farmers use SW. However, this situation may change if T/M tactics are implemented to increase the SW available there. In summary, then, SW withdrawal tactics do not seem promising for farmers.

Indirect methods for controlling the agricultural use of SW, such as controls on sprinkling or on the ownership of sprinklers, or even limitations on the planting of crops with large water demands, are more feasible; they could probably be implemented, monitored, and enforced. But these indirect controls are less efficient than direct controls. They distort production patterns, and they must usually be implemented permanently, even though they are required only occasionally.

On the other hand, simply forbidding SW withdrawals by farmers during certain periods and in certain regions is more promising. It was used successfully in the summer of 1976. Its implementation is easy and enforcement is not hard (field agents can be used to observe when farmers sprinkle). This is a relatively efficient access tactic since it can be applied in whatever degree is necessary, and it can be used for short periods whenever the need arises.

We suggest, then, further consideration of tactics directly controlling the annual SW withdrawals of DW companies, controls on the number of sprinklers owned by farmers, and access tactics controlling short-run SW use by farmers.

Groundwater. The control points, and the considerations for their use, are essentially the same for GW as for SW. Direct controls are theoretically the best, but are often not practical. Complete control of withdrawals would require metering all users, but metering is probably not practical for many farms and small industrial firms. Small farms have many wells, and monitoring withdrawals would not be cost-effective.

Furthermore, there would be little value in restricting access to GW by farmers and small firms for only the short run. The effect of a reduction in GW extractions cannot be felt immediately, except by the user who reduced his extractions. GW levels change gradually, and a reduction in one user's extractions becomes obvious to others only after a (perhaps substantial) period of time.[2] Short-run controls would probably not be effective until the crisis that induced them had passed. Moreover, their real effect would be on the long-run average GW level, which is what long-run controls are intended to affect.

Drinking Water. Public health considerations limit the applicability of DW control tactics solely to industrial firms, where they could reduce DW use considerably. For households and commercial establishments, it is probably not politically possible to place restrictions on DW withdrawals for personal or sanitary uses. Design standards to promote water-efficient fixtures and appliances for future construction or refurbishment of residential or commercial buildings might eventually conserve significant amounts[3] of DW, but it would take many years for their effects to become widespread.

Short-term controls on both the DW and GW intakes of industrial firms are technically feasible, but most industrial uses of these high-quality waters (sanitary uses, food and drink preparation, sensitive industrial processes) cannot easily be reduced without seriously, and expensively, disrupting the conduct of the firms' business. Thus, short-run reductions of industrial water uses would probably not be cost-effective.

23.3.3. Policy Instruments

Many alternative forms of prices and regulations could be applied to each combination of user group and control point. They include taxes, quotas, and access restrictions--each with many variations.

The choice of which policy instrument to use in a particular application depends on many factors, including: (1) the instrument's effectiveness in that application; (2) its effect on the efficiency of the tactic; (3) the wealth effects (sometimes called redistribution of income) associated with its use; (4) its administrative costs; and (5) the relative importance that decisionmakers attach to different social goals. Since PAWN did not investigate the preferences of Dutch policymakers, and since we could not obtain all of the information necessary to estimate administrative costs, we cannot, in general, recommend specific instruments for specific applications. We can, however, provide several types of information that should be useful to Dutch decisionmakers who must choose among alternative policy instruments.

First, we did a general screening of individual policy instruments.[4] We reviewed available literature on the general effects of different types of policy instruments, concentrating especially on those instruments that have actually been employed to allocate water or water rights in Europe and the United States. We concluded from this investigation[5] that:

1. Although withdrawal tactics and access tactics focus on different control points, they can be implemented with similar policy instruments.
2. Auction markets for access or withdrawal rights (where the authorities periodically sell rights or "quotas" to the highest bidders) are theoretically sound but have many practical limitations. Prices, government-specified quotas, and decentralized water markets (where the free-market trading of water rights is allowed) are more practical.
3. Quotas must be set individually for each user, they are practical if the number of users is small, and they give precise control over the amount withdrawn. Quotas are flexible. They can be used to redistribute wealth as well as water. But they do not, by themselves, promote the efficient use of water.
4. Prices are easier to implement than quotas, but control is less precise. Only a single price is required for each region, but the authorities do not know in advance the actual amount that will be withdrawn. Prices promote the efficient use of water; but, when used alone, they also usually redistribute wealth.
5. Selling water rights to recent users at a price equal to the marginal costs of supplying the water, and allowing the rights to be freely traded, ensures that water is allocated efficiently with minimal redistributions of wealth.

In the later PAWN stages of policy design and impact assessment, we also investigated the effects of some specific policy instruments. The cases analyzed in PAWN contain several different mixes of policy instruments. In the analysis of cases, summarized later in this report, we estimated the effectiveness and the redistributive impacts (including most implementation costs) of those particular mixes of instruments. We did not deal with administrative costs, and specifically we did not compare the attractiveness of alternative instruments in the same application. The information we do provide, however, should prove helpful to Dutch water management officials and decisionmakers. The selection of specific policy instruments for any actual situation depends on the existing wealth distribution in the affected regions and the relative importance attached to specific social goals. Future Dutch studies must deal with those topics.

23.4. CONCLUSIONS ON P/R SCREENING

The general conclusions arising from our screening of P/R tactics are summarized in Table 23.2.

Table 23.2

SUMMARY OF SURVIVING P/R TACTICS

	Tactics for the Control of		
User Group	SW	GW	DW
Agriculture	access/equip(a)	equip	
Commercial			
Households			
Industries		withdrawal	withdrawal
Shipping			
DW companies	withdrawal	withdrawal	

NOTE: Surviving tactics may be prices, quotas, or markets. Final selection must be based on implementation costs and distributional considerations.

(a) Access tactics are for the short-run control of agricultural SW extractions; equipment (equip) tactics would be used to control long-run extractions. All other entries for equipment and withdrawal tactics refer, of course, to long-run controls.

Of those considered in our screening, only six combinations of user groups and water types appear promising. We conclude that controls on SW use by agriculture and DW companies, GW use by agriculture, industrial firms, and DW companies, and DW use by industrial firms warrant further study. Withdrawal tactics are appropriate for firms and DW companies. For farmers, long-run controls on equipment ownership for SW and GW sprinkling and short-run SW access controls are appropriate.

As explained above, we are not able to recommend specific policy instruments for particular applications. But our general conclusions concerning the strengths and weaknesses of the various instruments, and the information generated during our policy design and impact assessment stages of analysis, when we consider specific mixes of instruments, should provide a solid foundation for further Dutch deliberations and analyses of these issues.

NOTES

1. Virtually limitless because, for each potential tactic, there are myriad possible variations. For example, the tax on a particular user may, in principle, be set at any level.

2. For example, suppose an extraction of GW were taking place at a distance of one kilometer from a stream. Suppose further that the subterranean flow from the stream is the ultimate source of the water being extracted. If the extraction were suddenly reduced by 1 m^3/s, it is clear that the subterranean loss from the stream would eventually decline by that same 1 m^3/s. But in Vol. V we calculate, using data and methods from Ref. 23.4, that only 20 percent to 40 percent of that reduction will have occurred by the time one decade has passed. If the distance were as much as five kilometers, less than two percent of the reduction would have occurred in a decade.

3. Rough calculations indicate that residential water use could eventually be reduced by perhaps 20 percent by the simple employment of water-saving bathroom and washing appliances. In similar ways, total industrial DW use could be reduced by perhaps 10 percent without incurring major costs. See Ref. 23.2, pp. 10-12 and Apps. 1 and 2.

4. See Ref. 23.5.

5. Our full report on these issues can be found in Ref. 23.5. Readers interested in a more complete investigation should consult Refs. 23.6, 23.7, and 23.8, which document a Rand study of water distribution, water rights, and water policy in California.

REFERENCES

23.1. MW-113-B (unpublished PAWN memorandum), "Screening of Pricing and Regulation Tactics on Water Quality," July 1979.

23.2. MW-092-B (unpublished PAWN memorandum), "Screening of Pricing and Regulation Tactics on Drinking Water," March 1979.

23.3. MW-127 (unpublished PAWN memorandum), "Screening of Pricing and Regulation Tactics on Shortage, Excess and Salinity Issues," September 1978.

23.4. De Vries, J. J., "Groundwater Flow Systems and Stream Nets in the Netherlands," Rodopi, N.V., Amsterdam, 1974.

23.5. MR-368 (unpublished PAWN memorandum), "Draft Chapter on P/R Screening for PAWN Summary Report," May 1980.

23.6. Lipson, A. J., Efficient Water Use in California: The Evolution of Groundwater Management in Southern California, The Rand Corporation, R-2387/2-CSA/RF, November 1978.

23.7. Phelps, C. E., Efficient Water Use in California: Executive Summary, The Rand Corporation, R-2385-CSA/RF, November 1978.

23.8. Phelps, C. E., N. Y. Moore, and M. H. Graubard, Efficient Water Use in California: Water Rights, Water Districts, and Water Transfers, The Rand Corporation, R-2386-CSA/RF, November 1978.

PART IV: DESIGN OF POLICIES

Chapter 24

GENERAL APPROACH TO DESIGNING POLICIES

Although screening ruled out many possible tactics, enough remain to make policy design difficult. In the chapters that make up this part we will describe the process, the methodology, and the results of our efforts to design promising policies for further evaluation in impact assessment.

Screening found long-run price and regulation tactics promising for reducing GW extractions by industry, DW companies, and agriculture, and for reducing DW withdrawals by industry and SW withdrawals by DW companies. Thus, in Chap. 25 we design long-run price and regulation strategies for these combinations of user groups and water types.

The screening of price and regulation tactics found equipment tactics promising for reducing long-run SW extractions by agriculture. These tactics and the promising waterboard plans are reflected in sprinkler scenarios and therefore enter the policy design process with them, as mentioned below.

Screening also found short-run price and regulation tactics promising for reducing SW extractions by agriculture. These access tactics are implemented in the DM as managerial rules that determine the degree of cutback, if any, in the amount of water delivered to SW sprinklers. Thus we consider such tactics as we design managerial strategies.

Screening found a number of technical tactics promising for modifying the current infrastructure and several managerial tactics promising for improving its operation. Of the many possible managerial tactics that remain, the superior combination will vary with the technical tactics and the circumstances (e.g., external supply). In Chap. 26 we design managerial strategies, with the goal of finding one or more strategies that are generally superior.

Technical and managerial tactics for eutrophication control in lakes differ in kind and extent from the other technical and managerial tactics considered. Thus, Chap. 27 considers the design of eutrophication control strategies.

Using the findings of these several chapters, along with sprinkler scenarios and the promising technical tactics in MAXTACS, we next design the primary policies and cases to be considered in impact assessment. Chapter 28 concludes this part by describing that process and its results.

Chapter 25

DESIGN OF LONG-RUN PRICING AND REGULATION STRATEGIES

25.1. INTRODUCTION

This chapter describes how we designed long-run pricing and regulation (P/R) strategies that might become part of policies to be analyzed in detail.

The P/R tactics we investigated in this analysis are all designed to conserve GW or increase the efficiency of its use. (Such tactics were found promising in screening.) Extractions of GW by industry, DW companies, and agriculture have been increasing rapidly in recent years, and have resulted in a precipitous drop in GW levels in many areas. Lowering the GW level can have serious consequences: It can cause agricultural and environmental damage in areas where the level of GW was previously within reach of the roots of crops; it can drop GW below the levels of existing wells, necessitating digging them deeper or replacing them; it can deprive the soil of mechanical support, resulting in soil subsidence and possible damage to structures; and it can remove a natural barrier to brackish and salt GW inflow from neighboring areas, resulting in contamination of local GW supplies.

Some of the P/R tactics investigated in this analysis also affect DW withdrawals by industry and SW withdrawals by DW companies, both of which screening identified as promising. As mentioned in the previous chapter, we deal with controls on agricultural access or equipment to use SW--also found promising in screening--as part of managerial strategy design and sprinkler scenarios, respectively.

25.2. TACTICS CONSIDERED

The two primary tactics we considered were the imposition of a charge on GW extractions (a pricing tactic), and the imposition of a quota to limit the amount of GW extractions (a regulatory tactic). In most cases we analyzed, we set the GW charge at zero, which reflects the current situation, but sometimes we used a charge of 0.20 Dfl/m^3. This is the maximum charge being considered by the Dutch Parliament in a proposed GW management law.[1] Because the proposed law contemplates imposing the charge only on industrial firms, we analyzed cases with the charge imposed on only them, and alternatively on other users as well.

The quotas we usually used were based upon "extractable amounts" established by RID for each province. These extractable amounts were intended to show how much GW can be extracted in each province during an average year without risking serious consequences from the accompanying drop in the GW level. Their values were determined by considering such factors as the possible damage to nature or agriculture and the effect on the long-run supply of GW. We used geographical units called districts[2] in our analysis and reallocated RID's extractable amounts accordingly to PAWN districts and pseudo-provinces. We refer to these quotas as a GW quota of 1.0. (This quota is a rough proxy for current policy and behavior in the Netherlands.) When the GW quota is 1.0, no more than the RID extractable amounts can be taken by industry, DW companies, and agriculture combined, in an average year. (In drought years, agriculture will take more, but industry and DW companies are not asked to cut back.)

The extractable amounts--and hence the quotas--should be viewed as expected values, that is, the amount that one could extract over many years of differing dryness. Although the GW demands by industrial firms and DW companies do not depend on the dryness of the year, those by agriculture do: GW demands by agriculture will be larger in dry years than in wet. The GW quota in a district may thus be exceeded in a dry year, but not fully exploited in a wet year. Only on the average may we be sure that the quota will be met. We must therefore expect the GW level to fluctuate from year to year. This is not so harmful as it may appear at first glance. The GW level fluctuates naturally from year to year, and during the seasons within a year. Damage due to an abnormally low GW level is slight unless the low level persists for several years. Thus, only if there should be a series of dry years, with too few interspersed wet years, will the variable nature of compliance with the quota result in harm.

For some cases, we used quotas only one-fourth as large, which we refer to as a GW quota of 0.25, to represent an extreme effort to conserve GW. The level may be thought of as the average between the quota of 0.50 that the IWW (the interdepartmental advisory group for PAWN) suggested we consider as a lower bound on the estimates of extractable amounts, and the quota of zero that results from giving highest priority to preserving GW supplies and the natural environment. Finally, we looked at a GW quota of 1.5, which is 50 percent larger in each province than the GW quota of 1.0; the IWW suggested this be considered as an upper bound on the estimates of extractable amounts.

We also considered some secondary tactics. One such tactic was the pricing scheme for DW. Prices for DW affect GW extractions and allocations because (1) a great deal of GW is used in the production of DW, and (2) for reasons of both quality and cost, GW is generally preferred to SW as a constituent of DW. Current DW prices are based on historical average costs, a practice common to most public water companies throughout the world. Rates can be more easily adjusted to balance expected future revenues with cost estimates based on known expenditures and proposed capital investments. However, economic theory tells us that if the objective is to minimize total costs or to obtain the most economically efficient use of a scarce resource (in this case GW), then prices for that resource ought to be based on its marginal costs of production.[3] Since it is our goal to determine the most economically efficient GW extractions, we will consider marginal-cost pricing as an alternative pricing scheme to the current practice of average-cost pricing.

25.3. RESPONSES TO TACTICS

Each of the GW extracting sectors has at its disposal different means to reduce its use of GW in response to P/R tactics. For example, industry may recycle cooling water rather than discharging it after a single use, or substitute SW or even DW where GW was used before. DW companies may construct SW reservoirs and treatment facilities, or a DW company in an area where GW was scarce could purchase DW from a DW company in another area. The full menu of possible responses by DW companies and industrial firms was described in Chaps. 14 and 15, respectively.

Realistically, industries and DW companies can only respond in the long run. If industry, for example, wishes to recycle cooling water instead of using once-through cooling, new pumps and pipes must be installed. Similarly, it takes time for a DW company to build a new SW reservoir.

Agriculture also responds to GW-related P/R tactics, although their responses are complicated by the fact that they depend so strongly on other kinds of tactics as well. For example, digging a canal that makes SW available to a previously unsupplied area may reduce the use of GW for irrigation, since irrigating from SW is generally cheaper.

Moreover, there is a serious question whether farmers could be made to respond to quotas or charges on GW extractions. To enforce either tactic requires that extractions be monitored. This is relatively easy to do for industries and DW companies, because they extract GW from a relatively few very large (i.e., high-capacity) wells. Farmers, on the other hand, extract GW from innumerable small wells scattered about the countryside. It would be very difficult to accurately and reliably monitor a myriad of tiny extractions. It may, however, be practical to limit the number of new GW sprinkler systems, perhaps by requiring permits to dig new wells or buy additional sprinklers.

For these reasons, we have not attempted to predict the responses of farmers who currently sprinkle from GW to the imposition of quotas or charges on their GW extractions. Rather, we consider the extent to which quotas would affect the number of new sprinklers that are permissible and how charges would affect the number that is economical. This is done, as described in Sec. 29.2.3, as part of our procedure for generating GW sprinkler scenarios.

25.4. THE RESPONSE DESIGN MODEL

Because of the numerous and diverse possible responses to P/R strategies by industrial firms, DW companies, and farmers, we needed a model to determine the most economically efficient mix of responses to a P/R strategy. Ideally, we wished to consider all three sectors--industry, DW companies, and agriculture--in one model because they all compete for the same GW and because some industry responses involve buying DW instead of extracting GW. However, it was not possible to consider agriculture in the same model with the other two sectors without making the model overly complex. Thus, we created the response design model (RESDM) to deal simultaneously with the industry and DW company sectors, and we used the tactic of setting priorities to deal with the competition between these sectors and agriculture. That is, we specified the priority that one sector has over another for GW extractions. In most cases, we let industrial firms and DW companies take as much GW as they wished, up to the quota, with the remainder available to agriculture (which is de facto the current situation[4]), but in others we reversed the priorities. The methodology and results of our analysis of priorities, including a conclusion on when it is more beneficial for the nation to give priority to agriculture or to the other two sectors, are discussed near the end of this chapter.

25.4.1. Basis of RESDM

RESDM is two models in one. It began as RID's DW model, RIDDWM, described in Chap. 14, which modeled only the responses of DW companies in the Netherlands to P/R tactics such as quotas. It became RESDM when it was enlarged to accommodate the responses of composite industrial firms, derived from IRSM, the industry response simulation model described in Chap. 15.

With 27 responses available to each of 1100 firms, we could not include all the data from IRSM in RESDM, but managed to capture most of them in a highly aggregated and greatly reduced form. In short, we sorted all firms by PAWN district, then collapsed the firms in each district into a composite firm having composite characteristics with respect to the water demands of its responses. Finally, we reduced the number of available responses (the menu) to the fewest possible relevant to our analysis (for example, several responses were never selected during test runs in RESDM and so were safely discarded). We ended up with 260 different responses, varying between two and nine per district for the 59 districts containing firms that used appreciable amounts of GW. (The process of aggregating industrial responses, which was very complex, is fully described in Sec. 2.2 of Vol. IV.)

The menu of industrial responses in RESDM thus captures the range of choices available to each composite firm, but only with respect to its demands for GW and DW. (We disregard industrial use of SW here because practically all of it is returned to the SW system.) The responses range from using only GW, through various combinations of GW and DW, to in some cases using all DW and no GW.[5] For responses requiring substantial changes either in capital investments or to production processes, costs are incurred in proportion to the size of the change or investment involved. An industrial response, known mathematically as an industry vector, contains for our purposes only three elements: (1) amount of GW extracted (thousands of m^3/yr); (2) "extra" amount of DW bought above the basic demand (thousands of m^3/yr); and (3) incremental net costs incurred through implementing the option (thousands of Dfl/yr).

The DW company sector in RESDM is modeled by RIDDWM, which assumes a composite DW company in each pseudo-province, with a large equivalent GW source located an average of 10 km away from the DW company. DW can be made from either GW, treated SW, or some combination of the two. But because of quality, quantity, and physical-space considerations, only certain SW sources can be used by DW companies (called SW projects in the model, typically representing reservoirs or infiltration plants). A menu of 20 SW projects, along with associated costs and maximum expansion capacities, was provided to PAWN by RID.

25.4.2. Operation of RESDM

Given the GW extraction quotas[6] and the GW charges (if any) to be imposed by district and pseudo-province,[7] RESDM determines the most economically efficient allocation of the available GW among industrial firms and DW companies, along with their associated responses. In doing so, it determines GW shadow prices[8] for each district and DW marginal production costs for each pseudo-province. The model implicitly assumes that DW is sold at its optimal price, which is equal to its marginal production cost.

RESDM, like RIDDWM from which it evolved, is mathematically a linear program. Because it incorporates the industrial sector, and because industry is represented in it by a composite firm in each district, both the objective function and constraints differ somewhat from those in RIDDWM. Specifically, RESDM minimizes an objective function that reflects the combined water-related costs of DW companies and industry, subject to the following constraints:

- Composite industrial firms cannot extract more GW than the quota in their respective districts.
- Composite DW companies cannot extract more GW than the sum of the quotas across districts in their respective pseudo-provinces, less the industrial extractions in those districts.
- DW companies cannot extract more SW from a particular SW project than it contains.
- The composite industrial firm in a district must be given at least as much GW as the minimum necessary to prevent the firm from shutting down for lack of GW (IRSM was never intended to entertain responses of such enormous consequence).
- Composite DW companies will meet exactly the DW demanded in their respective pseudo-provinces.

The objective function that is minimized in RESDM contains the following water-related costs:

- DW company costs for GW extraction and transportation.
- DW company costs for SW production and transportation, where the production costs include capital replacement.
- DW company to DW company shipping costs, if any.
- Costs to industry of responding to P/R strategies by adjusting their use of process and cooling water.
- GW charges, if any, imposed on industrial and DW company use of GW.

The objective function does not include the DW company surplus, which is the difference between the revenues obtained from selling DW at marginal-cost prices and the costs of supplying that DW (calculated from average costs). Because RESDM jointly minimizes the DW company and industry costs, the DW company surplus is excluded, for it is really a transfer payment from industries to DW companies.

RESDM, as we have developed it, is extremely versatile. We can modify all its constraints across the board (e.g., reduce the DW demand estimates by 10 percent everywhere) or only in particular places (e.g., close down all infiltration SW projects, or add on GW from the dunes in Noord-Holland only for DW company use). We can impose GW charges on industry alone, on DW companies alone, or on both; we can raise DW prices to consumers; we can impose and alter GW quotas by district; we can change any of the cost estimates in the model; and we can alter the demand for DW by province or by type of consumer.

For each case that is analyzed, RESDM produces considerable output in the form of printed reports and datasets that are readable by other computer programs. RESDM indicates the value of the objective function (the total water-related costs of the chosen mix of responses) and, as part of that mix, which SW projects were built or expanded, and how much water is extracted from each. In addition, it produces the following tables:

GW Balance:	Shows how the available GW in each pseudo-province is allocated: how much is given to industry, how much to DW companies, and how much remains for agricultural use. Also gives the GW shadow price in each pseudo-province.
DW Balance:	Shows for each pseudo-province that the DW supply equals the DW demanded. Supply--shows the amounts of GW, SW, and DW that make up the supply. Demand--shows the basic DW demands by households, commercial entities, and industry; the extra DW demanded by industry; and the DW shipped to other pseudo-provinces.

DW Supply Costs:	Shows for each pseudo-province the average unit costs for each type of water used in making DW, as well as average and marginal costs of supplying DW.
SW Extractions:	Shows SW extracted from SW projects by node or district in units of m^3/s.

These SW extractions by node and district are provided to adjust the corresponding extractions and discharges in the DM. (See App. C of Vol. IV.) In addition, the GW extractions by district are needed by DISTAG, which uses them to adjust the basic drainage coefficients in the basic drainage function of the GW storage model to reflect the changes in GW extractions from those to which the storage model was originally calibrated.

25.4.3. Validation of RESDM

We could not really validate the RIDDWM portion of RESDM because there was nothing to validate it against--RIDDWM is not a simulation model for the current situation but a long-run model incorporating features that do not exist in the real world. Moreover, most of the data are estimates; in such a case the proper action is to perform a sensitivity analysis--which we did as part of the actual analysis.

The same is true for IRSM, the source of the industry vectors. That model incorporates a range of potential options open to firms for coping with less GW, many of which are not yet implemented. Further, IRSM assumes perfectly rational cost-minimizing behavior and chooses for each firm the least-cost option or response for a given situation, which is often not found in the real world because firms must take into account political, legal, and social considerations as well as economic ones.

So for validation we could only compare RESDM results with IRSM results, to find out whether the set of industry responses chosen by RESDM in a given situation is the same as those that IRSM would have chosen in the same situation. How well the two sets of responses match is an indication of the validity of our data-reduction process and hence of the confidence that can be placed on the set of industry vectors in RESDM.

We performed the response comparison on the following case:

GW quota: 1.0 x RID extractable amounts
GW charge: None
DW demand: 1976 context

We selected this case because IRSM was created for a 1976 context, and because the situation with no government-imposed GW charges and a 1.0

GW quota most closely approximates its basic data. Since IRSM does not contain any GW quotas, the way to ensure that the same case is being run on both models is to introduce the GW shadow prices from RESDM (equivalent to the district quotas) as additional GW charges in IRSM. Similarly, because RESDM is an optimizing model and causes DW to be sold to customers at a price based on its marginal cost, these prices must also be fed into IRSM to keep the cases the same. The above procedures, which reflect how IRSM is generally used in impact assessment, were described in Sec. 15.3.

Our principal criterion for comparing the outputs of the run from both models was the extent to which GW consumption matched. Differences in SW and DW are less important; the net consumption of SW and the extra DW demanded by industry are both very small compared to other demands and flows in PAWN as well as in absolute terms.

We found that GW consumption in IRSM was perfectly matched by 43 percent and closely matched (discrepancies under 2 percent) by another 41 percent of the RESDM responses. Four additional responses had discrepancies between 6 and 10 percent, which do not seem unreasonable. The remaining five vectors--in Overijssel (districts 15, 16, and 21), Gelderland (district 26), and Zuid-Holland (district 45)--yielded discrepancies of between 12 and 30 percent.

During the validation process, we also found that it was necessary to modify RIDDWM in one important respect related to the menu of SW projects in the model. We learned from discussions with Dutch experts that the Biesbosch was actually supplying DW companies in Zuid-Holland with about 100 mcm/yr of SW. Yet preliminary runs using RESDM gave results that showed other SW projects being used in preference to the Biesbosch, the latter presumably supplying more expensive and hence less desirable SW. Since we had not overstated its costs, we were forced to conclude that the Biesbosch water was preferred in the real world for several reasons that RESDM could not account for, including: (1) Alternative reservoirs near the Biesbosch such as the Philipsland and Markiezaat, although available in RESDM, were not yet available in the real world; (2) in the real world, DW companies leave some of the available GW for future expansion, so the Southwest Lowlands needs water from the Biesbosch, yet RESDM allows all available GW to be extracted before other sources of water are brought into play from further afield; and (3) the Biesbosch water is of a superior quality to that of most other SW projects.

Accordingly, in an effort to represent the <u>long-run</u> world more closely, we set a lower bound in RESDM on extractions from the Biesbosch of 160 mcm/yr (an amount equal to its 1977 capacity), and thus take into account two of the three differences with the real world noted above. Thus, in every RESDM run after validation, at least 160 mcm/yr is assumed to be extracted from the Biesbosch. (Most of the time that water went to Zuid-Holland, but in cases where RESDM calculated that more than 160 mcm/yr was taken, some of it was also distributed to other nearby provinces.)

25.4.4. Qualifications on Results

We did not have time during the analysis phase to perform comparisons for other cases, for example, at lower GW quotas, or for a 1990 context. But based on our subsequent experience exercising both RESDM and IRSM, we believe that RESDM becomes less accurate the more the system is stressed.[9]

For quotas of 0.5 and above, RESDM underestimates costs. This is because RESDM is based on the standard version of IRSM rather than the modified version. As discussed in Chap. 15, the modified version, which did not become available in time for use in RESDM, makes fewer inexpensive responses available to many firms and therefore estimates smaller reductions in GW use and higher industrial costs for a given GW charge than does the standard version.

For quotas well below 0.5, such as the 0.25 considered in part of our analysis, RESDM considerably overestimates costs. This is because its derivative models--IRSM and RIDDWM--were not designed for such low quotas and thus do not include appropriate (and hence cost-effective) responses for dealing with such heroic cutbacks in GW extractions. RIDDWM produces unrealistically high costs for quotas below about 0.5 because RID did not include SW projects in the northern provinces on the grounds that those provinces were adequately supplied with GW. At lower quotas, such as the 0.25 used in the analysis, GW shadow prices and marginal costs of supplying DW in Groningen and Drenthe rise to very high levels because of a lack of planned SW facilities nearby.

IRSM was designed only for GW charges up to 1.00 Dfl/m^3. Yet, as we found out too late in the analysis, representing an equivalent case in IRSM for a 0.25-quota case in RESDM means imposing GW shadow prices as charges on industries in IRSM, many of which charges exceed 1.00 Dfl/m^3. Thus, the menus of responses in IRSM and RESDM do not contain the kinds of extreme measures firms would take were they to face charges over 1.00 Dfl/m^3; using the responses they do contain in circumstances where they are inappropriate means incurring unnecessarily high costs.

As a different kind of qualification, we note that RESDM does not operate at the local level (i.e., model the world of an individual DW company or industrial firm), and so any findings that follow from using it cannot take into account local situations. (Through IRSM, we can trace effects of P/R strategies down to the individual firm; but we cannot do that for DW companies.)

25.5. ANALYSIS AND FINDINGS

Our analysis investigated a range of GW extraction quotas and charges that, in various combinations, could be thought of as progressively stressing the system (i.e., putting more pressure on GW, by restricting its supply, raising its cost, or assuming a higher demand for GW or DW).

In addition, we examined the effect of GW extraction priorities, DW pricing schemes, and whether there was full or partial coordination between industry and DW companies. The latter item is a hitherto unmentioned tactic that could not be discussed conveniently before. It addresses the following real-world question: Would it be less costly overall if industry coordinated and cooperated fully with DW companies in their use of GW than it would be if each sector worried only about optimizing its own use? Joint optimization of the two sectors' responses, as carried out by RESDM, is a proxy for a full exchange of information and full cooperation between the sectors, based on the principle that what is good for the sectors together takes precedence over what is good for each one separately ("good" meaning economically efficient). Partial coordination and cooperation is what currently exists in the Netherlands.

25.5.1. Findings on Pricing Schemes and Coordination

The following two findings were important not only for their potential policy implications, but also for their influence on the rest of the analysis.

DW Pricing Scheme. At a GW quota of 1.0, DW prices based on average costs of supplying DW produce results that are as economically efficient as if they were based on marginal supply costs. As we stress the system more, and especially at a GW quota of 0.25, DW prices based on average costs yield less economically efficient allocations of GW than those based on marginal costs. Whether or not it would behoove DW companies throughout the Netherlands to adopt a marginal-cost pricing policy depends on a number of considerations excluded from this analysis, such as implementation costs and political acceptability. The latter is important because under marginal-cost pricing, and so long as marginal costs exceed average costs (which in this study they do), DW sales will generate large monetary surpluses. Because DW companies are a regulated public-service industry, these surpluses go to the government, where they can be used to finance additional public services or to reduce taxes. The political acceptability of marginal-cost pricing thus depends in large part on the magnitude of the surplus and what the government decides to do with it. This is covered in impact assessment and fully discussed in Vol. X.

Because RESDM is an optimizing model, and hence implicitly bases its DW prices on marginal production costs, it was not appropriate for the few cases with average-cost pricing. Instead we used an iterative procedure involving RIDDWM and IRSM, detailed in Sec. 2.3.3 of Vol. IV. We first ran RIDDWM to obtain an average DW production cost and used it to develop DW prices for input to IRSM. We next ran IRSM to estimate the amounts of GW and DW that industry would use. With these amounts we adjusted the GW quotas and DW demands that served as input to RIDDWM, and then reran RIDDWM to obtain new average production costs. We continued to iterate in this fashion between the two models until the DW production costs and the GW and DW use by industry ceased to change. (In practice, we found that one iteration was enough.) RESDM was used at the beginning of this procedure merely to provide shadow prices to IRSM representing the district GW extraction quotas.

Full versus Partial Coordination. Results of the analysis suggest that optimizing the two sectors jointly rather than separately yields a more economically efficient allocation of GW the more the system is stressed; at a GW quota of 1.0 the difference was negligible. That result is intuitively reasonable as both sectors draw GW from common sources; even the extra DW that industry buys from DW companies contains much GW. It follows, then, that as GW becomes scarcer, serious consideration should be given to encouraging a jointly optimal allocation, for example by using a free market to allocate rights to GW and by making information on options and implications available to both sectors.

To analyze coordination, we compared cases run with RESDM, which jointly optimized the two sectors, with cases where the two sectors were optimized separately. For the latter cases, using a special procedure detailed in Sec. 2.3.3 of Vol. IV, we ran IRSM first without any GW charges and with no incremental DW prices (i.e., only the actual 1976 prices by firm contained in its database), to determine how much extra DW industry demands. This amount was added to the DW demands by pseudo-province in RIDDWM, while the GW extractions by industry estimated with IRSM were subtracted from the GW available to DW companies in each pseudo-province (the quotas by pseudo-province). We then ran RIDDWM to estimate the DW company responses and costs.

Implications for Remaining Analysis. Because both marginal-cost pricing for DW and joint optimization are as economically efficient as average-cost pricing and nonjoint optimization, respectively, at a GW quota of 1.0, and moreso as the system is progressively stressed, the rest of our analysis is predicated on marginal-cost pricing and joint optimization.

25.5.2. Findings on GW Quotas and Charges

Using RESDM, we ran a number of cases with different GW quotas in combination with different choices for GW charges: none, a 0.20 Dfl/m^3 charge on only industrial firms, and the same charge on both industrial firms and DW companies. Figure 25.1 shows the GW extractions from these cases, and Fig. 25.2 shows the corresponding combined costs, as measured by the value of the RESDM objective function. From studying the figures, and certain other data in the runs, we arrived at the following findings.

GW Quota. The largest amount of GW can be saved simply by restricting withdrawals, but at costs that increase substantially with the severity of the restriction; such blanket restrictions would hurt

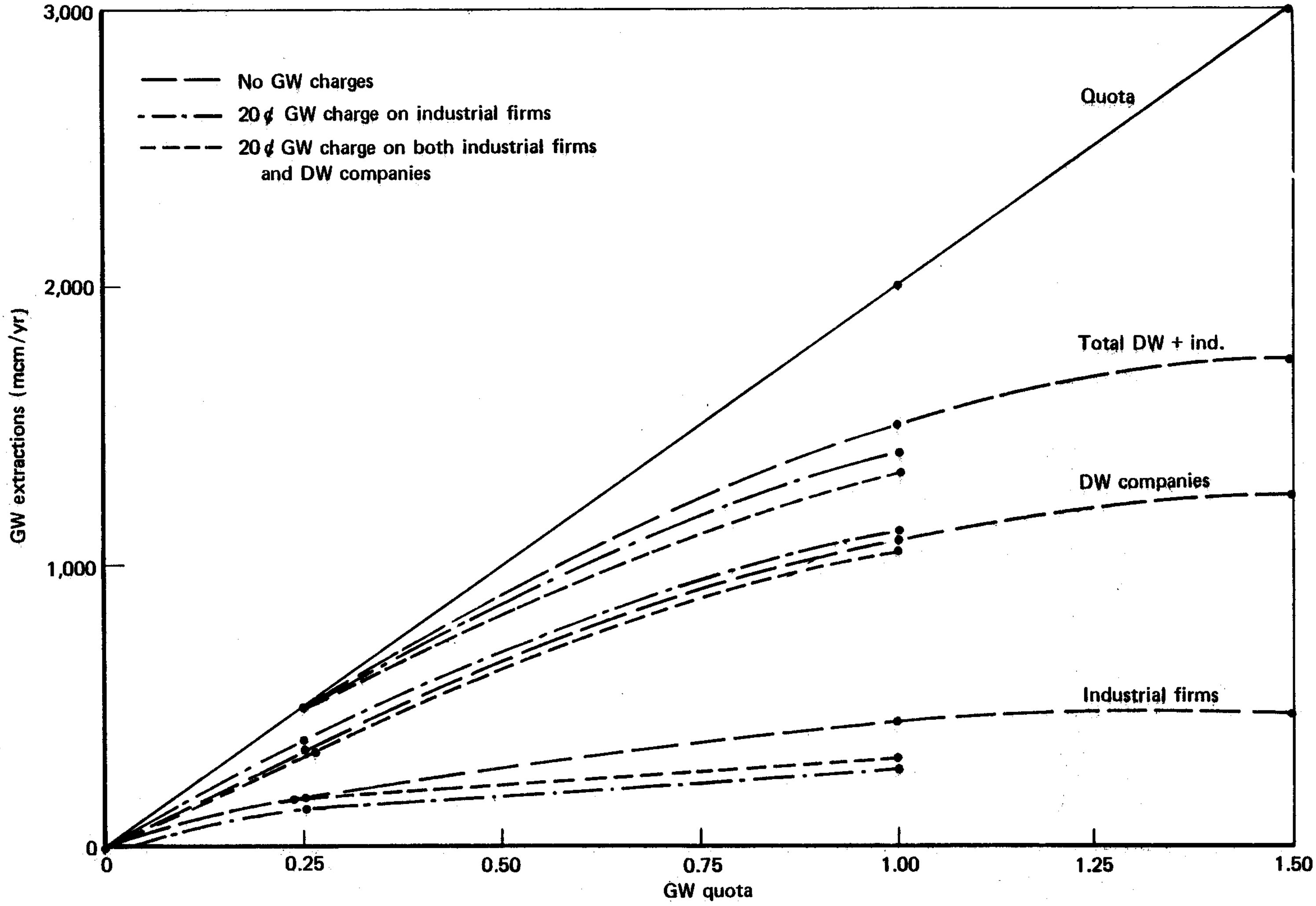


Fig. 25.1--GW extraction as a function of quota and charge

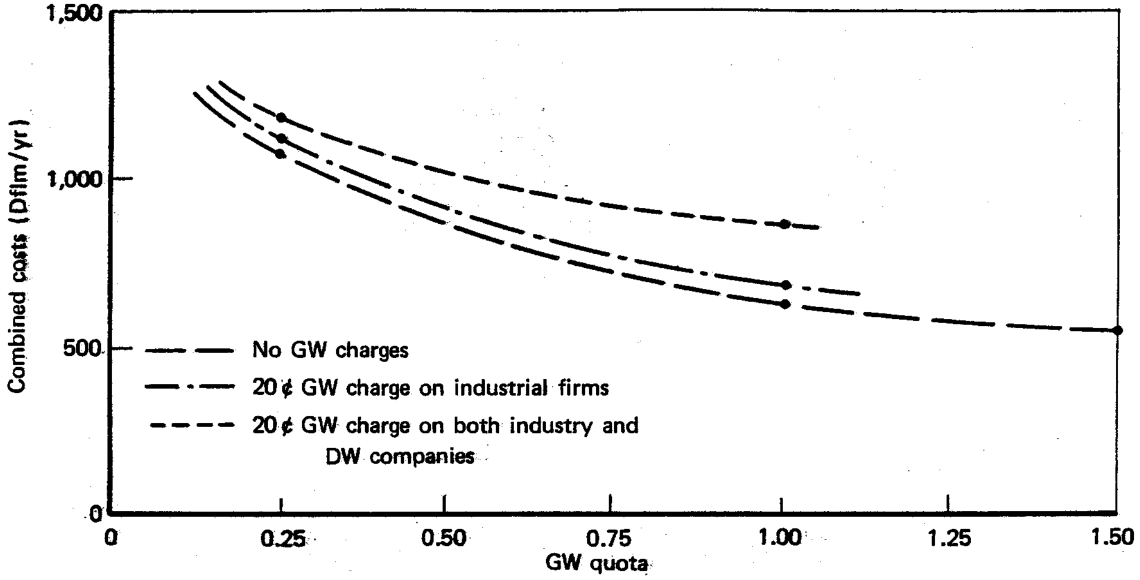


Fig. 25.2--Industry and DW company combined costs as a function of GW quota and charge

the western Lowlands provinces the most, as their GW supplies currently are inadequate. Nonetheless, it is clear that both industry and DW companies can find sufficient responses among the menus we provided to considerably reduce their GW consumption, albeit at higher cost and, for DW companies, by producing DW with a much higher proportion of SW. Indeed, at a quota of 0.25, DW companies must build 10 to 12 additional SW projects, and industries must replace some of their GW with relatively expensive DW.

GW Charges. Imposing charges of 0.20 Dfl/m^3 on GW use (the maximum charge being contemplated for industry under the proposed GW law), whether on industry alone or jointly on industry and DW companies, saves only a little GW overall but at a considerable extra cost. (This cost is the payment of the charge by the sectors it is levied on. Strictly speaking, it is not a cost from the nation's point of view, since it is a revenue to the government.) In a highly stressed system (where the GW quotas are one-fourth their usual values), essentially no GW is saved by the charge, yet a cost--in the amount of the charges paid--is incurred. The primary effect of this tactic is to reallocate some GW from the industrial to the DW company sector where it is more cost-beneficial. This explains why in Fig. 25.1 we observe that DW companies extract more GW when a 0.20 Dfl/m^3 charge is levied only on industrial firms than they do when there is no charge at all. Less directly, it also explains why the figure shows that GW extractions of industrial firms are less when the charge is applied only to them than when it is applied both to them and to DW companies. When a charge is applied to DW companies, they demand somewhat less GW than they do without the charge. In this situation, applying the charge to industry reallocates less water to DW companies.

Sensitivity Analyses. Our findings are based largely on estimates that have considerable associated uncertainty, and may be too broad in their scope to be universally applicable (for example, local impacts of these findings are unknown and may be crucial to their ultimate acceptance). We carried out four sensitivity analyses to try to understand how altering either a basic assumption or the values of certain strategy variables might affect the results. We found that the results are very sensitive to lowering SW project costs by about one-third and to lowering nonindustrial DW demand by 10 percent; in both cases, the pressure on GW is eased and the marginal cost of supplying DW is reduced substantially. On the other hand, our results are relatively insensitive to lowering the annual growth rate for industrial production (and GW demand) from 4.3 to 3.0 percent, and to increasing the GW quota from 1.0 to 1.5 (i.e., increasing the GW extractable amounts by 50 percent).

This explains why in Fig. 25.1 we observe that DW companies extract more water when a 0.20 Dfl charge is levied only on industrial firms than they do when there is no charge at all. Less directly, it also explains why the figure shows the GW extractions of industrial firms are less when the charge is applied only to them than when it is applied to both them and DW companies. When a charge is applied to DW companies, they demand somewhat less GW than they do without the charge. In this situation, applying the charge to industry reallocates less water to DW companies.

25.5.3. Findings on GW Extraction Priority

Thus far we have only considered the current situation with respect to GW extraction priorities: That is, industrial firms and DW companies take as much GW as they wish, up to the quota, and the remainder is available to agriculture. But now we address the question of whether there would be a larger benefit to the nation from giving agriculture priority, and, if so, under what circumstances.

To answer this question, we calculated the gain in expected annual net benefits to agriculture that would result from giving it priority and then compared this with the corresponding gain to industry and DW companies from giving them priority. (The "gain" is just the benefits calculated *with* priority minus those calculated without.) (It should be noted that throughout the analysis of priority, we deal with expected values--the average value one would observe over many years of differing dryness. Benefits to agriculture are expected benefits. In dry years greater benefits may be anticipated; in wet years, lesser benefits. Similarly, the amount of GW extracted by agriculture is an expected annual amount; dry years will see larger extractions. Of course the GW demands and benefits of industry and DW companies do not vary with the dryness of the year.)

When we gave agriculture priority, we used the procedure of Sec. 12.4.2 to calculate the expected net benefits and expected extractions of GW for sprinkling for each district, given whatever sprinkler intensities were being considered and the grass multiplier. The national totals could then be obtained from the district totals.

In districts where the estimated amount of GW needed for sprinkling exceeded the extraction quota, we had to find a way to reduce sprinkling. A convenient remedy was to assume that sprinklers would not be installed in areas where their use would cause an extraction quota to be exceeded. We did this by reducing the sprinkler intensity of each plot in the problem district by some common proportion, chosen so that when the new sprinkler intensities were applied, the district's extraction quota was not exceeded. We permit one exception to the rule that GW used for sprinkling must never exceed the GW quota in question: Currently installed GW sprinklers continue to operate, even if their extractions cause the quota to be violated. In fact, this rarely causes the GW quota constraint to be violated, and when it does the quota is not overstepped by much. (Some additional details are given in Sec. 29.2.3.)

When we did not give agriculture priority, we merely reduced each district's quota by the amount of the industrial and DW company extractions, and then proceeded as above to find the expected net benefits.

When we gave industry and DW companies priority, we used RESDM in the usual fashion to obtain the GW extractions and the combined water-related costs for the cases being considered. Because RESDM satisfies industrial and DW company demands so that they do not have to reduce their production, it assumes that their benefits remain constant--only their costs change. Thus, the joint gain to industry/DW companies can be calculated as the costs <u>without</u> priority minus the costs <u>with</u> priority. The costs without priority are also calculated with RESDM, but after the GW quotas in each district have been reduced by the expected GW extractions by agriculture.

Because we conducted this analysis from the viewpoint of <u>national</u> benefits, we excluded from these costs any GW charges paid to the government by industry, which we regard as transfer payments. This viewpoint also caused us to include DW company surpluses in these costs; the surpluses reflect real costs to the users of DW and are analogous to net agricultural benefits, which reflect the costs of using GW for sprinkling.

We used the general approach described above to compute and compare the expected annual net benefits of different priorities for a variety of assumptions about the context (1976 and 1990), the sprinkler intensity (medium and high), the eligible area (RNONE and RALL), and the GW extraction charge on industry (0, 0.20, and 0.40 Dfl/m^3). (For these comparisons the quota was always 1.0.) After examining the results, we reached the following conclusion on GW extraction priorities:

From the standpoint of the nation, it is more beneficial to give priority for extracting GW to industry and DW companies when industrial and DW company GW demands are significantly higher than they are currently and when agricultural demand for GW is much higher (i.e., high sprinkler intensities).[10] In other instances, giving priority to agriculture is more beneficial.[11]

NOTES

1. In the Grondwaterwet or GW law that Parliament was debating at the time of this study, they considered imposing a GW charge on industry according to the following formula: a certain percentage of the average difference between the costs of producing one cubic meter of DW using SW and similar costs using GW. The maximum percentage might be 30, although different percentages could be imposed on different regions for different purposes. According to our estimates, that maximum percentage translates into a maximum surcharge on industrial GW use of 0.20 Dfl/m^3. This figure thus came to be used as one value of GW charge in our analysis. The law has since been approved by Parliament without this provision.

2. The districts are small enough that details of SW movement within a district can be regarded as unimportant for our purposes. Since GW moves much more slowly than SW, it is conceivable that the rate is important for us; but we have assumed it is not. In any event, we have no data to support estimates of GW movement either between districts or within them, and hence have assumed that each district contains a single pool of GW, isolated from the GW pools of all other districts.

3. This pricing scheme is economically efficient in the sense that there is no means (among the possibilities considered in our study) by which each province may enjoy the same or larger supplies of DW at a lower total nationwide cost.

4. In the current situation, farmers are compensated for losses if they are damaged by the GW withdrawals of DW companies, which implies DW companies and industries get first priority.

5. For a given context, we assume industry's basic use of DW remains constant. However, insofar as industry needs extra DW to replace or partially replace GW in response to a particular P/R tactic, the DW amounts contained in the various industrial responses actually represent these extra amounts and not the composite firm's total DW demands.

6. In cases where agriculture had priority, we introduced the farmers' extractions as a reduction in the quotas given to RESDM.

7. The GW quotas and prices by district are applied to industry, and those by pseudo-province are applied to DW companies. Note that the GW extractable amounts by pseudo-province, which were the basis for the quotas, have been increased by 33, 13, and 6 mcm/yr, respectively, in Noord-Holland, Zuid-Holland, and Zeeland, to account for additional storage in the dunes. This dune water is only available to DW companies, not to industry. These extractable amounts are shown in Table 2.1 of Vol. IV.

8. Recall that the GW shadow price for a district is the (common) value of one additional cubic meter of GW to each user. It is also the price each user should be willing to pay for that unit of GW. If all users are charged this price for each unit of GW, they should demand in total exactly the amount of GW available under the quota specified for the district.

9. The system is stressed when either more GW is demanded, or less is available than allowed, or some combination of the two. For example, the system is stressed least when no GW charges are imposed and 1976 DW demands are assumed, more when 1990 DW demands are assumed, and still more when the GW quota is reduced to less than half of the RID extractable amounts. Of the cases we considered, it is stressed the most when the following P/R tactics and conditions apply simultaneously: a GW charge of 0.20 Dfl/m^3 imposed on industry alone, 1990 DW demands (and high industrial production growth rates), and a GW quota of 0.25.

10. In Sec. 25.4.4 we mentioned that RESDM underestimates costs for quotas of 0.5 or above. As the stress on the system increases within this limit, the amount by which RESDM underestimates costs also increases. This means that the benefits to industrial firms and DW companies from giving them priority, which are reductions in their costs from the situation where they were without priority, are also underestimated. To the extent that this occurs, it broadens this conclusion about when to give priority to industry and DW companies so that it applies to smaller increases in demand. For the 1990 context, it probably applies when the GW sprinkler intensity is medium, and possibly even less.

11. As mentioned in earlier chapters, there are several reasons (e.g., the grass multiplier) to believe that the estimates of agricultural benefits may be somewhat optimistic. To the extent that this is true, it weakens this conclusion, or at least narrows the range of circumstances for giving priority to agriculture.

Chapter 26

DESIGN OF MANAGERIAL STRATEGIES

26.1. THE PROBLEM

This chapter investigates the problem of designing managerial strategies, which can be stated as: Determine what day-to-day actions will bring about the distribution of surface water (SW) that will be most beneficial to all water users and uses. We address this problem in a multitude of circumstances that vary according to the amount of water available to be distributed, the day-to-day actions for distributing it made possible by whatever facilities are available, and the demands for water by the various users.

Why may new managerial strategies be needed for the SW system? First, the current system facilities are being modified (much of PAWN's effort has been devoted to analyzing changes in facilities). Second, water management goals are changing. Only during the past few years have Dutch water managers had to concern themselves with any water quality issue besides salt, and that in only a few locations. Now they must also take into account thermal pollution, heavy metals, BOD, and other pollutants.

Finally, the current managerial strategy may not be the best possible for extremely dry years or other rare circumstances. The Netherlands is a relatively wet country, and most of the time almost any managerial strategy will yield satisfactory results. The current fragmented and somewhat uncoordinated managerial strategy, which evolved piecemeal as major and minor construction projects slowly changed the facilities, was in general satisfactory until the very dry summer of 1976. The resulting problems were sufficiently unsettling as to shape the PAWN study, for which preparations were already under way. This chapter describes a method of developing more rational managerial strategies, and applies the method to both the current water management infrastructure and to a SW system that incorporates some possible future changes (e.g., MAXTACS). (Chapter 28 will describe how we combine the resulting managerial strategy with the technical and long-run price and regulation strategies to form water management policies.)

26.2. MANAGERIAL TACTICS CONSIDERED

The current Dutch SW management system can be considered as a network of rivers, canals, lakes, and reservoirs, called an infrastructure. (See Figs. 1.5 and 4.1.) Day-to-day control can be exercised over the flows in some rivers and canals by pumping stations and weirs. Some of the withdrawals of water from the infrastructure can also be controlled. We call the individual day-to-day control measures managerial rules. The RWS already has a set of such rules for operating the current infrastructure. A tactic that changes one of these rules--i.e., that changes the way the infrastructure is operated is called amanagerial tactic. Combinations of managerial tactics form a managerial strategy. Managerial rules that are not explicitly changed by a managerial strategy are understood to remain in their current form.

We distinguish managerial tactics from other, longer-term kinds of control that might be exercised over the distribution of SW. The digging of a new canal, the enlargement of an old one, or the construction of a new sluice or pumping station will influence water distribution. Such technical tactics differ from managerial tactics in that they require a considerable time to implement and they are more or less permanent once implemented. Managerial tactics, by contrast, are short-run; they can be implemented almost at a moment's notice, and as quickly canceled.

Below we give an overview of the classes of managerial tactics considered in our analysis of managerial strategies. Detailed discussions of individual tactics are presented in Vol. V.

26.2.1. The Weir at Driel

From Lobith, where it enters the Netherlands, the Rijn River flows west in the Waal and the Neder-Rijn, and north in the IJssel. The division of the Rijn flow among these three river branches is determined in part by hydrological factors,[1] and in part by the weir at Driel, on the Neder-Rijn. Altering this division by adjusting the weir at Driel is one of the most important managerial tactics.

When the weirs on the Neder-Rijn were completed in the early 1970s it was decided to operate them at times of low Rijn flow so as to send a maximum amount of water north to the IJssel lakes via the IJssel River, which would also maximize the depth of the IJssel for the benefit of shipping. Thus, only at relatively high Rijn flows is the weir at Driel set to allow more than a minimum flow in the Neder-Rijn.

26.2.2. The Amsterdam-Rijnkanaal

At Tiel, further west on the Waal, water can be withdrawn into the Amsterdam-Rijnkanaal and sent north to the Neder-Rijn at Wijk bij Duurstede, where it will augment the Neder-Rijn flow. Or it may be sent across the Neder-Rijn (where it can be augmented by Neder-Rijn water), along the Amsterdam-Rijnkanaal to Amsterdam, and then west in the Noordzeekanaal into the North Sea. The adjustments of the flows on the Waal, the Neder-Rijn, and the Amsterdam-Rijnkanaal constitute another group of important managerial tactics.

The Amsterdam-Rijnkanaal was completed in 1952. It was decided to maintain the flow high enough to permit desired extractions from the canal, and to keep both the Amsterdam-Rijnkanaal and the Noordzeekanaal flushed adequately for water quality maintenance. Originally, this flow could be supplied from the Neder-Rijn, but after the weirs on the Neder-Rijn had been completed the water had to be taken from the Waal at Tiel.

26.2.3. The IJssel Lakes

The water sent north on the IJssel River flows into the only major water storage basin in the Netherlands, the IJssel lakes. There are two large lakes, the IJsselmeer and the Markermeer, plus several smaller Randmeren (border lakes, such as the Gooimeer, Eemmeer, and Veluwemeer).

After the Afsluitdijk (barrier dam) was completed in 1932, and the freshwater IJssel lakes were formed, it was discovered that the IJssel flow is almost always large enough to maintain the lakes at their maximum safe levels. Thus, the lake levels are controlled merely by getting rid of excess water. The preferred method extracts water from the IJmeer (at the southwest corner of the Markermeer) to augment the flow in the Noordzeekanaal; only when there is a large excess of water is any discharged through the sluices in the Afsluitdijk. So seldom have the IJssel lakes levels dropped significantly below their maxima that no doctrine exists for dealing with that circumstance; in fact, a major unsettling event in the summer of 1976 was that the ad hoc managerial responses to the shortage of water allowed the lakes to drop near their minimum levels. Given the maximum and minimum lake levels, which are determined by the infrastructure, the tactics governing various flows in and out of the lakes constitute another important group of managerial tactics.

26.2.4. Salt/Fresh Locks

At 11 points on the infrastructure, we consider locks that separate seawater from fresh water. (See Chap. 7 on locks.) The separation is imperfect, however, for some salt water intrudes as the locks are cycled to pass ships. This salt intrusion can be reduced by the managerial tactics of (1) flushing fresh water through the lock (or accompanying sluice), (2) reducing the number of lock cycles by altering the lock operation (e.g., never cycling the lock for a single ship, or delaying ships for a fixed amount of time), and (3) if the lock is equipped with technical devices such as bubble screens, determining when and how to use them.

26.2.5. The Maas

The Maas River is fully canalized by a system of weirs, so that even during periods of very low Maas flow (which happens frequently), the water can be maintained deep enough for shipping to use the river. Water can be diverted from the upper reaches of the Maas into a system of canals (the Zuid-Willemsvaart, the Wessem-Nederweertkanaal, and the Wilhelminakanaal) built to make inland shipping possible. The canals also deliver water for irrigation and other purposes to areas throughout the southern provinces of the Netherlands.

Most of this area is at a high elevation (for the Netherlands), and at present can only be supplied from the upper reaches of the Maas. At times of low Maas flow, there is little freedom to choose among managerial strategies. The water manager must conserve water as best he can, mostly by reducing the losses at shipping locks. He must release water impounded behind the weirs to make up any deficits, thus reducing the depth of the Maas to the detriment of shipping. And if there is still too little water, users (mostly farmers) must go without, and shipping will cease.

26.2.6. Regional Waterways

In addition to the major parts of the SW network discussed above, which have national importance, there are many small rivers and canals with only regional significance. North Holland, which is just to the west of the IJsselmeer and Markermeer, extracts its SW from those lakes. The northern provinces to the east of the IJsselmeer also obtain their SW from the IJssel lakes, by way of the Prinses Margrietkanaal. The provinces in the Northeast Highlands pump water from the IJssel River via the Twenthekanaal, and from the Zwartemeer via the Meppelerdiep. The Northeast Highlands also obtain some water from the Overijsselsche Vecht, which enters the Netherlands at De Haandrik. The Midwest region is bounded on the south by the Lek and Nieuwe Maas rivers, on the east by the Amsterdam-Rijnkanaal, and on the north by the Noordzeekanaal. Its SW is supplied partly from the Amsterdam-Rijnkanaal and partly from the Nieuwe Maas via the Hollandsche IJssel River. Every diversion of water from the national system into a regional waterway can be controlled, at least in part, by managerial tactics. In general, current practice supplies all the water demanded to each region, as long as the water is available.

26.2.7. Fresh/Fresh Locks

In the Southeast Highlands, there are seven lock complexes through which freshwater losses may be unacceptably large in dry periods. Managerial tactics considered include reducing the number of lock cycles or using lock equipment (e.g., pumps or holding ponds) to reduce water consumption per cycle.

26.2.8. Possible Future Changes

Changes to the infrastructure are likely to occur in the future, making it necessary to extend and modify the managerial strategy. For example, pumping stations have been proposed on the Zuid-Willemsvaart to permit water from the lower reaches of the Maas to supply more of the southern Highlands. If a canal were also built to connect the Waal and the Maas at St. Andries, Waal water could be used in place of Maas water to supply the southern Highlands.

As another example, if MAXTACS (see Sec. 22.7.6) were added to the current infrastructure, the associated decrease in the minimum summer level for the IJsselmeer and Markermeer would probably make it appropriate to modify the managerial strategy to change the flows in and out of the IJssel lakes. Indeed, the increases resulting from MAXTACS in the capacity of the current infrastructure would create a wider range of possibilities for managerial tactics, many of which are concerned with how much water to send through a particular link during a particular decade. In general, changes to the infrastructure produce changes in the menu of managerial tactics that are possible.

26.3. WATER USERS AND USES, AND THEIR BENEFITS

We have considered the following broad categories of water users and uses:

1. Water management, including flushing and level control
2. Water quality, environment, and public health
3. Shipping
4. Agriculture
5. Power plants (for cooling)
6. Households, commerce, and industry (except power plants)

26.3.1. Monetary Value of Some Water Uses

For some water users or uses, the benefit from receiving a certain amount of water can be measured in monetary terms. For example, if water is diverted from the Waal and IJssel rivers, their depths will decrease and some shippers will be unable to carry full loads. We estimated the additional cost for transporting goods in partially loaded ships (in Chap. 6 on shipping), from which we can infer that the value to shipping of leaving the water in the major rivers may be as high as 0.1 Dfl/m^3 when the river flows are unusually small.[2] But the value of water is highly variable for shipping, as it is for all users. Figure 26.1 illustrates this variability in the case of shipping on the Waal, where the value of water depends mostly on the Rijn flow.

But to leave the water in the major rivers might mean depriving some farmers of irrigation water. We have estimated that the value of water for irrigation can range as high as 0.3 or 0.4 or even 1.0 Dfl/m^3, in a period with no rain and dry, hot conditions favoring a high rate of evaporation.[2]

The diversion of water from the Waal could also provide water to cool the electricity generating plants on the Amsterdam-Rijnkanaal and the Noordzeekanaal. At the present time, water temperatures in these canals are permitted to rise as much as 7 deg C above their natural or

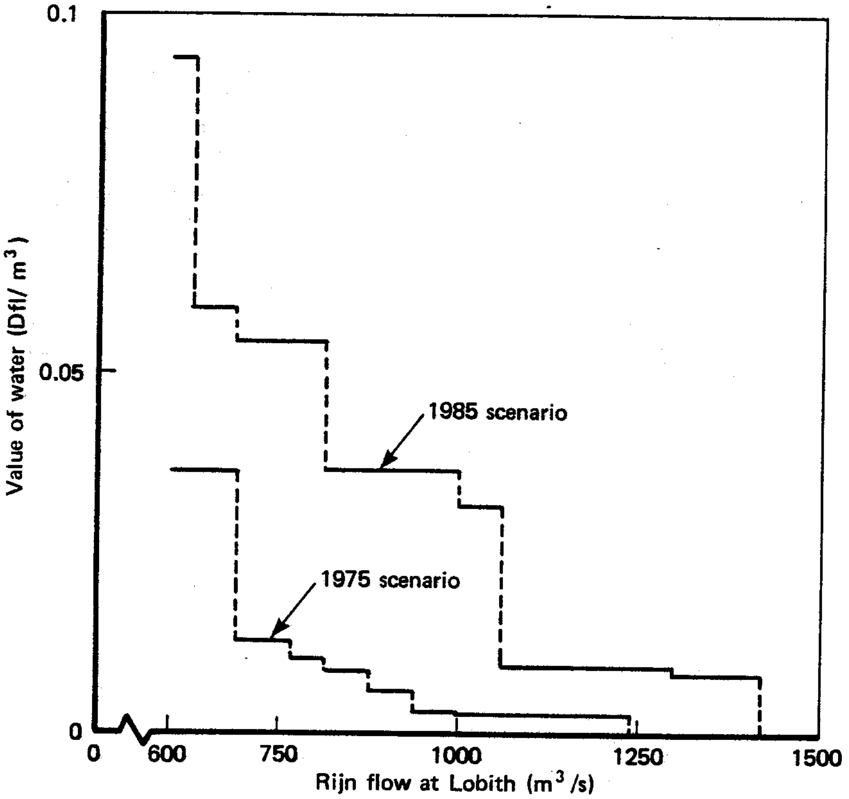


Fig. 26.1--Value to Waal shipping of reducing withdrawals at Tiel

background levels, but we have also considered the effect of imposing a 3-deg limit on the excess temperature. Whatever the limit, if the flow of cooling water is insufficient these plants must reduce their heat discharges. This is done by operating the plants below capacity and generating the missing power at other, less efficient plants. We have estimated the additional cost of generating power at less efficient plants, and infer that for a 3-deg standard, the value of water for cooling on these canals is between 0.01 and 0.03 Dfl/m^3.[2]

Diverting water into the Amsterdam-Rijnkanaal from the Waal or Neder-Rijn also reduces the flow of water in the Nieuwe Maas. Water from the North Sea, being denser than the fresh Rijn water, flows upstream in the Nieuwe Waterweg and Nieuwe Maas in a layer at the bottom of the channel. When the flow in the Nieuwe Maas is too low, this salt wedge can penetrate as far inland as the mouth of the Hollandsche IJssel. In dry periods, water flows north in the Hollandsche IJssel from its mouth to Gouda, where it is extracted to supply most of the water needs of the Midwest. The salt admitted along with the water can cause significant damage to the crops grown in glasshouses in the Midwest, largely because the water cannot soon be flushed out of the region. Thus, diverting water from the Waal or Neder-Rijn into the Amsterdam-Rijnkanaal indirectly damages glasshouse crops in the midwest. We have estimated the damage caused by the diversion of one cubic meter of water to be as high as 0.35 Dfl when the Rijn flow is extremely low.[2]

The withdrawal of water (for a variety of uses) from the Waal at Tiel can lead to sedimentation, with a sandbar forming somewhat downstream of the withdrawal point. If nothing is done, the sandbar will be washed downstream until, several months later, it reaches a critical point for shipping, reducing the depth there. Moreover, several years will pass before the sandbar has completely passed the critical point, so shipping will bear the cost of a reduced depth on the Waal for a considerable period of time. Alternatively, the sandbar can be removed by dredging before it reaches the critical point. This avoids the cost of a reduced shipping depth but substitutes the cost of dredging. As explained in Vol. V, we have converted the cost of dredging a cubic meter of sand into an expected cost of dredging attributable to each cubic meter of water withdrawn, and shown this cost to be less than 0.0002 Dfl. In contrast, the corresponding expected cost of allowing the sandbar to build up and interfere with shipping is about 20 times this.

26.3.2. Water Uses with Nonmonetizable Values

For other uses of water, it is impossible to estimate a monetary value. For example, it is considered essential by Dutch water managers to maintain the water in regional canals and ditches in the Lowlands at constant levels. To allow the levels to rise would cause flooding and to allow them to drop would expose numerous industrial water intakes. Letting the water levels drop would also reduce the hydraulic pressure that limits the rate of seepage of seawater into these below-sea-level areas. (Actually, these levels do vary by as much as 10 cm, probably because they are difficult to control more closely. Ten centimeters sounds small, but the total area of water involved is so large that a 10-cm change in level accommodates a large store of water.) Two other effects of a drop in water level are (1) the drying out and subsequent subsidence of the land and (2) the exposure to air of usually submerged wooden foundation piles. The first effect would make permanent an increase in the seepage rate of seawater, since the water level could not thereafter be raised as high as previously without flooding. The second effect would accelerate the decay of the foundation piles.

Another use of water for which we cannot estimate a monetary value is water quality improvement. How much is it worth to lower the concentration of phosphate or BOD by one mg/l? To do so might reduce the amount of algae growing in the water, improving its appearance. It might change somewhat the species of fish and water plants found there. There could even be some public health benefits. But we know of no sensible method for turning these benefits into money equivalents.

In this chapter we consider five measures of water quality. They are phosphate, which is a nutrient contributing to algae growth (heavy growths of algae are a major nuisance in many Dutch lakes); the many substances comprising BOD, which can deplete water of oxygen, causing fish kills and noxious odors; chromium, which is a toxic substance; salt, which degrades the taste of drinking water, may cause high blood pressure, and may damage agricultural crops; and thermal pollution, which may drive some species out of their traditional habitats. The damage done to agriculture by salt can be monetized, and we have done so, but the taste and public health aspects cannot. Similarly, the cost of reducing heat discharges from power plants can be estimated, but not the "cost" of living with a high increment of temperature above the background (the excess temperature). For the other pollutants, we considered no monetizable aspects.

We treated nonmonetizable water uses by imposing constraints on them. Instead of estimating the damage caused by a change in the water level in a ditch from some preferred value, we simply impose the requirement that the ditch water level remain constant, and we always supply (or extract) enough water to keep it so. Similarly, instead of trying to value a reduction in pollutant concentrations, we impose a water quality standard that prohibits the concentration from rising above a specified value. The values chosen for the water quality standards and the preferred ditch levels are based on prevailing Dutch opinion and practices.

26.4. THE MANAGERIAL STRATEGY DESIGN MODEL

We constructed a managerial strategy design model (MSDM) to solve the problem stated at the beginning of this chapter, namely, to determine the managerial strategy that results in the greatest possible net benefit to water users. Because the managerial strategy should depend on the external supply and accumulated store of water, which change from decade to decade, each decade will require a new strategy. (Day-to-day actions in the real world can only change by decade in PAWN because the decade is the smallest time-step.) The model to find the strategy for a single decade is formulated as a mathematical programming problem, which is a class of problems having variables whose values are restricted by constraints, and whose purpose is to find, among all variable values that satisfy the constraints, those values that minimize an objective function. (Reference 26.1, which is widely available, contains a good introduction to mathematical programming.)

In MSDM the variables are flows in rivers and canals and water levels in lakes and reservoirs, as well as concentrations of pollutants at numerous locations. Some constraints on flows and water levels define the managerial tactics, whereas others impose requirements for water uses whose values we could not monetize. Many constraints can be changed (usually relaxed) by changing the infrastructure, e.g., building new canals, pumping stations, or weirs. Such changes increase or decrease the range of managerial tactics available to the water manager. Water quality standards are expressed in MSDM as constraints on pollutant concentrations.

The objective function is the sum of all monetized costs associated with any set of flows, water levels, and pollutant concentrations. The monetized costs consist of the direct economic losses (disbenefits) to water users that are monetizable (see above), plus the direct costs of managerial tactics, such as pumping costs.[3] These monetized costs are short-run variable costs; they are the only costs affected by the short-run tactics considered in MSDM. As explained immediately below, we calculate these costs using modified versions of other PAWN models and results of various PAWN analyses that are incorporated in MSDM.

Thus, for a specified decade, MSDM finds the mix of variables that minimizes the objective function (relevant costs and economic losses) while satisfying constraints in the form of standards and requirements, water balances at nodes, and limits on lake levels. (How we develop the managerial strategy for an entire year from MSDM results will be discussed in Sec. 26.5 below.)

26.4.1. Relation to Other Parts of PAWN

MSDM is closely related to other parts of the PAWN methodology. For example, as in the DM, some of MSDM's variables represent flows in rivers and canals and water levels in lakes and reservoirs. Constraints involving these variables describe the water management infrastructure as a network with 37 nodes and 65 links. (See Fig. 26.2.) This network is an aggregated and simplified version of the network used in the DM, so there is a reasonably close correspondence between water distribution in the two models. (The aggregation leaves the MSDM network almost identical to the DM network in the portions that represent the national waterways. The regional parts of the DM network are highly aggregated to form the MSDM network. The MSDM network, however, remains sufficiently detailed that almost all managerial and technical tactics can be reasonably well represented.) In Fig. 26.2, major and minor links are distinguished on the basis of the amount of water typically carried. Links are not shown to represent minor extractions for irrigation, industry, or leakage from the SW system, because such extractions occur at every node.

In MSDM, as in the DM, these constraints can be changed (usually relaxed) to reflect infrastructure changes such as new canals, pumping stations, or weirs. Such changes increase or decrease the range of day-to-day actions--i.e., the managerial tactics--available to the water manager.

Terms in the objective function are associated with many of the flow and water level variables. On links where pumping occurs, for example, there are energy costs for pumping. Associated with various other links are either the shipping low-water loss functions or the sedimentation/dredging cost functions (described in the shipping

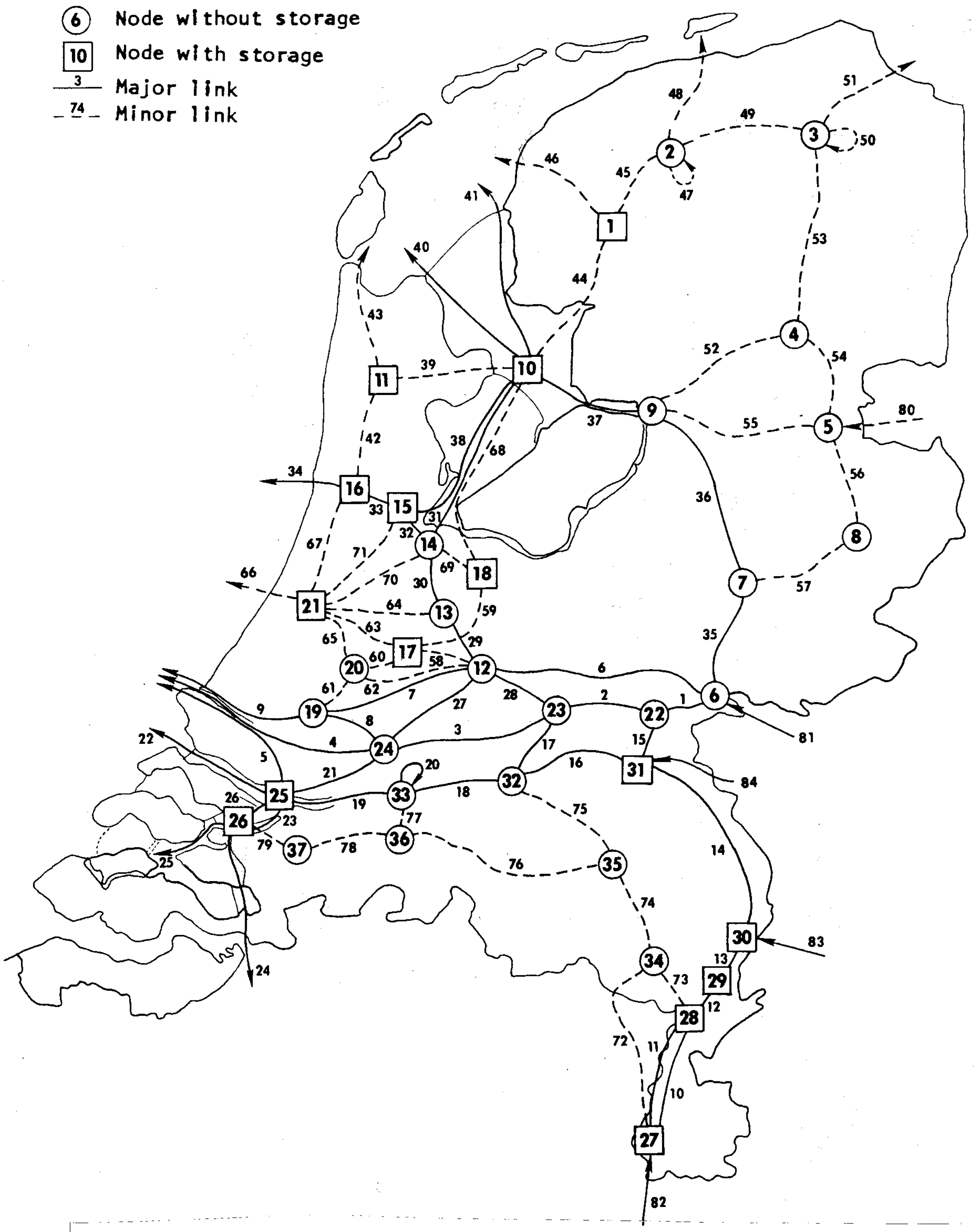


Fig. 26.2--the MSDM network

methodology chapter), or the shipping delay costs at locks (described in the locks chapter).

Other variables represent withdrawals of water from the infrastructure, notably by agriculture. Associated with these variables are terms in the objective function that estimate the value of water used for irrigating crops. The estimated value of water consists of the eventual crop damage (now and in the future) that one expects to avoid by irrigating at the present time, less the cost of irrigation. MSDM's representation of agriculture is related to the representation in DISTAG in that each MSDM withdrawal variable provides irrigation water to an identifiable collection of DISTAG plots, and in that the crop values and crop damage functions in DISTAG served as the basis for estimating the value of water for irrigation. (The MSDM representation of agriculture was developed by a complex process, summarized in Vol. V. and detailed in Vol. VA.)

Still other variables represent concentrations of five different pollutants: salt, heat from electric power plants, BOD, phosphate, and chromium. In MSDM, as in the DM, we assumed that pollutants are swept passively downstream by the flow of water and that they may experience exponential decay while doing so. Pollutant concentrations in the DM were calibrated to observations by adjusting the decay rates. Because the MSDM and DM networks are so closely related, we were able to use the same decay rates in both, rather than having to recalibrate for MSDM. MSDM also uses the same inventory of pollutant discharges as does the DM, and much the same representations of the Rotterdam salt wedge and salt intrusion through locks described in earlier chapters. In addition, some of the terms in the MSDM objective function represent the costs of tactics for reducing salt intrusion through locks by varying amounts.

Finally, the inventories of electric power plants are the same in MSDM as in the previously described EPRAC model, as are the assumptions regarding their operation and the method for determining the costs of generating electric power (which appear in the MSDM objective function). The difference is that EPRAC is a stand-alone model whereas its counterpart in MSDM is closely integrated with the rest of the MSDM methodology.

26.4.2. Differences from Other Parts of PAWN

There are some major differences, however, between MSDM's use of these methodology components and their use in other parts of PAWN. With MSDM we wish to find the day-to-day water management actions (i.e., the managerial tactics) that will yield the greatest possible net benefits to the Netherlands as a whole. Since MSDM is concerned only with day-to-day actions, it is unnecessary to include costs that are unaffected by these actions. Thus, the investment cost of a new weir or lock will not appear in MSDM, although the operating cost will. In general, short-run costs are included, and long-run costs are excluded. It is thus difficult to compare MSDM cases with different infrastructures.

But precisely because MSDM focuses on day-to-day actions, it must closely associate those actions with their effects on the various users of water. In the DM, an algorithm is specified that describes the managerial strategy to be used, and the consequences of that strategy are then calculated. The process stops there. In MSDM, by contrast, after the consequences are calculated, the strategy must be reexamined, to see whether it might be improved--i.e., whether better overall consequences can be achieved. This requires that the consequences be much more closely linked to day-to-day actions in MSDM than was necessary in other parts of PAWN.

26.4.3. The Solution Algorithm

The model can be decomposed naturally into a subproblem dealing only with water distribution (i.e., flows and water levels), and five water quality subproblems, each dealing with a single pollutant. The model finds a managerial strategy for any specified water supply and infrastructure by repeatedly cycling through the six subproblems. In the first cycle, it solves the water distribution subproblem, considering only the user costs that are expressed directly in terms of water-flows and levels. It considers pumping costs, costs of low water to shipping, and costs to agriculture of failing to supply water for irrigation, but it does not consider certain other quality-related costs such as the effect of changing the water distribution on the cost of meeting the demand for electric power under a thermal limitation, or the cost to agriculture of excessive salt concentrations, even though a different water distribution might reduce those concentrations. Continuing the first cycle, the model uses the flows and levels thus calculated as inputs to each of the water quality subproblems in turn, and computes the pollutant concentrations.

In the next cycle, MSDM again solves the water distribution subproblem. This time, however, it uses the solutions of the water quality subproblems to estimate the effect of changing the water distribution on quality-related costs, and adds these estimates to the user costs already expressed directly in terms of water-flows and levels. It is not possible to calculate the exact effect, so if the solution to the new water distribution subproblem differs from the previous solution, it is necessary to solve each water quality subproblem again, form another estimate of the effect, and start another cycle.

MSDM does not invariably converge upon a single water distribution, even after arbitrarily many cycles. It may oscillate, or it may drift seemingly at random. When this happens, we can usually obtain convergence by manually imposing some artificial constraints, thus reducing the freedom available to MSDM. Because of this, we cannot be certain that the managerial strategy selected actually minimizes the objective function (i.e., is <u>optimal</u>). But we have experimented enough with MSDM to assure ourselves that the managerial strategies selected are nearly optimal. (See Vol. V for details.)

26.5. ANALYSIS AND RESULTS

Given a specified infrastructure (expressed as a network), the menu of managerial tactics that are possible in that infrastructure, and a specified sprinkler scenario, MSDM finds the strategy for a specified decade that minimizes the objective function while satisfying constraints imposed by standards and requirements, water balances at nodes, and limits on lake levels. The specified decade is characterized by its external supply and accumulated storage of water.

For each infrastructure, associated menu of managerial tactics, and sprinkler scenario, we ran MSDM for a wide variety of decades, representing different SW supplies. We constructed these SW supplies as combinations of

- Four different river flows for the Rijn and the Maas, ranging from extremely low to moderately high.[4]
- Two values for net rain (actual rain minus open-water evaporation), ranging from extremely dry (net evaporation of 66 mm/decade--the first decade in July 1976) to moderately wet (net rain of 11 mm/decade--the second decade in February 1976).[5]
- Two values for the level of the IJssel lake system, ranging from high (the target level) to low (the minimum level), to represent extremes of accumulated storage of water. The level values depend on the infrastructure being considered.

We looked primarily at two combinations of an infrastructure and a sprinkler scenario: The first is the current infrastructure combined with the current sprinkler scenario (SPRLOW-RNONE). The second is the current infrastructure with MAXTACS and the fresh Zoommeer combined with the SPRHI-RALL sprinkler scenario (high sprinkler intensity with all the promising waterboard plans implemented). They represent the low and high extremes of SW demand.

We ran MSDM for the decades and SW demands described above, examined the outputs, and obtained three principal results. These results are described below with some additional details of how they were derived. (Volume V presents a complete discussion of these and other results.)

26.5.1. Result I: Dilution Is No Solution to Pollution

Our first experiments with MSDM demonstrated that, with a few exceptions, managerial tactics have little effect on water quality. In the first of these experiments, we imposed water quality standards on all five pollutants (salt, thermal, BOD, phosphate, and chromium), and found that the resulting problem had no feasible solution. That is, MSDM could find no way to force compliance with all water quality standards at all locations.

For later experiments in this series, therefore, we allowed the standards to be exceeded, but imposed very high costs on violations, costs so high that MSDM's first priority was to reduce pollutant concentrations wherever they exceeded the standards. In some experiments, such costs were imposed on only one pollutant, while in others, costs were imposed on more than one.

Results from these experiments showed that with few exceptions, managerial tactics can effect only minor improvements in water quality at only a few locations. Often, a reduction in the concentration of one pollutant at a location is accomplished only at the cost of an increase in the same pollutant's concentration elsewhere, or of another pollutant's concentration somewhere. Moreover, a tactic that causes a minor reduction in the pollutant's concentration somewhere usually imposes large monetary costs on agriculture, shipping, or other water users. Accordingly, for later MSDM cases we relaxed the water quality standards for phosphate, BOD, chromium, and salt. We retained the thermal standards, at least for some cases, because we had included in MSDM the means to shift power generation from one plant to another in order to meet them. We also retained the costs associated with high salt concentrations.

A cautionary note: As already noted, although MSDM represents the nationally important part of the SW network in reasonable detail, it represents the regional waterways in a highly aggregated way. The pollutant concentrations it calculates in regional waters, therefore, are averages over relatively large areas. It is quite possible that a more detailed examination of regional waterways would uncover instances where the diversion of water from one small canal to another might dilute a highly polluted but rather small area.

We mentioned above that there are a few instances where managerial tactics can affect water quality to a significant degree. MSDM showed such results for the salt concentration in the Hollandsche IJssel, which is elevated by salt intrusion from the North Sea when the Nieuwe Maas flow is low. The Nieuwe Maas flow can be increased by opening the weir at Driel or by withdrawing water from the Waal at Tiel to augment the Neder-Rijn flow. Even though the salt standards are ignored, these tactics will be employed under some circumstances because salt in the Hollandsche IJssel would otherwise be taken into the Midwest and damage crops under glass. This damage is included in the MSDM objective function.

MSDM also showed siginficant results for the use of water from the IJssel lakes to cool the discharges from power plants on the Noordzeekanaal and on the Bergumermeer (a small lake northeast of the IJssel lakes). These tactics have been employed in all of the MSDM cases in which a thermal standard has been imposed.

26.5.2. Result II: The Value of Storing Water for Future Uses

Using MSDM, we have developed superior managerial strategies for individual decades with widely varying water supply conditions. As expected, the costs to all users rise as the water supply falls, whether the water is rain or river water, or water stored in the IJssel lakes from previous decades. But if having water in storage at the start of a decade reduces the costs to users during the decade, then there must have been some value to putting water in storage in previous decades. By shifting our time perspective, we can see that there is some value to putting water in storage during the present decade for possible use in later decades.

To estimate this value, we selected and ran a number of pairs of MSDM cases. In one case from each pair, the IJssel lakes were initially set at their maximum levels, and in the other case they were set at their minimum levels. Otherwise, any two paired cases were identical. Different pairs, however, incorporated different amounts of rainfall and potential evapotranspiration, and different river flows.

The cost differential between the two cases in each pair gave us an estimate of the value of having water in the IJssel lakes, as a function of net rain and river flows. From external supply data, we derived estimates of the probabilities that various combinations of river flow and net rain would occur. (See Vol. VA.) By combining these probabilities with the aforementioned cost differentials, we estimated the average value of storing water in the IJssel lakes to be between 0.0011 and 0.0045 $\mathrm{Dfl/m^3}$. This value is smaller than the value of using water to cool the power plants on the Noordzeekanaal and the Bergumermeer to meet a 3-deg thermal standard (if so strict a standard is imposed). Thus, it would seem preferable to use the water for cooling the power plants rather than saving it for possible future needs.

We caution, however, that the average value of stored water hides a large variation. Most of the time, the stored water is not needed at all, and has zero value. But on rare occasions, when dry conditions persist long enough to draw down the IJssel lakes to their minimum tolerable level, water must be diverted from all possible users to avoid drawing down the lakes further. On these occasions, the value of having more water in the lakes is as large as the highest value of water found among the users who have been deprived. Many people might therefore prefer to store up water even when average value calculations indicate it is not economical to do so, to avoid occasional, but catastrophic, losses.

26.5.3. Result III: A Superior Managerial Strategy

<u>The MSDM Strategy</u>. To construct a strategy for an entire year, it is not correct to string together strategies for individual decades, as if the decades were completely independent. We knew that the decades were not completely independent because the strategy for one

decade could influence the accumulated storage in the next, and this effect would alter the value of the objective function that could be achieved in the next decade. In MSDM, we incorporated this "memory" effect by adding a term to the objective function of the present decade to account for the future value of stored water; managerial strategies for single decades then reflected the memory effects between decades. With these effects included, it is correct to string together single decade strategies found by MSDM to obtain a strategy for the entire year.[6]

In our analysis with MSDM, we considered many different cases, reflecting extremes of both SW demand (different infrastructures and sprinkler scenarios) and SW supply (different river flows, net rain, and levels in the IJssel lakes). Because each case resulted in a different managerial strategy, it would not appear that we could draw any general conclusions from the MSDM results. And further, each managerial strategy, expressed as it is in numerical values, does not suggest what form the corresponding managerial rules it represents should take in the real world. We found we could compare MSDM results among different cases by comparing the final allocations of water in each. When we found that one water use took precedence over another use in most cases (determining causal relationships where we could), we determined that the water use with the preferential allocation had a higher priority among water uses, and that water thus had (broadly speaking) a higher relative economic value when put to that use.

For example, a close study of the cases used to estimate the value of water stored in the IJssel lakes showed that whenever agriculture received less water than it demanded, the shortage was almost always caused by one of the constraints of MSDM and not by competition for water with another user, suggesting that irrigation had the highest economic value for SW among discretionary uses. This occurred frequently in the Northeast Highlands, where the ability to transport water is limited to the available pumping capacity. In decades with little rain and high potential evapotranspiration, the demand by agriculture can exceed the capacity.

We observed reasonably consistent prioritization of water uses among cases at both the low and high extremes of SW demand and supply, so we were able to draw from our observations a priority ordering of water uses that is generally the same for all the strategies designed by MSDM. We ordered water uses in six groups, from highest to lowest priority:

Priority 1: Supply level control requirements for boezems and lakes, meet any water quality standards that have been specified, and satisfy all other constraints on MSDM.

Priority 2: Supply water to farmers for irrigating their crops. Also, establish certain nominal flushing rates for locks at which salt intrusion causes damage to crops grown locally.

Priority 3: Trade off shipping losses due to low water on the Waal and the IJssel, and salt damage to agriculture due to the Rotterdam salt wedge, by simultaneously adjusting the Neder-Rijn flow (by adjusting the weir at Driel) and withdrawals at Tiel.

Priority 4: Use water from the IJssel lakes for cooling the power plants on the Noordzeekanaal and the Bergumermeer to whatever thermal standard has been set for them.

Priority 5: Raise the IJssel lakes to their maximum levels to meet possible future needs for water.

Priority 6: Use water for flushing boezems and ditches and for raising the flushing rates of locks with local salt intrusion above the nominal rates established in Priority 2.

This priority ordering, then, is the MSDM strategy.

Frequently, a particular cubic meter of water is in a location where it can be used to satisfy only some demands. Under such circumstances, the priority scheme requires that each cubic meter of water be used for the highest priority use for which it can be used. Thus, water stored in the IJssel lakes might be used to cool the power plants on the Noordzeekanaal or the Bergumermeer (Priority 4), since no means exist to transport it to the southern Highlands to meet demands for irrigation water (Priority 2). Note, however, that if the infrastructure were changed to make IJssel lakes water accessible to the southern Highlands (a highly uneconomical but nevertheless technically feasible undertaking), the water would then be diverted to the higher priority use (irrigation).

Differences from RWS Managerial Strategy. The major difference between the MSDM strategy described above and the RWS managerial strategy (briefly defined in the chapter on the screening of technical and managerial tactics) lies in the tradeoff called for in Priority 3. For Rijn flows below average, the RWS strategy closes the weir at Driel almost completely, leaving only a minimum flow on the Neder-Rijn. This maximizes the depth of the IJssel, and hence benefits IJssel shipping. However, it minimizes the total flow to the west (Neder-Rijn plus Waal), which allows a maximum of salt damage to agriculture due to the Rotterdam salt wedge. Finally, by minimizing the Neder-Rijn flow, the RWS strategy requires a maximum withdrawal from the Waal at Tiel, which is unfavorable to Waal shipping. The tradeoff performed in the MSDM strategy can yield large savings over the RWS strategy during decades with very low Rijn flows.[7]

Another difference between the RWS and MSDM strategies involves the flow in the Amsterdam-Rijnkanaal. The RWS strategy supplies a considerable amount of water to cool the Noordzeekanaal power plants by withdrawing at Tiel. According to Priority 4, the MSDM strategy provides the water from the IJssel lakes instead. This reduces the cost to Waal shipping and leaves more water in the Waal to help combat the salt wedge, but it does tend to draw down the lakes to lower levels.

Finally, the RWS strategy carries out some flushing of boezems and ditches using water from the IJssel lakes, even when the lakes are not at their maximum levels.[7] This is a reversal of Priorities 5 and 6, and is not done by the MSDM strategy.[8]

The SIMPLE MSDM Strategy. To test whether the MSDM strategy is truly superior to the RWS strategy, we wanted to compare the two in the same model. Accordingly, we attempted to describe the MSDM strategy in a manner suitable for use in the DM. Our best approximation to RWS strategy was, of course, already implemented in the DM.

Although we had too little time to formulate the entire MSDM strategy for the DM, we were able to implement the tradeoff described in Priority 3 above by means of a special subroutine written for the DM. We call the resulting strategy--and the subroutine that implements it--SIMPLE MSDM.[9] As will be shown in a later chapter, SIMPLE MSDM is not by itself always preferable to the RWS strategy. However, it appears that adding Priorities 4 through 6 could well make it so.

Velsen Strategy. For eventual comparison with the RWS and SIMPLE MSDM managerial strategies, we also devised the Velsen (VEL) strategy. The VEL strategy is essentially the same as the RWS strategy, except that the VEL strategy obtains more water for cooling power plants on the Noordzeekanaal (especially the Velsen plant) from the IJssel lakes, and less from the Waal or Neder-Rijn via the Amsterdam-Rijnkanaal.

NOTES

1. According to Webster's New Collegiate Dictionary, 1975, hydraulics is "a branch of science that deals with practical applications (as the transmission of energy or the effects of flow) of liquid (as water) in motion," whereas hydrology is "a science dealing with the properties, distribution, and circulation of water on the surface of the land, in the soil and underlying rocks, and in the atmosphere." The main distinction seems to be that the term "hydraulics" and related terms (e.g., hydraulic, hydraulically) refer to man-caused effects on water, while terms such as "hydrology", "hydrological", and the like, refer to natural effects. The hydrological factors meant here are the shape, resistance, and gradient of the river channels. Although man has certainly

influenced these factors, for example by dredging, they were largely shaped by nature. By contrast, the weir at Driel, being a man-made object intended to influence the flow of water, would be referred to here as a hydraulic factor.

2. It is relatively easy to estimate rough values of water in all these uses. For shipping, we can use the material in the shipping chapter to relate changes in low-water shipping losses to changes in water depths at critical points, and to further relate the changes in depths to changes in flows of water. For irrigation, we can compare the average annual net income from an irrigated field with that from an unirrigated field, and divide the difference by the average amount of irrigation water used annually. For cooling electric power plants, we can compute the flow of water in a canal needed to permit a given power plant to generate one more kilowatt (e.g., a flow in the Noordzeekanaal to cool Velsen), and compare that with the incremental cost of generating that kilowatt at some other suitable power plant. For the Rotterdam salt wedge, we must estimate the monetary damages to crops grown in glasshouses in the Midwest (these are the most salt-sensitive crops grown in the Netherlands) caused by an increase of one mg/l in the chloride concentration at Gouda, and compare this with the flow in the Nieuwe Maas needed to change that concentration by one mg/l. The damage can be estimated using runs of the DM, or more directly using the crop damage functions described in Vol. XII. More refined estimates of the value of water in each of these uses are obtained in Vols. V and VA.

3. The objective function actually shows net losses. First, some user groups may experience gains, but most will experience losses. (A managerial strategy can partly ameliorate, but not eliminate, the costs and damages from drought.) Second, the losses to a user group are its gross losses minus its gains.

4. The Rijn flows were 750, 1000, 1250, and 1500 m^3/s; the corresponding Maas flows (at the Mastricht node) were 26, 31, 36, and 41 m^3/s.

5. As defined here, net rain gives the net change due to weather in the water level of an open body of water during a decade. To obtain the corresponding change in the level of soil moisture, the open-water evaporation term would have to be reduced by factors corresponding to the actual evapotranspiration of the crops on the soil; this is done automatically within MSDM.

6. This conclusion is correct because it is based on the "principle of optimality" from the mathematical field of dynamic programming. See Refs. 26.1 or 26.2 for a discussion of the theory.

7. The same is true for the current strategy, for its behavior is similar to the RWS strategy in most respects. The current strategy was briefly defined in the chapter on the screening of technical and managerial tactics.

8. Despite our arguments about how it is possible to string together single decade strategies from MSDM to obtain a strategy for the entire year and the fact that we considered a wide range of initial conditions for the single decade, Dutch reviewers remain skeptical that the effects of initialization have been adequately handled in the MSDM strategy.

   They have voiced their concern especially for two issues. First, salt water admitted to the Midwest persists into later decades, affecting their initial conditions. The Dutch reviewers fear we have underestimated the carryover cost to the Midwest of initially admitting salt water. Second, because the primary concern is with developing strategies for dry years, they believe that a higher value for stored water corresponding to dry years should have been used in our analysis rather than a value representing the average for all years. However, we note that for this approach to be valid it must be known that the year being analyzed will continue to be dry. A different notion, and one we agree with, would be to use a function that values each cubic meter of stored water more highly as the total amount of water in storage declines.

   The methodology and results of the MSDM investigation appear to have considerable promise for eventual application in Dutch water management. However, the reader is cautioned that the MSDM strategy reported here is sensitive to model assumptions and schematizations that have not been fully validated, such as the salt carryover cost mentioned above. Thus, considerable care should be exercised in transferring the strategy into actual policy.

9. To use the subroutine in any decade, the DM first calculates the extractions from each node and the flows in each link of the network using the RWS (or any other desired) managerial strategy. The SIMPLE MSDM strategy then modifies the flows in some of the links to improve the value of an objective function; the objective function is the sum of the low-water shipping losses on the Waal and IJssel, the dredging costs on the Waal, a proxy for the salinity losses due to the Rotterdam salt wedge, and the (future) loss due to any decrease in the water stored in the IJssel lakes.

REFERENCES

26.1. Hillier, F. S., and G. J. Lieberman, Introduction to Operations Research, 3d ed., Holden-Day, Inc., San Francisco, 1980.

26.2. Denardo, E. V., Dynamic Programming: Models and Applications, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1982.

Chapter 27

DESIGN OF EUTROPHICATION CONTROL STRATEGIES

27.1. PAWN's STUDY OF EUTROPHICATION

Our work suggested that strategies to improve water quality should be tailored to individual localities. To require uniform strategies in all parts of the Netherlands would result in strategies with limited effectiveness, or high cost, or both. We offer our study of eutrophication, perhaps the most widespread and pressing water quality problem in the Netherlands, as an example of what is needed to determine promising local strategies to improve water quality.

In the Netherlands, eutrophication is taken to mean excessive growth of algae (phytoplankton, mostly blue-green algae), which can cause a number of problems. Where there is excessive growth, the oxygen concentration in the water can fluctuate dramatically within 24-hour periods, because while the algae photosynthesize by day, they only respire by night. The collapse of the algae bloom (the sudden death of the algae) leaves a large amount of dead organic matter in the water, and its decomposition can deplete the water of oxygen and cause bad odors and taste. Some algae, particularly blue-greens, have a toxic effect on domestic animals. The growth of blue-green algae also results in turbid or scum-covered water. Finally, algae can interfere with water treatment, by clogging filters and intakes.

We carried out this study for 11 Dutch lakes, which are shown in Fig. 27.1. Six of the lakes are among the IJssel lakes: the IJsselmeer, Markermeer, Veluwemeer, Wolderwijd, Gooimeer plus Eemmeer, and IJmeer. The Slotermeer is in the province of Friesland, just to the east of the IJsselmeer. The Westeinderplassen is a lake in the Midwest formed by peat excavations. The Stuwpand Lith is the "lake" formed by the water impounded above the weir in the Maas at Lith. It is a lake during the summer, but during winter, when the Maas flow becomes large, it is merely another part of the river. The Haringvliet, located in the Delta, has sluices, but water resides there for long periods, particularly in the summer. Finally, we considered the shallow part of the future Zoommeer that lies near Bergen op Zoom.

The most important descriptors of these lakes are their average depths and their <u>background extinction coefficients</u>. The background extinction coefficient is the fraction of incident light absorbed by nonalgal substances over each meter that the light penetrates. Light absorbed by such substances is not available for algae. Table 27.1 shows these two quantities for each of the 11 lakes studied.

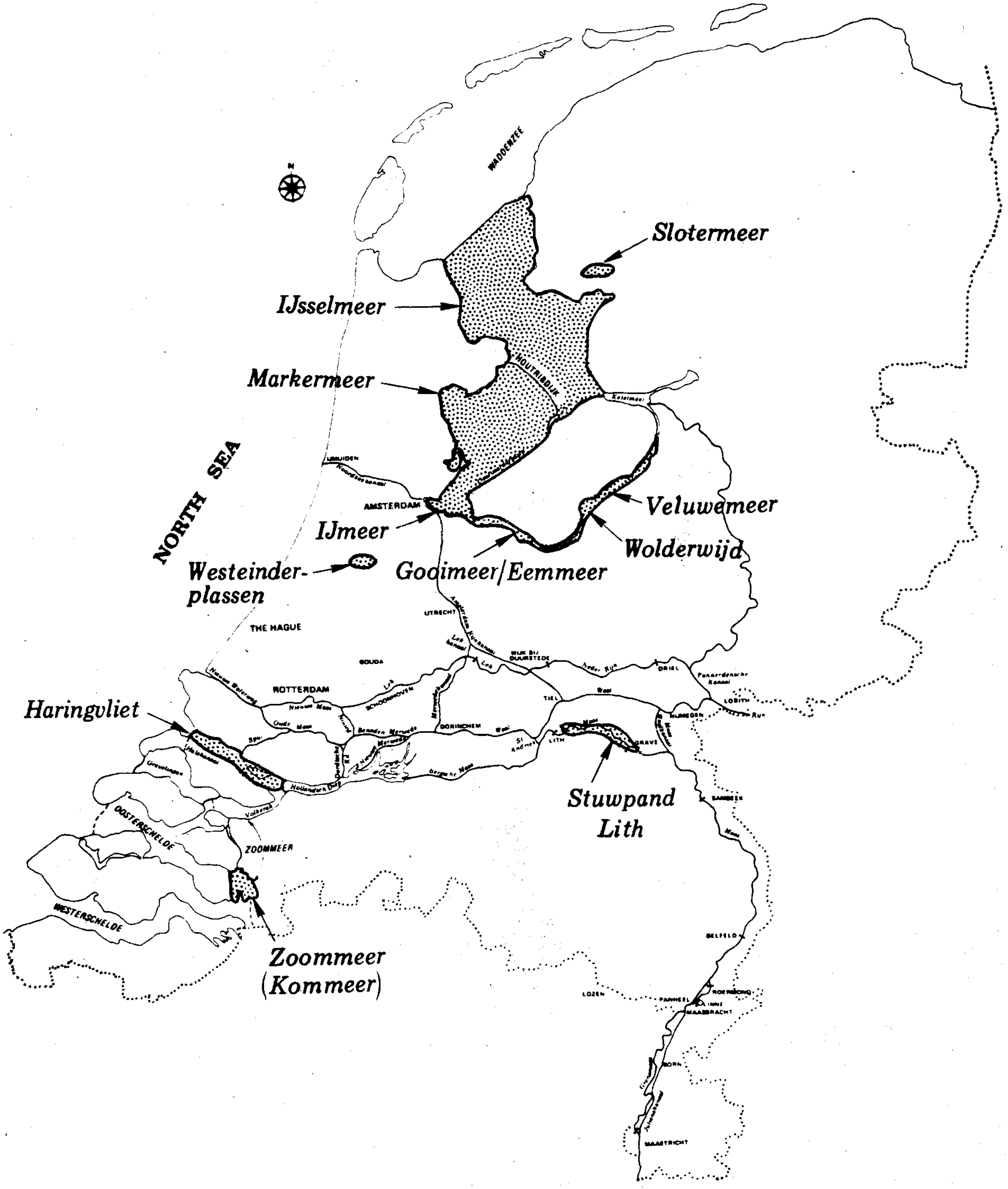


Fig. 27.1--Lakes investigated in PAWN's eutrophication study

Table 27.1

DEPTH AND BACKGROUND EXTINCTION COEFFICIENTS FOR LAKES IN EUTROPHICATION STUDY

Lake	Depth (m)	Background Extinction Coefficient (1/m)
IJsselmeer	4.5	1.8
Markermeer	3.3	4.0 (a)
Veluwemeer	1.2	4.5
Wolderwijd	1.5	2.5
Gooi/Eemmeer	1.7	5.5
IJmeer	2.0	2.5 (a)
Slotermeer	1.2	6.5
Westeinder	2.5	4.0
Stuwpand Lith	5.0	2.3
Haringvliet	6.0	1.2
Zoommeer	2.5	1.2

(a) For these lakes, the background extinction coefficient was highly variable. We estimated different values in different weeks of the year based on an observed correlation with wind speed. The values in the table are typical of the weekly values actually used.

27.2. EUTROPHICATION MEASUREMENT AND STANDARDS

27.2.1. Nutrient (Phosphate) Standards

Algae require nutrients in order to grow (the nutrients we consider in BLOOM II are phosphate, nitrogen, and silicon), which suggests that controlling nutrients will indirectly control algae. Accordingly, in Ref. 27.1 there are suggested water quality standards for nutrients. The most important of these for our purposes are the standards for phosphate, because they have been proposed for the sole purpose of controlling algae blooms, and because the Dutch have begun implementing a program to reduce phosphate discharges into their surface waters. The standards suggested in Ref. 27.1 are of two kinds, a provisional limit and a stricter target value. For phosphate, the provisional limit is 0.3 mg/l and the target value is 0.05 mg/l.

27.2.2. Chlorophyll Standards

The amount of algae is usually measured in terms of the chlorophyll concentration because instruments are available that make such measurements simple. RIZA (Rijksinstituut voor Zuivering van Afvalwater, the State Institute for Wastewater Treatment) has therefore expressed its suggested water quality standards as maximum allowable chlorophyll concentrations, including a lenient standard (100 µg/l) and a strict one (50 µg/l). However, the problems caused by algae correlate more closely with the biomass, its dry weight. The ratio of dry weight to chlorophyll content varies over a factor of two, depending on the size and species of the algae cells present. Recall that BLOOM II predicts the biomass of algae present, and not the chlorophyll. Thus, for our study, we translated each of RIZA's chlorophyll standards into a corresponding range of biomass whose upper and lower limits differ by a factor of two.

27.2.3. Dissolved Oxygen Standards

Perhaps the most objectionable aspect of algae blooms is the large mass of organic matter left behind when the algae die. The dead cells sink to the bottom and must be mineralized by bacterial action. This imposes a demand for oxygen on the water near the bottom and can result in severe oxygen depletion and sometimes in anaerobic conditions. In Ref. 27.1 there is proposed a provisional range (rather than a single limit) and a target range for dissolved oxygen. Provisionally, dissolved oxygen should be no less than 50 percent of saturation and no more than 150 percent of saturation. The target range is between 80 and 120 percent of saturation. The ranges are expressed in terms of percent of saturation because the amount of oxygen present at saturation varies strongly with temperature, and hence even 100 percent oxygen-saturated water (evidently the ideal) would sometimes violate a standard expressed in terms of amounts. In addition, the percent of saturation is a good measure of the ability of aquatic life to extract oxygen from the water.

27.3. TACTICS CONSIDERED IN BLOOM II SIMULATIONS

In BLOOM II simulations, we considered six different tactics that had been suggested as possibly effective (at least under some conditions) in reducing algae blooms. They are

1. Reducing phosphate, a nutrient required by all algae
2. Increasing the background extinction coefficient
3. Adding silicon, a nutrient required by some algae
4. Promoting complete mixing to prevent stratification
5. Flushing
6. Dredging

These tactics are generic, in that we have only tentative suggestions in mind for implementing them. For example, phosphate can be reduced by removing it from treated sewage rather than allowing it to remain in the treated discharge; or by precipitating phosphate by means of iron or aluminum compounds added to the lake or reservoir; or possibly by other means as well. A particular implementation may have elements of several of our generic tactics. Dredging, for example, not only increases the depth but removes nutrients sequestered in the bottom sediments.

27.3.1. Reducing Phosphate

The most widely suggested tactic for controlling algae blooms is reduction of phosphate. It is guaranteed to work if the phosphate is reduced to sufficiently low levels because every cell of algae requires a minimum amount of phosphate. To simulate this tactic in BLOOM II, we parametrically reduced the phosphate concentration available to the algae, holding all other inputs (e.g., other nutrients, light intensity) constant.

Figure 27.2 shows the results for our 11 test lakes. For each lake there is a line in the figure with a dot at its right-hand end. The dot is positioned horizontally at the maximum total phosphate concentration observed in the lake in 1976. The total phosphate is the sum of the dissolved phosphate and the phosphate incorporated in algae. The dot is positioned vertically at the maximum algae biomass calculated by the model for that lake in 1976. The fact that the upper right-hand section of each line is horizontal indicates that the algae in the maximum calculated bloom do not contain the maximum total phosphate observed during the year. It is necessary to reduce the phosphate below the amount incorporated in the maximum bloom before phosphate reduction can affect the bloom size.

Several observations may be made from this figure. First, in the lakes with the largest blooms, enormous percentage phosphate reductions are necessary before the RIZA chlorophyll standards are met. (The figure shows the ranges of biomass that correspond to the 100 μg/l and 50 μg/l chlorophyll standards. Recall that there is an uncertainty of a factor of two in the biomass that corresponds to any chlorophyll level.) Second, the provisional limit of 0.3 mg/l phosphate is far too lenient to meet even the more lenient chlorophyll standard. Finally, the target value of 0.05 mg/l phosphate may be (or may not be) strict enough to meet the 50 μg/l chlorophyll standard.

There now arises the question of what must be done to achieve a reduction of "x" percent in the phosphate concentration. The answer requires an acquaintance with the phosphate cycle in lakes. Phosphate enters dissolved in inflowing waters and leaves dissolved or in algae that are swept out with the outflowing waters. While in the lake, the phosphate may be in the dissolved state or incorporated in algae cells. Any molecule of phosphate can transfer back and

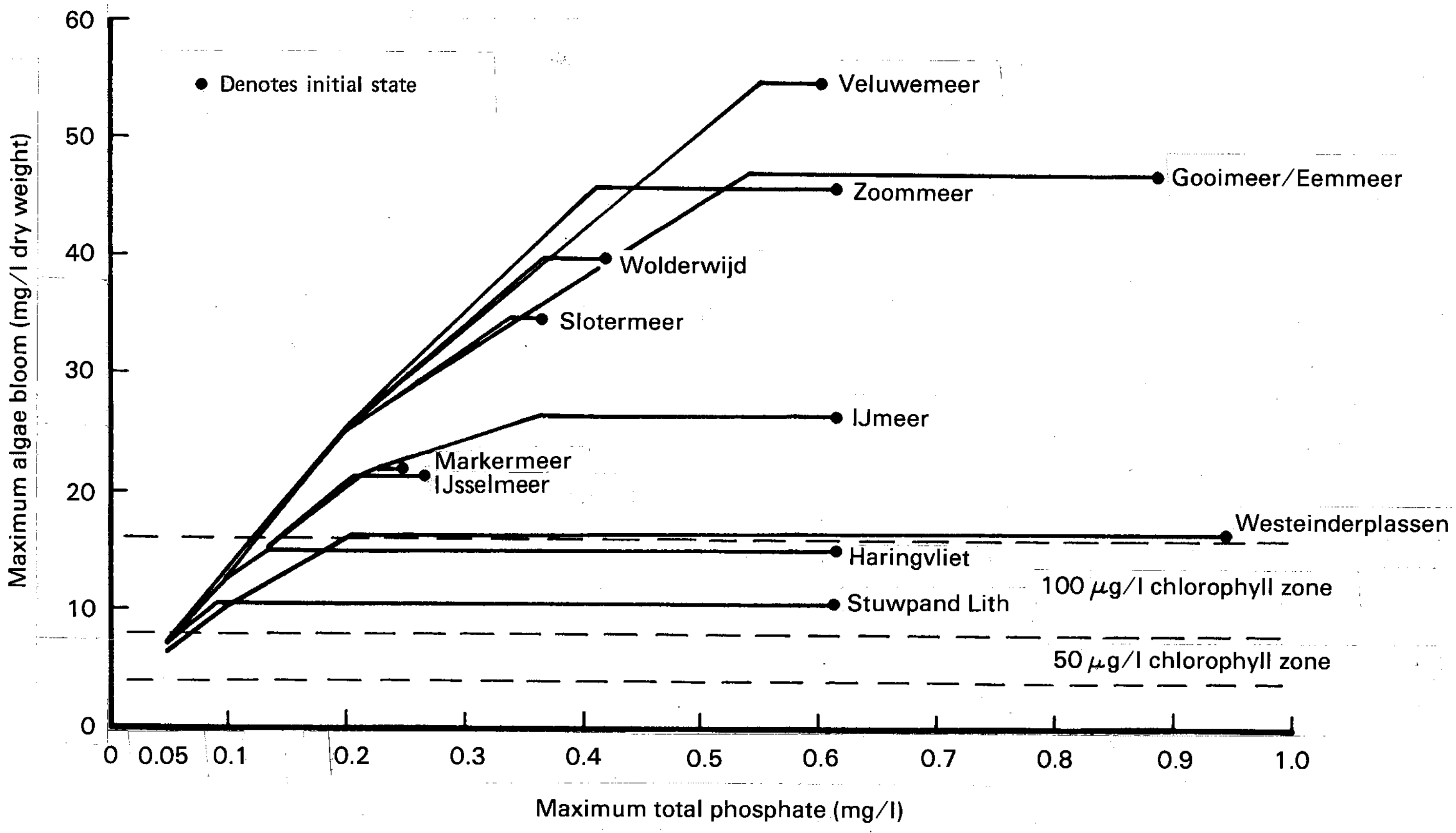


Fig. 27.2--Effect of phosphate reduction on yearly maximum biomass predictions

forth between these two conditions numerous times. Finally, if an algae cell dies and sinks to the bottom, the phosphate may form compounds with the bottom material.

Once the bottom has tied up the phosphate, the algae cannot use it. But phosphate is not permanently sequestered in the bottom. There are normal fluxes of phosphate that occur between the bottom and the bulk water. At the phosphate concentrations currently found in most Dutch lakes, the net flux is out of the water and into the bottom, but if the phosphate concentration in the water were reduced, the net flux might be outward. In addition, explosive fluxes of phosphate from the bottom can occur. Our studies indicated explosive fluxes occurring in the IJsselmeer, the Veluwemeer, and the Wolderwijd in 1976, and in the Veluwemeer and Wolderwijd in 1975. Other instances may also have occurred; results were ambiguous.

To reduce phosphate concentrations, both the contributions from inflowing waters and the net flux from the bottom must be controlled. Phosphate can be removed from point sources--the Dutch have a program to do so [27.1]--but much phosphate will remain in some waters (e.g., the Rijn). There are also techniques for sealing lake bottoms to prevent or slow nutrient release, but many of these techniques may harm bottom organisms (an undesirable side effect). In addition, the Dutch have been experimenting for several years with precipitating phosphate from the inlet water of a reservoir (the Grote Rug) using iron and aluminum compounds. Preliminary calculations and the results from Grote Rug agree that the phosphate reductions necessary to meet RIZA's chlorophyll standards will not come easily.

27.3.2. Increasing Background Extinction

Algae must absorb light to live. In principle, if the background extinction coefficient were large enough, so little light would be left for algae that only a few cells could survive. Special colored dyes exist that absorb light when dissolved in water. They can even be tailored to absorb only those wavelengths of light that algae exploit most. A rough estimate of their cost is 0.0046 Dfl/m^3/yr. In our discussions with the Dutch, we found considerable resistance to this tactic on aesthetic grounds. In any case, the model results shown in Fig. 27.3 suggest that this tactic is only effective in deep lakes, in which algae blooms are generally not a problem.

27.3.3. Adding Silicon

The tactic of silicon addition is an attempt to defeat blue-green algae, which are the most objectionable algae species, by other species of algae. Objections to blue-green algae are partly due to the fact that few fish can eat blue-greens, whereas many feast on other species. Blue-greens thus depress the value of a lake for commercial and recreational fishing. Also, blue-greens clump together, forming an unsightly scum on the water surface, whereas

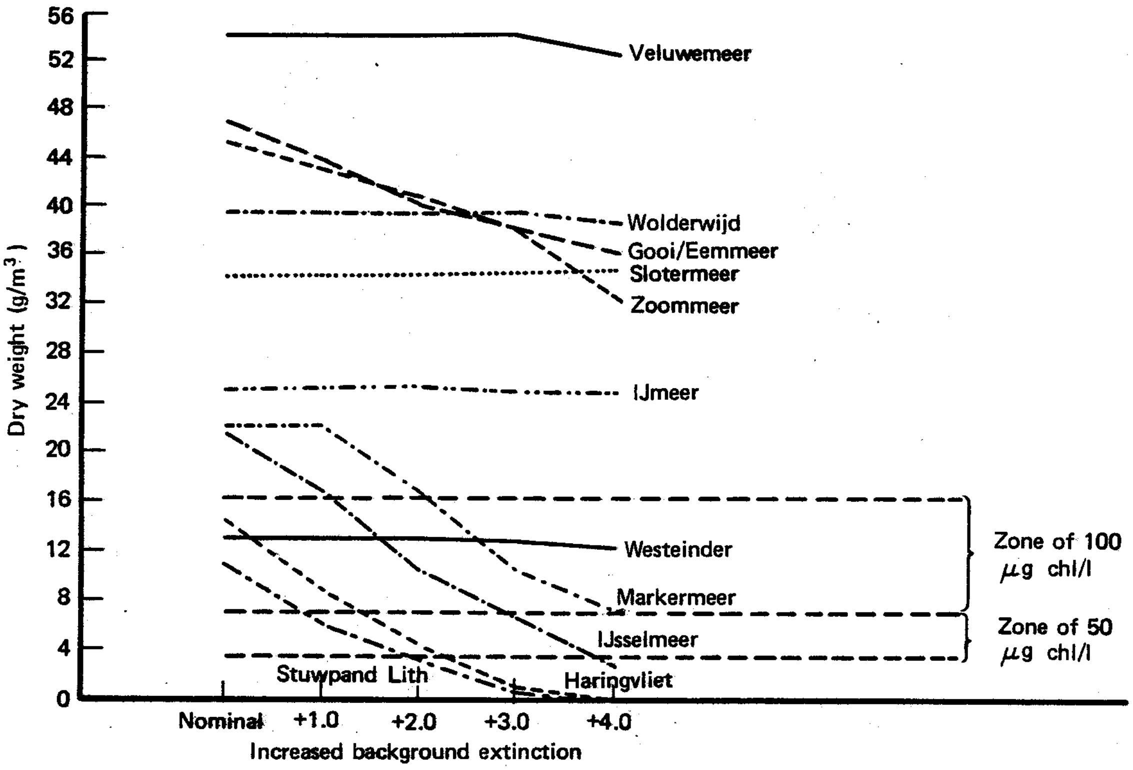


Fig. 27.3--Effect of increasing the background extinction coefficient on yearly maximum biomass predictions

other species distribute themselves almost invisibly throughout the water.

Theoretically, silicon addition could promote the growth of diatoms in place of blue-greens. Diatoms require a plentiful supply of silicon, which they incorporate in their microscopic shells. If the only factor restraining the growth of diatoms were the lack of silicon, adding silicon would cause the diatoms to grow, using up not only silicon but all the other nutrients as well. The other nutrients (e.g., phosphate, nitrogen) are also needed by blue-greens, so the growth of diatoms could reduce the blue-green population.

Unfortunately, the model results suggest that adding silicon is ineffective under almost all circumstances. Blue-greens are more efficient users of light and nutrients than diatoms, and outdo the diatoms even in the presence of ample silicon.

27.3.4. Promoting Complete Mixing

One of the advantages that blue-green algae have over competing species is an ability to control their vertical position in the water column. By adjusting their buoyancy, they occupy the depths at which the light intensity and nutrient concentrations are most favorable for growth. This ability can be overcome, however, by gently mixing the water column, for example, by pumping air through a perforated pipe on the bottom and letting the rising bubbles stir the water. This method of mixing has been tried at the Biesbosch reservoirs near Rotterdam [27.2] with varied but promising results.

In BLOOM II, each species of algae is assigned a depth in which to grow. For most species, the depth is the same as the actual depth of the lake; but for blue-greens it is half the lake depth, to represent their talent for controlling their vertical position. To represent the complete mixing tactic, the depth for blue-greens is made equal to the lake depth.

As may be seen in Table 27.2, complete mixing effectively reduces the maximum total biomass in lakes that have either a large background extinction, or a large depth, or both. In the deep Markermeer, the predicted maximum bloom level is strongly reduced compared with the nominal case. In the IJsselmeer, which although deep has a low background extinction, and in the Gooimeer, Slotermeer, and Westeinder, which have low depths but high background extinctions, maximum total biomass is reduced by about one-third to one-half. In the nominal cases, maximum blooms are strongly dominated by blue-green algae (except in the Zoommeer). Complete mixing reduces blue-greens substantially in all lakes, although they remain dominant in some of them.

Table 27.2

EFFECT OF COMPLETE MIXING ON YEARLY MAXIMUM BIOMASS PREDICTIONS
(mg/m^3)

	Nominal Simulations		Complete Mixing	
Lake	Total Biomass	Blue-Green Biomass	Total Biomass	Blue-Green Biomass
IJsselmeer	22.6	22.6	17.8	6.5
Markermeer	21.6	21.6	4.0	4.0
Veluwemeer	47.4	47.4	34.9	31.5
Wolderwijd	34.4	34.4	33.7	20.6
Gooimeer	50.1	50.1	34.6	14.8
IJmeer	30.4	30.4	27.8	18.8
Slotermeer	29.1	29.1	24.2	16.3
Westeinder	16.3	16.3	10.2	10.2
Zoommeer	45.5	39.0	40.7	4.5

27.3.5. Flushing

Flushing is the continuous replacement of water in the lake by water from outside. The water taken from the lake carries with it both live and dead algae, as well as nutrients dissolved in the water. It is suggested that by increasing the effective mortality of the algae and by getting rid of nutrients, the tactic can reduce algae blooms. However, the replacement water also contains nutrients, and depending on their concentrations, the tactic may do more harm than good.

To simulate this tactic in BLOOM II, we assume that the nutrient concentrations in the replacement water are just sufficient to maintain the total amount of each nutrient constant. Any other assumption would combine the flushing tactic with a nutrient-reducing (or increasing) tactic. We also assume that the replacement water contains only dissolved nutrients, and no live or dead algae.

The results are shown in Fig. 27.4. In lakes with depths greater than 3 m, flushing produced the expected decrease in algae biomass.

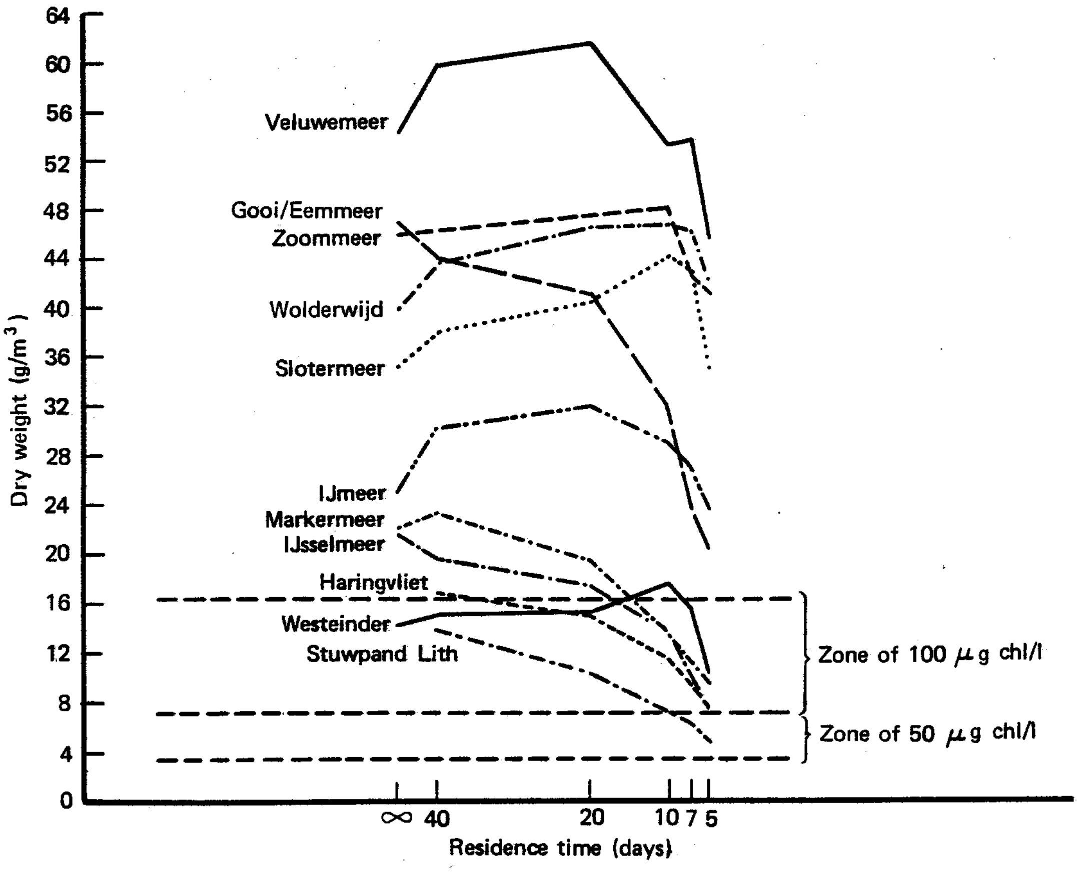


Fig. 27.4--Effect of flushing on yearly maximum biomass predictions

In shallow lakes, however, the yearly algae biomass maxima increase, rather than decrease, for all attainable flushing rates. The reason is that flushing has two contradictory effects. First, the algae have to devote more of their reproductive potential to replacing losses than to actual growth. But as long as they have the reserve potential to do so, they profit from flushing, because the dead algae are swept out and the nutrients they contain are replaced in dissolved form in the replacement water. The net effect is to make more nutrients available to live algae.

In deep lakes, the yearly bloom maxima are generally limited by the availability of light, which cannot penetrate far into the water. Because energy is simply not available for algae to reproduce rapidly, flushing at any rate reduces the bloom maxima. In shallow lakes, however, the bloom peaks are usually limited by the availability of nutrients, and a reserve reproductive potential exists. Thus, only if flushing of shallow lakes occurs at very high rates will the reproductive reserve be depleted and the bloom peak reduced.

27.3.6. Dredging

As Fig. 27.5 shows, dredging to increase the depth of a lake proved to be a universally effective tactic for reducing bloom maxima when simulated by BLOOM II. However, it generally proved necessary to deepen lakes by several meters before RIZA's chlorophyll standards were met. Dredging until the standards are met involves moving and disposing of enormous quantities of spoils. For example, for the Veluwemeer alone, dredging to 5.5 m, where the 50 µg/l standard is certain to be met, requires the removal of about 280 mcm of bottom sediment. We have estimated the cost of dredging in the Waal to be 16.2 Dfl/m^3. If we use this cost for the Veluwemeer as well, we find the total cost of dredging to 5 m to be over 4500 Dflm. Although dredging costs are highly variable, we think this estimate is not orders of magnitude too high, and that for all but small lakes and reservoirs dredging is therefore probably prohibitively expensive.

However, dredging to remove only the top 10 cm of bottom sediments has been suggested. This layer of sediment contains much of the nutrient sequestered in the bottom, and its removal could be an effective nutrient-reduction tactic. There are technical problems associated with preventing the nutrient-laden interstitial water from flowing back into the lake from the dredging barge, and there are difficulties in disposing of the spoils. But removing only 10 cm of sediment from a lake the size of the Veluwemeer would cost only 100 Dflm (again using the cost of dredging we estimated for the Waal), and hence may not be prohibitively expensive.

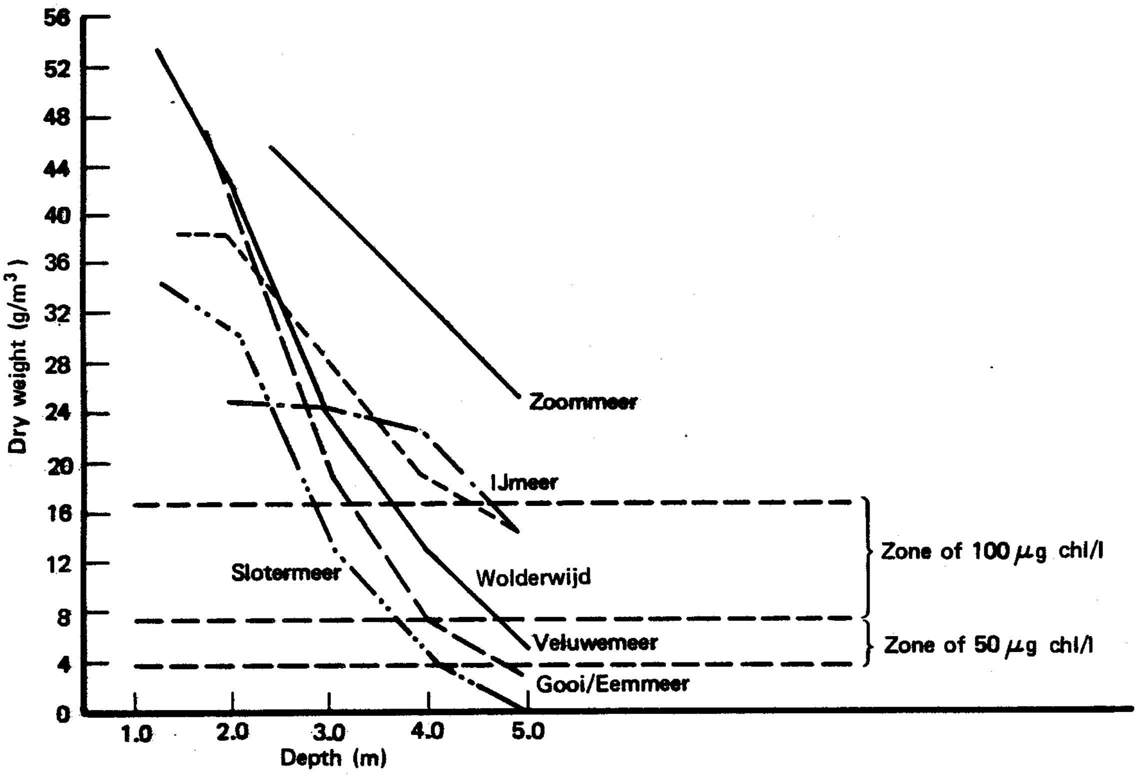


Fig. 27.5--Effect of dredging on yearly maximum biomass predictions

27.4. OTHER TACTICS

We also considered a number of tactics that were not amenable to simulation by BLOOM II. These are

1. Use of algaestatic agents
2. Use of biological controls
3. Harvesting nuisance organisms
4. Nutrient balancing

The first three of these tactics were not simulated because the simulations would have been trivial. Both would be represented in BLOOM II by an increase in the mortality rate of algae; but how large an increase would depend on the particular implementation of the tactic. A large enough increase in mortality, of course, would inevitably reduce bloom maxima to any desired level. The last tactic, nutrient balancing, was not simulated because the model is simply not adequate.

27.4.1. Algaestatic Agents

The most widely used algaestatic agents are chlorine compounds, which are used to suppress algae growth in swimming pools. More suitable for large bodies of water, because they persist longer, are copper salts. The cost per application of these agents is not large--about 0.001 Dfl/m^3, or 78000 Dfl per application for a lake the size of the Veluwemeer--but repeated applications, e.g., weekly, are necessary throughout the half-year of summer. The main objection to these agents is that they are poisons, and if applied in injudicious dosages may contaminate irrigation water (and hence crops), water for livestock, or even drinking water. We believe the objection is strong enough to make this tactic unpromising.

27.4.2. Biological Controls

Biological controls of algae could be pathogens such as bacteria or viruses, or they could be predators (grazers) of algae. There are two problems with predators: First, they have to be fed at times when the algae are absent, and second, few organisms will graze on blue-greens. Some viruses do appear to infect blue-greens, but viruses tend to mutate quickly, so one could never be sure what diseases of fish or cattle might eventually follow the introduction of viruses for blue-green control. In general, this does not appear to be a promising tactic.

27.4.3. Harvesting Nuisance Organisms

Techniques for mechanical harvesting of rooted aquatic plants are well established and widely used. But there are no reports of successful harvesting of algae. Attempts have been made to design a harvester that would skim the blue-green algae scum from the surface of a lake, but without success. Filtering algae suspended in the water would appear unpromising because of the large volumes that would have to be filtered to remove a significant amount of algae.

27.4.4. Nutrient Balancing

The objective of nutrient balancing is to take advantage of the high productivity of eutrophic waters instead of simply trying to suppress algae growth. One example of nutrient balancing is silicon addition, which we discussed earlier. Another is nitrogen addition, which has been reported to suppress blue-greens and encourage other, more desirable algae in some lakes [27.3].

The addition of nitrogen may not be the only way to increase the nitrogen available to algae. Air injection can inhibit the bacteria responsible for denitrification (conversion of nitrate to nitrogen gas, which is lost to the atmosphere). Air injection also has the effect of destratifying and vertically mixing the water, which we earlier suggested might be a promising tactic for controlling blue-greens (although not necessarily for controlling total algal biomass). Experimental evidence suggests the same conclusion [27.4].

27.5. DISSOLVED OXYGEN

In the lakes studied, algae dominate the dissolved oxygen budget. BOD from external sources is much less important. The provisional (lower) limit of 50 percent saturation for dissolved oxygen is violated in the most eutrophic lakes, namely the Wolderwijd, Veluwemeer, and Gooi/Eemmeer. The target level (80 percent saturation) is violated in all the lakes.

Calculations have shown that most lakes will suffer from severe oxygen depletion problems upon the collapse of an algae bloom. These anaerobic conditions may last for several days. Complete anaeroby is unlikely in three lakes, namely the Markermeer, IJmeer, and Westeinder, but even here the dissolved oxygen concentrations can drop below 50 percent saturation.

A reduction in chlorophyll to the suggested RIZA standard of 50 µg/l or even 100 µg/l will generally be sufficient to prevent the dissolved oxygen concentration from dropping below the 50 percent saturation provisional limit. In some lakes, a chlorophyll level as high as 60 µg/l may be sufficient to ensure that the dissolved oxygen target level of 80 percent saturation is met. However, chlorophyll must be reduced to 30 µg/l to guarantee that the target level for dissolved oxygen is met in all lakes. This range reflects the differences in the chlorophyll-to-biomass ratio and differences in local conditions, such as depth. A chlorophyll standard between 50 and 100 µg/l will ensure that a bloom collapse will not cause anaerobic conditions.

We have used OXYMOD to assess the impact of two eutrophication control tactics on the dissolved oxygen budget. The first tactic, phosphate reduction, has a limited impact on the oxygen budget; reductions of up to 90 percent are needed to ensure that the target level of 80 percent saturation for dissolved oxygen is met. The second tactic, dredging, also has a limited impact. At a depth of 3 m or more, dissolved oxygen budgets can improve significantly, but the risk of anaerobic conditions following the collapse of a bloom remains high.

27.6. CONCLUSIONS AND RECOMMENDATIONS

PAWN's eutrophication study justifies three general conclusions and recommendations. First, the preferred Dutch eutrophication control strategy of phosphate reduction will be largely ineffective by itself. The Dutch plan to control phosphate discharges into the surface waters from point sources (mostly sewage treatment plants) within the

Netherlands. But Rijn and Maas water from outside the Netherlands already contains high concentrations of phosphate. Further, the bottom sediments of eutrophic Dutch lakes are phosphate-rich, and their phosphate is available to support algae blooms.

In fact, no single tactic is capable of solving the eutrophication problem in all lakes. Thus, overall reductions of algae blooms are only possible if the eutrophication control strategy is specially adapted to regional and local circumstances. For example, phosphate reduction could be employed for areas not receiving much Rijn or Maas water; increasing the background extinction could be tried in deep lakes; and dredging could be attempted in small lakes and reservoirs.

Finally, we think a single tactic will seldom solve the problem in <u>any</u> lake, and that combinations of tactics should be considered. Although we have not simulated any such combinations, we can suggest a few possibilities. For example, a reduction in phosphate loading could be combined with dredging of the top few decimeters of the bottom sediments, which are rich in nutrients. Or an increase in depth by dredging could be combined with artificial mixing in reservoirs, which have to be dredged anyway. This latter combination would be more effective if the background extinction were relatively high as well.

In addition, we believe that the PAWN/WABASIM eutrophication methodology should be quite helpful in determining the particular combination of tactics appropriate for each lake. However, the paucity of field-test data in the literature precludes more than a cursory examination of technical feasibility. Because of the large technical uncertainties in eutrophication control, we recommend that, for many of the tactics considered, field tests or demonstration projects should precede widespread implementation.

REFERENCES

27.1. Ministerie van Veerkeer en Waterstaat, <u>De Bestrijding van de Verontreiniging van het Oppervlaktewater: Indicatief Meerjarenprogramma 1975-1979</u> (The Combat Against Surface Water Pollution in the Netherlands: Prospective Multiyear Program 1975-1979), Ministry for Transport and Public Works, The Hague, 1975.

27.2. Knoppert, P. L., et al., "Destratification Experiments at Rotterdam," <u>Journal of the American Water Works Association</u>, Vol. 62, No. 7, July 1970.

27.3. Schindler, D. W., "Evolution of Phosphorous Limitation in Lakes," <u>Science</u>, Vol. 195, No. 4275, 1977, pp. 260-262.

27.4. Sirenko, L. A., et al., "Effect of Artificial Aeration of Pond Water on Algae Flora," Hydrobiological Journal, Vol. 8, No. 1, 1972, pp. 52-58.

Chapter 28

DESIGN OF POLICIES AND CASES FOR IMPACT ASSESSMENT

28.1. INTRODUCTION

Previous chapters in this part developed various techniques and conclusions for designing strategies, which are components of overall water management policy. In this chapter, we describe how we used the results of those chapters, along with the results of screening, to design the policies--and the cases--considered in impact assessment. Cases, which combine policies with scenario assumptions, must be designed carefully: We want to avoid incompatible combinations of policies and scenario assumptions. And we want to learn as much as possible from analyzing a limited number of cases.

The results of previous chapters are insufficient to prescribe one promising policy, or even just a few. The number of possible scenarios remains large. And analytic resources are limited. Thus, the process of designing policies and cases for impact assessment involves considerable art.

In this chapter we briefly discuss this process. We first identify some potential components of policies that the results of previous chapters allow us to rule out. Next we list the alternative choices for the remaining components out of which we will fashion policies and cases. Then we describe the primary policies and cases that we will consider in impact assessment, and how we arrived at them. Finally, we indicate what additional kinds of cases should, and will, be considered in sensitivity analysis.

28.2. POTENTIAL POLICY COMPONENTS RULED OUT

Screening found the commercial, household, and shipping sectors unpromising for the application of price and regulation tactics. It found the same result for drinking-water (DW) use by agriculture and DW companies, and SW use by industry. Furthermore, it found <u>short-run</u> price and regulation tactics unpromising for all sectors' use of GW except agriculture, for industrial uses of DW, and for DW companies' use of SW.

In our analysis of how to design long-run price and regulation strategies, we found that, as GW became less available, it became less economically efficient to use either average-cost pricing schemes for DW or uncoordinated (non-joint) allocation of GW between DW companies and industrial firms. Thus, in designing policies we consistently use marginal-cost pricing for DW and joint allocation of GW between DW companies and industrial firms.

In the screening of technical and managerial tactics, we ruled out the current managerial strategy, waterboard plans other than the 46 found promising, and national and regional tactics other than those contained in MAXTACS.

In both the screening of technical tactics and the design of managerial strategies, we found that dredging below Tiel was more cost-effective than allowing a sandbar to build up there. Thus we incorporate dredging below Tiel, and the associated costs, in all of our impact assessments and rule out the alternative of allowing the sandbar to build up and cause shipping to incur sedimentation losses.

In designing managerial strategies, we found that dilution is no solution to pollution; that is, with few exceptions, managerial tactics have little effect on nationwide water quality. Thus, our managerial strategies consider quality only to the extent of attempting to deal with the exceptions (most notably the salt intrusion in the Hollandsche IJssel and the thermal pollution from the power plants on the Noordzeekanaal and the Bergumermeer).

In the analysis of how to design eutrophication control strategies, we found that, by itself, the preferred Dutch strategy of phosphate control will be largely ineffective, and that indeed no single tactic can solve the eutrophication problem in all lakes. Overall reductions of algae blooms appear possible only if the eutrophication control strategy, usually requiring a combination of tactics, is specially adapted to regional and local circumstances. Thus, we shall not consider eutrophication control tactics further in PAWN, either in designing policies or assessing their impacts. This should be done by more detailed studies, based in part on the eutrophication methodology used in PAWN, but with a regional or local focus.

28.3. CHOICES FOR EACH REMAINING COMPONENT OF A POLICY

Having ruled out the components noted above, the following components and choices remain.

For the managerial strategy that changes the rules that govern the operation of an infrastructure, the choice is among the RWS strategy, the (SIMPLE) MSDM strategy, and the VELSEN strategy. As implemented in the DM, the managerial strategy embodies rules that determine the degree of cutback, if any, in the amount of water delivered to SW sprinklers each decade compared with their demands; these rules can be construed either as managerial tactics (as done hereafter for methodological reasons) or as regulatory tactics limiting sprinklers' short-run access to SW (as was done in screening).

For technical tactics to change the current infrastructure, the choice is between adding MAXTACS or not. This choice, together with that for waterboard plans, constitutes the technical strategy.

For the waterboard plans, the choice is whether to implement the 46 promising ones. This choice determines the area eligible for SW sprinklers, and, as its complement, the area eligible for GW sprinklers.

For the SW sprinkler intensity, the choice is among low (i.e., current), medium, and high (i.e., optimal). For the GW sprinkler intensity, the names of the three choices are the same as for SW, but the corresponding numerical values differ somewhat because the sprinkling costs, which influence the intensities, differ. Note that although the sprinkler intensity has been called a scenario variable up to this point, it is at least partly a policy variable as well, for the intensities that result will depend partly on what farmers desire to do and partly on what they are permitted to do. That is, regulatory tactics could limit the number of new sprinklers that are permissible to fewer than farmers might desire, keeping them, for example, at low levels rather than permitting them to increase to high.

For the GW extraction quota, we limit the choices to 1.0 (roughly the current policy) and 0.25 (which reflects an extreme effort to protect future GW supplies and the natural environment). This latter value can be thought of as the average between the quota of 0.50 that the IWW suggested as a lower bound on extractable amounts and the quota of zero that results from giving highest priority to preserving GW supplies and the natural environment.

For GW extraction priority, the choice is between industry/DW companies, de facto the current policy, and agriculture. Recall that we permit one exception to the rule that the district quotas should not be violated: Currently installed GW sprinklers may continue to operate, even if their extractions cause the quota to be violated. Thus the priority described here should be considered the priority above current sprinklers.

For the level of the charge on GW extractions, the choice is between zero, the current policy, and 0.20 Dfl/m^3, the maximum that was considered for the new groundwater (GW) law. That law considered the charge only for industry, but we consider imposing it, both individually and in combination, on industry and agriculture. We did not consider it for DW companies because the Dutch declared it politically infeasible.

Our analysis considers the extent to which quotas and priorities would affect the number of new GW sprinklers that are permissible and how charges would affect the number that are economical. Thus, because of the quota, the actual number of GW sprinklers in a particular case may be considerably less than that implied by the GW sprinkler intensity, which is in effect an upper bound on what is permissible. (A charge on agricultural extractions will reduce the number of sprinklers that are desirable, i.e., reduce the magnitude of the high intensity.)

28.4. DEFINITION OF PRIMARY POLICIES AND CASES

The primary policies are those to be analyzed and compared in most of our impact assessment. Although limited in number, they are intended to span the range of promising tactics, with each policy providing a considerably different mix of impacts, both in the aggregate and in their distribution among different users and regions.

The primary cases are merely the primary policies in combination with the future context and the reference assumptions for the rest of the scenario. We use the future context in the primary cases--and, indeed, in essentially all of the analysis reported in this volume--because its time frame is more relevant to the prospective decision about a national water management policy than the 1976 context and because its impacts, both positive and negative, are generally larger (as a result of economic growth). Although we consider some variations in sensitivity analysis, we use the reference assumptions for the rest of the scenario because they are a natural starting point. The sprinkler scenarios, discussed previously, are henceforth embodied in the primary policies and require no separate mention. Finally, we consider several sets of primary cases, one for each of several external supply scenarios.

Table 28.1 defines the primary cases in terms of their policy components.

Table 28.1

DEFINITION OF PRIMARY CASES

	Case					
Item	A	C	D	E	F	G
Managerial strategy	RWS	MSDM	MSDM	MSDM	MSDM	MSDM
Waterboard plans	No	Yes	Yes	Yes	Yes	Yes
MAXTACS	No	No	Yes	Yes	Yes	Yes
SW sprinklers	Low	Med	Med	Med	Hi	Hi
GW sprinklers	Low	Low	Low	Med	Hi	Low
GW extraction quota	1.0	1.0	1.0	1.0	1.0	.25
GW priority above current sprinklers	-	-	-	I/D	I/D	AGR
GW charge on IND and AGR (Dfl)	0	0	0	0	0	0

NOTE: I/D = industry/DW companies; IND = industry; AGR = agriculture. MSDM indicates the simple MSDM strategy.

Case A is the base case, the reference against which the others are compared. With the exception of the managerial strategy, it approximates the current policy. We used the RWS managerial strategy rather than the current managerial strategy because, for the reasons given in Chap. 22, we believed the new Markermeer flushing policy would be adopted. (And indeed it was.)

Although we use the RWS managerial strategy in the base case, we use the MSDM strategy in the remaining cases because, on the basis of the analysis in Chap. 26, we expect it to perform somewhat better, particularly in very dry years.

We include the waterboard plans in all the primary cases except the base case because they are relatively inexpensive but quite cost-beneficial. (We consider several cases without the waterboard plans in sensitivity analysis.)

(Case B was such a minor variation on case A that we decided not to consider it a primary case, but only a sensitivity analysis case.)

Cases C-F represent progressively increasing demands for both SW and GW sprinkling. The GW sprinkler intensity is kept low (current) in cases C and D to represent an attempt to help protect GW supplies and the natural environment, and then permitted to increase in cases E and F. In cases C-F, we maintain the current GW extraction quota.

In case C the SW sprinkler intensity is permitted to increase to medium, which represents plausible growth, but MAXTACS is not included to provide increased supplies of SW for the waterboard plans and for other uses.

Case D is the same as case C except that it adds MAXTACS to provide increased supplies of SW for sprinkling and other uses. The remaining cases include MAXTACS for the same reason.

In case E the GW sprinkler intensity is allowed to increase to medium, matching the SW sprinkler intensity. This case represents quite plausible growth in both types of sprinkling.

Case F represents high growth for both SW supply and SW demand. Both SW and GW sprinkler intensities are allowed to increase to the high level, which represents an optimistic estimate of growth.

In cases E and F, where GW sprinkler intensities have been allowed to increase above current levels, we must also specify a priority on GW extractions. Based on the conclusions of Chap. 25 about when different priorities are appropriate, we give priority to industry/DW companies here--their demands are significantly higher in the future context than in 1976 and agricultural demands are much higher. This may somewhat reduce the actual number of GW sprinklers below that implied by the specified intensity.

Case G is intended to emphasize the preservation of GW supplies and the natural environment. It keeps the GW sprinkler intensity at the current (low) level. And it introduces a GW extraction quota of 0.25, a 75 percent reduction from the current policy. (It uses a quota rather than charges because Chap. 25 concludes that quotas are the most effective means of achieving large reductions in GW extractions. The effect of charges is considered in a number of sensitivity analyses.)

Based on the conclusions of Chap. 25, the GW extraction priority is given to agriculture.

Case G includes the waterboard plans and MAXTACS for several reasons. First, they maximize the surface water (SW) supply, which helps reduce pollution concentrations (mainly salinity) in some locations. Second, maximizing the area that is eligible for SW sprinklers and the amount of water supplied to it reduces the area where GW sprinkling is attractive (and, in our models, where GW sprinkling is eligible).

In case G, we use a high SW sprinkler intensity in an attempt to get an upper bound on the potential (agricultural) net benefits when GW sprinklers are limited to current levels.

28.5. CASES FOR SENSITIVITY ANALYSIS

We considered a number of additional cases in sensitivity analysis that differed from the primary cases in both policies and scenario assumptions. There were different sets of cases to investigate the effects of:

- Different managerial strategies
- Increasing SW sprinkling
- Increasing GW sprinkling
- Changing GW quota, priority, and charges
- Decreasing the Rijn BOD load
- Increasing the Rijn salt load

The additional cases will be defined, and their impacts discussed, in Chap. 32, which presents the sensitivity case impacts. Appendix D summarizes the definitions of the 38 cases considered in impact assessment, and indicates for which comparisons they were used.

PART V: ASSESSMENT OF POLICY IMPACTS

Chapter 29

OVERVIEW OF IMPACT ASSESSMENT

29.1. INTRODUCTION

The primary task of this chapter is to describe how all the components of the PAWN methodology fit together and how they are used for impact assessment. We will then explain the scope and organization of the remaining chapters in this part.

29.2. HOW THE PAWN METHODOLOGY WAS USED FOR IMPACT ASSESSMENT

Figure 29.1 presents the master flowchart that shows how the PAWN methodology fits together. Special symbols distinguish different kinds of components. Rectangles represent models or major analytic processes, usually employing models. Parallelograms represent policy variables. Trapezoids represent scenario variables. Half-cylinders represent impacts considered in our analysis. And ovals represent other inputs and outputs. Most of these outputs are intermediate results that serve as inputs to another model/process, but some are minor impacts, ones that received scant attention in our analysis; the inputs are generally system assumptions.

29.2.1. Impact Assessment Flowchart

The flowchart describes how the impacts of a specified policy are calculated for an entire year, beginning with various policy and scenario variables and ending with a complete set of impacts. It shows the interrelations among the various models, processes, and datasets described in previous chapters. However, if the purpose of a previously described process was merely to provide data or analytical building blocks for use in some other model, we have not shown the process on the diagram, only its product. Thus, the low-water loss functions, the dredging cost functions, the DISTAG model, the Rotterdam salt wedge model, the Gouda inlet salinity model, and certain other components are shown inside the DM, where they operate as subroutines. Likewise, we show the estimates for the costs of major infrastructure tactics without the process that produced them, and the sprinkler system cost functions without the sprinkler system design and cost models that produced them.

The influence of MSDM and of the filling and dike safety models for the IJssel lakes appears only indirectly; the managerial strategies designed with the former are incorporated in the DM as options that can be invoked by specifying the appropriate keyword, and managerial tactics shown to be unsafe with the latter models do not survive to this stage of the analysis. The eutrophication models do not appear here because the results of Chap. 27 allowed us to rule eutrophication control strategies out of impact assessment. And the techniques of

Chap. 19 for estimating the distribution of monetary benefits and costs are not shown because they are ubiquitous.

In each symbol on the flowchart, except for some of the policy variables, we indicate the number of the section or subsection in this report where it is discussed. A few processes have not been discussed previously because their role would not have been clear outside the flowchart. These processes, flagged by asterisks on the flowchart, are described below. With this additional discussion, plus what has come before, we believe the flowchart is self-explanatory. Note that on the flowchart we refer to tactics like those in MAXTACS as major technical and managerial tactics so as to distinguish them from more localized tactics of the same type, such as waterboard plans or lock tactics, which enter the methodology differently.

29.2.2. Determine GW Quota for Industry/DW Companies

The method of determining the amount of groundwater (GW) that can be extracted by industry and drinking-water (DW) companies varies depending on whether they, or agriculture, have extraction priority. When industry/DW companies have priority, setting their quota is simple; they may extract up to the total quota. However, when agriculture has priority we must compute the expected amount of GW sprinkling in each district to determine the amount of GW available to industry/DW companies. We do so by first using PREPDM to create the appropriate sprinkler scenario. We then take the plots sprinkled from GW and multiply their areas by the expected amount of GW sprinkling per hectare that was determined as part of the optimal intensity analysis. We then aggregate this product by district to obtain the expected GW sprinkling (which is the same as the expected GW extraction). The amount of GW available to industry/DW companies is then simply the total quota in each district less the agriculture extractions.

29.2.3. Generate Sprinkler Scenarios

As has been discussed in Chaps. 12 and 20, the sprinkler intensities and eligible areas are embodied in sprinkler scenarios. What was omitted, however, was any mention of the effect on these scenarios of GW extraction charges or quotas. Charges reduce sprinkler intensities because they make this kind of sprinkling more expensive. Thus, to determine the effect of a particular charge, we merely recalculate the optimal intensities with the operating costs increased by the amount of the charge.

By limiting GW extractions, quotas may mean that fewer GW sprinklers are permitted than implied by the intensities. To account for the effect of quotas, we make the generation of sprinkler scenarios a three-step process.

In the first step we create a sprinkler scenario using PREPDM, but assume that there is no GW quota. This produces a set of plots that

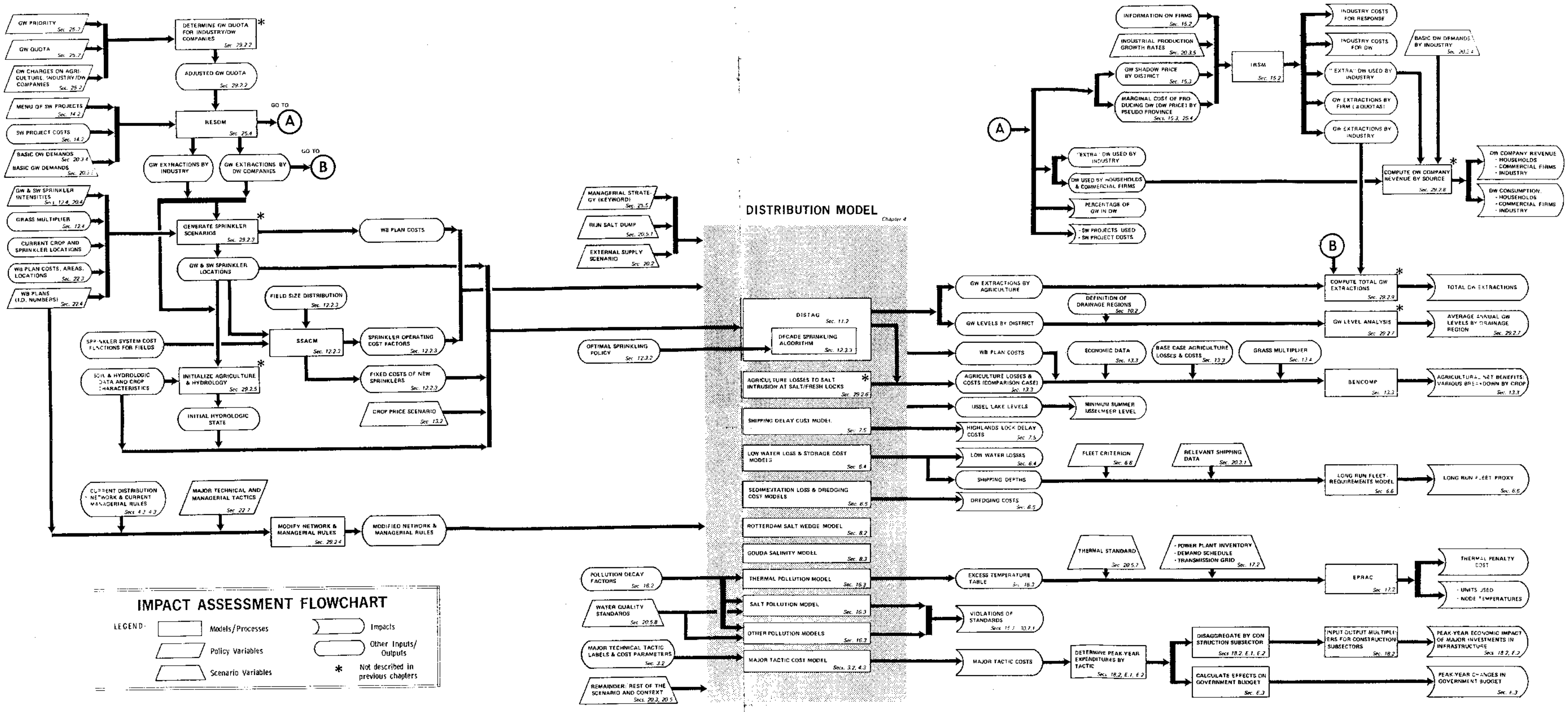

GW PRIORITY Sec. 25.2
GW QUOTA Sec. 25.2
GW CHARGES ON AGRICULTURE, INDUSTRY/DW COMPANIES Sec. 25.2
DETERMINE GW QUOTA FOR INDUSTRY/DW COMPANIES Sec. 29.2.2 *
ADJUSTED GW QUOTA Sec. 29.2.2
MENU OF SW PROJECTS Sec. 14.2
SW PROJECT COSTS Sec. 14.2
BASIC DW DEMANDS Sec. 20.3.4
BASIC GW DEMANDS Sec. 20.3.
RESOM Sec. 25.4
GO TO A
GW EXTRACTIONS BY INDUSTRY
GW EXTRACTIONS BY DW COMPANIES
GO TO B
GW & SW SPRINKLER INTENSITIES Secs. 12.4, 20.4
GRASS MULTIPLIER Sec. 12.4
CURRENT CROP AND SPRINKLER LOCATIONS
WB PLAN COSTS, AREAS, LOCATIONS Sec. 22.3
WB PLANS (I.D. NUMBERS) Sec. 22.4
GENERATE SPRINKLER SCENARIOS Sec. 29.2.3 *
WB PLAN COSTS
GW & SW SPRINKLER LOCATIONS
FIELD SIZE DISTRIBUTION Sec. 12.2.3
SPRINKLER SYSTEM COST FUNCTIONS FOR FIELDS
SSACM Sec. 12.2.3
SPRINKLER OPERATING COST FACTORS Sec. 12.2.3
SOIL & HYDROLOGIC DATA AND CROP CHARACTERISTICS
INITIALIZE AGRICULTURE & HYDROLOGY Sec. 29.2.5 *
FIXED COSTS OF NEW SPRINKLERS Sec. 12.2.3
CROP PRICE SCENARIO Sec. 13.2
INITIAL HYDROLOGIC STATE
CURRENT DISTRIBUTION NETWORK & CURRENT MANAGERIAL RULES Secs. 4.2, 4.3
MAJOR TECHNICAL AND MANAGERIAL TACTICS Sec. 22.7
MODIFY NETWORK & MANAGERIAL RULES Sec. 29.2.4
MODIFIED NETWORK & MANAGERIAL RULES
MANAGERIAL STRATEGY (KEYWORD) Sec. 25.5
RIJN SALT DUMP Sec. 20.5.1
EXTERNAL SUPPLY SCENARIO Sec. 20.2
OPTIMAL SPRINKLING POLICY Sec. 12.3.2
POLLUTION DECAY FACTORS Sec. 16.2
WATER QUALITY STANDARDS Sec. 20.5.8
MAJOR TECHNICAL TACTIC LABELS & COST PARAMETERS Sec. 3.2
REMAINDER: REST OF THE SCENARIO AND CONTEXT Secs. 20.3, 20.5
DISTRIBUTION MODEL
Chapter 4
DISTAG Sec. 11.2
DECADE SPRINKLING ALGORITHM Sec. 12.3.3
AGRICULTURE LOSSES TO SALT INTRUSION AT SALT/FRESH LOCKS Sec. 29.2.6 *
SHIPPING DELAY COST MODEL Sec. 7.5
LOW WATER LOSS & STORAGE COST MODELS Sec. 6.4
SEDIMENTATION LOSS & DREDGING COST MODELS Sec. 6.5
ROTTERDAM SALT WEDGE MODEL Sec. 8.2
GOUDA SALINITY MODEL Sec. 8.3
THERMAL POLLUTION MODEL Sec. 16.3
SALT POLLUTION MODEL Sec. 16.3
OTHER POLLUTION MODELS Sec. 16.3
MAJOR TACTIC COST MODEL Secs. 3.2, 4.3
A
INFORMATION ON FIRMS Sec. 15.2
INDUSTRIAL PRODUCTION GROWTH RATES Sec. 20.3.5
GW SHADOW PRICE BY DISTRICT Sec. 15.3
MARGINAL COST OF PRODUCING DW (DW PRICE) BY PSEUDO PROVINCE Secs. 15.3, 25.4
IRSM Sec. 15.2
INDUSTRY COSTS FOR RESPONSE
INDUSTRY COSTS FOR DW
"EXTRA" DW USED BY INDUSTRY
GW EXTRACTIONS BY FIRM (≤QUOTAS)
GW EXTRACTIONS BY INDUSTRY
BASIC DW DEMANDS BY INDUSTRY Sec. 20.3.4
"EXTRA" DW USED BY INDUSTRY
DW USED BY HOUSEHOLDS & COMMERCIAL FIRMS
PERCENTAGE OF GW IN DW
- SW PROJECTS USED
- SW PROJECT COSTS
COMPUTE DW COMPANY REVENUE BY SOURCE Sec. 29.2.8 *
DW COMPANY REVENUE - HOUSEHOLDS - COMMERCIAL FIRMS - INDUSTRY
DW CONSUMPTION, - HOUSEHOLDS - COMMERCIAL FIRMS - INDUSTRY
B
GW EXTRACTIONS BY AGRICULTURE
COMPUTE TOTAL GW EXTRACTIONS Sec. 29.2.9 *
TOTAL GW EXTRACTIONS
DEFINITION OF DRAINAGE REGIONS Sec. 10.2
GW LEVELS BY DISTRICT
GW LEVEL ANALYSIS Sec. 29.2.7 *
AVERAGE ANNUAL GW LEVELS BY DRAINAGE REGION Sec. 29.2.7
WB PLAN COSTS
ECONOMIC DATA Sec. 13.3
BASE CASE AGRICULTURE LOSSES & COSTS Sec. 13.3
GRASS MULTIPLIER Sec. 13.4
AGRICULTURE LOSSES & COSTS (COMPARISON CASE) Sec. 13.3
BENCOMP Sec. 13.3
AGRICULTURAL NET BENEFITS: VARIOUS BREAKDOWN BY CROP Sec. 13.3
IJSSEL LAKE LEVELS
MINIMUM SUMMER IJSSELMEER LEVEL
HIGHLANDS LOCK DELAY COSTS Sec. 7.5
LOW WATER LOSSES Sec. 6.4
FLEET CRITERION Sec. 6.6
RELEVANT SHIPPING DATA Sec. 20.3.1
SHIPPING DEPTHS
LONG RUN FLEET REQUIREMENTS MODEL Sec. 6.6
LONG RUN FLEET PROXY Sec. 6.6
DREDGING COSTS Sec. 6.5
THERMAL STANDARD Sec. 20.5.7
- POWER PLANT INVENTORY - DEMAND SCHEDULE - TRANSMISSION GRID Sec. 17.2
EXCESS TEMPERATURE TABLE Sec. 16.3
EPRAC Sec. 17.2
THERMAL PENALTY COST
- UNITS USED - NODE TEMPERATURES
VIOLATIONS OF STANDARDS Secs. 15.3, 20.7.1
MAJOR TACTIC COSTS
DETERMINE PEAK-YEAR EXPENDITURES BY TACTIC Secs. 18.2, E.1, E.2
DISAGGREGATE BY CONSTRUCTION SUBSECTOR Secs. 18.2, E.1, E.2
INPUT OUTPUT MULTIPLIERS FOR CONSTRUCTION SUBSECTORS Sec. 18.2
PEAK-YEAR ECONOMIC IMPACT OF MAJOR INVESTMENTS IN INFRASTRUCTURE Secs. 18.2, E.2
CALCULATE EFFECTS ON GOVERNMENT BUDGET Sec. E.3
PEAK-YEAR CHANGES IN GOVERNMENT BUDGET Sec. E.3
IMPACT ASSESSMENT FLOWCHART
LEGEND:
Models/Processes
Policy Variables
Scenario Variables
Impacts
Other Inputs/Outputs
* Not described in previous chapters

Fig. 29.1

are used in the next step. In it we calculate the expected amount of GW sprinkling that will occur in each district by multiplying the area of each plot sprinkled from GW by the expected amount of sprinkling per hectare for the plot and then aggregating by district. (We obtain the expected sprinkling per hectare from the optimal intensity analysis described in Chap. 12.) Since we now know the expected GW sprinkling amount by district, which is the expected GW extraction by agriculture per district, we can compare it with the amount of GW available to agriculture. (When industry/DW companies have priority, the GW available to agriculture is the quota--the total available--less their extractions.) In districts where the expected extraction will exceed the amount available to agriculture, we compute factors by which the original GW sprinkler intensities must be adjusted for the quota to be met. However, in so doing, we assume that currently installed sprinklers continue to operate, even if their extractions cause the quota to be violated. This rarely occurs, and when it does the quota is seldom overstepped by much.

In the final step of the process, we rerun PREPDM, but this time apply the factors just computed to reduce the number of new GW sprinklers installed.

29.2.4. Modify Network and Managerial Rules

In the water distribution system, as represented by the DM, district discharges and extractions are apportioned among the nodes by means of district extraction and discharge distribution keys. These keys assign a fraction of the total district extraction (discharge) to one or more nodes. They also define the capacity of the district link to the node. When waterboard plans are implemented, the cultivated area that can be supplied with surface water (SW) for sprinkling increases. This increase necessitates changes in the DM's distribution keys. The modifications are performed by PREPDM, in addition to its other task of creating sprinkler scenarios. In performing the modifications, PREPDM uses the waterboard plan database, which contains information on how much of the newly suppliable area should be apportioned to each node and on the additional capacities in the district links to the nodes.

29.2.5. Initialization of DISTAG

The quantity of water available in the soil for plants during some interval of time depends both on how much water enters the soil, from rain, sprinkling, and other sources, and on how much water is already in the soil at the beginning of the interval. Similarly, how much salt is taken up by plants depends both on how much enters the soil and on how much is present at the beginning. Finally, the GW level at the end of a time interval depends in part on its level at the beginning. To account for these facts, DISTAG computes the quantity of water and salt in the soil, and the GW level, at the end of each decade; these quantities become the initial conditions for the beginning of the next decade. However, DISTAG must be supplied with "initial" initial conditions to be used for the first decade in the year.

To estimate these "initial" initial conditions, we first made rough estimates of initial soil moisture, salt, and GW levels, taking intermediate values of all quantities (e.g., moisture conditions roughly halfway between "very wet" and "very dry"). Starting from these rough estimates, we ran DISTAG for a simulated year, using the weather conditions likely to be encountered in an "average" year, and calculated the soil moisture and salt content of the soil resulting at the end of this year. These estimates were saved and read into DISTAG to begin its calculations for each subsequent run.

Industries and DW companies extract GW, and these extractions affect the GW levels. Whenever GW withdrawals by industry and DW companies changed, the initialization files had to be recomputed.

29.2.6. Agricultural Losses to Salt Intrusion at Salt/Fresh Locks

Salt intrusion at salt/fresh locks in the Lowlands diffuses upstream in the canals on the fresh side of the locks. Water extracted by the districts from these canals has increased salinity over the background salinity of the water (its salinity in the absence of salt intrusion). Estimates of the losses to agriculture due to this increased salinity are included in the DM for the canal locks at Delfzijl, Den Helder, Harlingen, Parksluizen, and Spaarndam. These estimates are based on a simple model developed by a Dutch member of the PAWN team and are considered to be only rough approximations to the actual losses. (See Sec. 7.1.3.2 of Vol. XI.)

29.2.7. Compute Average GW Levels by Drainage Region

DISTAG, operating as a subroutine of the DM, computes the district GW levels, decade by decade, and writes them on an output file. A simple statistical analysis program takes this file, plus the definition of the 29 drainage regions in terms of districts, and computes the average GW level over the year for each of the drainage regions.

29.2.8. Compute DW Company Revenue by Source

RESDM outputs the quantity of DW consumed by industries and by the commercial/household sector, as well as the costs of producing that water. To determine the revenue received by the DW companies from those sectors we simply multiply the quantity of water they consume by its indicated marginal cost of production. We obtained separate consumption estimates for the commercial and household sectors by applying factors based on their actual 1976 water use[1] to RESDM estimates of their joint consumption. To get total industrial demand for DW, we took the basic DW demand by industry and added the "extra"

DW demand by industry (calculated by IRSM) to it. (We did not use the RESDM estimates of extra DW demand by industry because they are less precise.)

29.2.9 Compute Total GW Extractions

To compute the total GW extractions, we merely add up the extractions by DW companies, by industry, and by agriculture. The extractions by DW companies come from RESDM. The extractions by industrial firms come from IRSM. (Although we also receive such extractions from RESDM, we use the ones from IRSM because they are somewhat more precise.) The extractions by agriculture (sprinkling with GW) come from the DM.

29.3. ORGANIZATION OF THE REMAINDER OF THIS PART

The next two chapters present the impacts of the primary cases, sector by sector, under two different external supply scenarios. Chapter 30 uses the DEX (extremely dry) scenario to estimate extreme values of the impacts. Chapter 31 uses the 1943 scenario to estimate average values of the impacts. Together, these chapters should give each decisionmaker an idea of the range of impact magnitudes that might result from each policy and should enable him to factor into his decision whatever degree of risk aversion he believes appropriate. For convenience, we repeat the definition of primary cases below.

Table 29.1

DEFINITION OF PRIMARY CASES

	Cases					
Item	A	C	D	E	F	G
Managerial strategy	RWS	MSDM	MSDM	MSDM	MSDM	MSDM
Waterboard plans	No	Yes	Yes	Yes	Yes	Yes
MAXTACS	No	No	Yes	Yes	Yes	Yes
SW sprinklers	Low	Med	Med	Med	Hi	Hi
GW sprinklers	Low	Low	Low	Med	Hi	Low
GW extraction quota	1.0	1.0	1.0	1.0	1.0	.25
GW priority above current sprinklers	-	-	-	I/D	I/D	AGR
GW charge on IND and AGR (Dfl)	0	0	0	0	0	0

NOTE: I/D = industry/DW companies; IND = industry; AGR = agriculture. MSDM indicates the SIMPLE MSDM strategy.

Chapter 32 uses a number of different cases for various sensitivity analyses, including the effect of managerial strategies, the effect of changes in sprinkling, the reductions in the Rijn BOD, and increases in the Rijn salt dump. Additional sensitivity analyses that are quite lengthy are contained in supporting appendixes.

In reading these chapters it is essential to recall that the results contained are basically those presented at the PAWN final briefing in December 1979. Rand and the RWS considered these results to be tentative because some of the methodology was not available until late in the analysis phase, and because the RWS planned to do additional analysis. Because the understanding gained in the original PAWN analysis led to improvements in the data--and, in some instances, the models--used to represent the water management system in the additional analysis, the reader is hereby cautioned that the numerical results and conclusions presented in the impact assessment chapters will not always agree with those presented in the Nota Waterhuishouding or its companion reports.

PAWN's most important task was to develop a comprehensive methodology for analyzing alternative water management policies. Thus, the results below should be considered more illustrative than definitive. However, most of the components of the new national water management policy for the Netherlands presented in the Nota Waterhuishouding arose either from the PAWN analysis or from the additional RWS analysis done with the PAWN methodology. The concluding chapter of this report identifies these components and relates them to the PAWN results. It also indicates how the PAWN methodology and approach can be useful for other locations and other policy problems.

NOTE

1. In 1976, 42 percent of the DW produced in the Netherlands went to households, 28 percent went to industrial firms, and 30 percent was consumed by commercial businesses.

Chapter 30

EXTREME IMPACTS OF THE PRIMARY CASES

30.1. INTRODUCTION

In this chapter, we consider the extreme values of the annual impacts that various water management policies, as defined in the primary cases, may have. Because we wanted extreme effects, we use the DEX external supply scenario. Most of the impacts, particularly the monetary ones, are described in terms of "net of the base case"--that is, the size of the change from the base. However, some impacts, such as GW extractions and pollution concentrations, are presented in terms of actual values, to be compared with the corresponding values for the base case.

We treat each sector in turn and describe the impacts of the various cases on it. When there are interesting distributional effects, we present them in the discussion of that sector. We conclude the chapter with a summary scorecard of the most important impacts. The impacts that appear on the summary scorecard and the reasons for selecting them are:

- Dutch net benefits: This figure takes into account all the costs and benefits of implementing the tactics in question. It is a summary figure that includes gross benefits and costs over various sectors. This usage differs from the one in screening and from the one used for individual sectors in impact assessment. In examining an individual sector, we do not include the costs of tactics implemented in another sector or of tactics implemented by the national government that affect multiple sectors (e.g., MAXTACS).
- Minimum IJsselmeer level during the summer: This provides an index of the risk of shortage if the external supply scenario becomes more severe than DEX.
- The percentage of GW contained in DW: This provides an index of water quality for public health and of reliability of the drinking-water (DW) supply, i.e., its susceptibility to shortages or accidental pollutant spills.
- The frequency and geographic extent with which basic standards are violated for BOD, total phosphate, and salt: This provides an index of water quality for both public health concerns and the environment.
- The amount of GW extracted: This provides an index of possible damage to the environment and an indication of the effect on the long-run supply of GW.
- The number of SW projects built by DW companies: This supplies an index of possible damage to the environment, including the amount of land to be used.

- Presence or absence of MAXTACS: This provides an index of change/damage to the environment, and indicates whether the Grevelingen will be salt or fresh.

For a variety of reasons, the tables in this discussion sometimes contain figures that differ from the figures given in the PAWN final briefing in December 1979. Such tables are clearly marked; the differences between the figures in them and those presented in the final briefing are noted and explained in App. L.

30.2. AGRICULTURAL IMPACTS

The methodology used in impact assessment to analyze agriculture differs markedly from that used in screening. In screening, net benefits were considered to be the difference of gross benefits and total costs. Gross benefits were the damages prevented by implementing tactics. The calculation of gross benefits was based on potential crop values per hectare that were set for each external supply scenario. Total costs were made up of variable and fixed sprinkling costs and waterboard plan investment costs. This method of measuring net benefits ignores several factors which may be important: (1) the effect of changes in crop yield on crop price, (2) the way in which costs and benefits are allocated to impact groups, and (3) the fact that some of the benefits may go to foreign countries. In agricultural impact assessment, we have incorporated these factors into our calculation of net benefits by using the benefits comparison program (BENCOMP), described in Sec. 13.3.[1]

The primary cases were designed to provide an insight into the effect that a wide range of policy and scenario variables have on selected impact groups. The base case, case A, approximates the current policy. It includes the current infrastructure and sprinklers, but uses the RWS managerial strategy rather than the current one. The remaining primary cases, C through G, use the MSDM managerial strategy and augment the current infrastructure and/or sprinklers. Waterboard plans are included in cases C through G. In cases D through G, MAXTACS are also implemented. Surface water (SW) sprinkler levels are above the current level in cases C through G; at medium in C, D, and E; at high in F and G. Groundwater (GW) sprinkler levels in cases E and F differ from current levels. In case E they are medium; in F they are high. A GW extraction quota of 0.25 is in effect in case G.

Table 30.1 summarizes the crop area with sprinklers for the primary cases. Case A, representing the current situation, has sprinklers on 14 percent of the crop land. Of the primary cases, F has the most sprinklers, covering nearly 40 percent of the crop area. In each of the primary cases, grass sprinkling accounts for about 70 percent of the total. This is important because in impact assessment we assume the grass multiplier is 2.

Table 30.1

CROP AREA OF NETHERLANDS WITH SPRINKLERS
INSTALLED FOR THE PRIMARY CASES

	Area in Percent, by Case					
Item	A	C	D	E	F	G
Percentage of crop area sprinkled with SW	10	22	22	22	31	31
Percentage of crop area sprinkled with GW	4	4	4	6	9	4
Total	14	26	26	28	40	35
Percentage of SW-sprinkled area containing grass	68	71	71	71	72	72
Percentage of SW-sprinkled area not containing grass	32	29	29	29	28	28
Percentage of GW-sprinkled area containing grass	74	74	74	70	69	74
Percentage of GW-sprinkled area not containing grass	26	26	26	30	31	26

NOTE: Components may not sum to total due to rounding.

Table 30.2 presents agricultural net benefits for the primary cases in the DEX external supply scenario. (As the net benefits to the agriculture sector, they do not reflect the 56.4 Dflm cost of MAXTACS, an expenditure by the national government affecting many sectors.) In all cases the benefits are very large. Case C yields the lowest Dutch benefits, 891 Dflm; case F has the highest, 2148 Dflm (nearly $900 million). Benefits increase with the number of sprinklers. And the implementation of MAXTACS (cases D through F) increases benefits because it is possible to supply some SW sprinklers with water at times when they could not otherwise be supplied.

Although there is a great deal less GW sprinkling in case G than in case F, the Dutch benefits are only 269 Dflm higher for case F because most of the benefits derive from SW sprinklers. In addition, case G has a GW quota of 0.25, which reduces GW extractions by industry and DW companies. These reductions, coupled with the reduced extractions by agriculture, produce agricultural benefits in two ways. First, they cause higher GW levels in the vicinity of the wells. Because the higher levels increase capillary rise for the crops, they reduce damages from water shortages. This effect occurs primarily in the Lowlands and in the low Highlands. Second, because less GW is being extracted, there is more basic drainage from the GW system into the SW system. This increase is reflected in more water in the Maas, which helps combat the Rotterdam salt wedge, and more water downstream in the Rijn, which lowers the salinity for downstream withdrawals. This second effect occurs in the Lowlands.

In each of the primary cases, Dutch government benefits represent nearly 40 percent of total Dutch benefits, while Dutch consumer benefits and

Table 30.2

TOTAL AND DISTRIBUTED ANNUAL MONETARY BENEFITS FROM THE AGRICULTURE SECTOR: PRIMARY CASES, DEX EXTERNAL SUPPLY

	Impacts in Dflm/yr, by Case				
Item	C	D	E	F	G
Gross benefits					
Grass	663	763	925	1626	1357
Non-grass	420	598	676	993	889
Sprinkling cost					
Variable cost	-93	-112	-141	-266	-199
Fixed cost	-58	-58	-77	-140	-103
Waterboard plan costs	-22	-22	-22	-22	-22
Net benefits	910	1169	1361	2191	1922
Net benefits, grass mult. of 1	576	784	895	1373	1240
Division of net benefits					
Dutch					
Producer	513	654	767	1243	1083
Consumer	26	34	36	55	52
Government	352	451	527	850	744
Total Dutch	891	1139	1330	2148	1879
Total Dutch, grass mult. of 1	559	757	867	1335	1200
Foreign					
Producer	-131	-196	-202	-275	-275
Consumer	246	370	380	521	521
Government	-96	-144	-148	-203	-203
Total	19	30	31	43	43

NOTES: Differences from the final briefing are explained in App. L. The annual cost of MAXTACS is not included because it is an expenditure by the national government affecting many sectors.

foreign net benefits are relatively small. This distribution is a result of the agricultural market assumptions made in BENCOMP.

Table 30.3 shows the distribution of net benefits by crop. Grass, clearly the most important crop, represents about 60 percent of the benefits (of increased crop production or reduced salinity damage) under each case. This calculation assumes a grass multiplier of 2. If we were to set the multiplier to 1, grass would still be the most important crop. However, net benefits would decline significantly, to 576 Dflm in case C and 1373 Dflm in case F.[2] Significantly, the case rankings would not change.

In case C, without MAXTACS, increased SW sprinkling of glasshouse crops increases salt damage to them--thus the negative benefits. The implementation of MAXTACS in cases D through G alleviates this problem and allows sprinkling to take place where it had previously been cut back. Glasshouse crops are also helped by the imposition of the GW extraction quota in case G because of the quota's role in decreasing

Table 30.3

BENEFITS FROM AGRICULTURE BY CROP: PRIMARY CASES, DEX EXTERNAL SUPPLY

	Impacts in Dflm/yr, by Case				
Item	C	D	E	F	G
Grass	551	639	768	1330	1136
Consumption potatoes	105	132	136	207	203
Milling potatoes	14	21	37	70	48
Seed potatoes	21	23	28	45	38
Sugar beets	29	35	42	59	50
Cereals	32	37	44	56	51
Cut corn	19	28	46	86	52
Bulbs	13	14	14	22	22
Vegetables, open air	97	117	120	174	171
Fruits	35	37	38	52	53
Trees	22	25	29	58	49
Vegetables, under glass	-4	43	42	29	38
Flowers, under glass	-4	40	39	26	33
Subtotal	932	1191	1383	2213	1944
Waterboard plan costs	-22	-22	-22	-22	-22
Net benefits	910	1169	1361	2191	1922

salinity in the Maas and the Rijn. In comparison with case F, the reduced GW sprinkling in case G reduces benefits for most other crops, particularly milling potatoes and cut corn. Increasing sprinkling from case E to F increases the net benefits of all crops except the glasshouse crops.

Table 30.4 depicts net agricultural benefits by pseudo-province. It is clear that Noord-Brabant always reaps the largest agricultural benefits. The benefits to Friesland and Overijssel are also always large. In case D, the implementation of MAXTACS is important to Drenthe, Zuid-Holland (where it alleviates case C's salinity problem), Noord-Brabant, and Limburg. The effect of increasing GW sprinklers in cases E and F is felt primarily in Drenthe, Gelderland, and Noord-Brabant. In comparison with case F, the GW extraction quota in case G causes net benefits in most Lowlands pseudo-provinces to rise because the resulting higher GW level increases basic drainage into the SW system. The reduced GW sprinkler intensity in case G causes benefits to fall in most Highlands pseudo-provinces as compared with case F. This is because nearly all of the new GW sprinkling is in the Highlands pseudo-provinces. Increasing SW sprinklers from medium to high (E versus F and G) aids Highlands provinces except Limburg, which has no SW sprinklers, and Friesland.

Table 30.4

BENEFITS TO AGRICULTURE BY PSEUDO-PROVINCE:
PRIMARY CASES, DEX EXTERNAL SUPPLY

	Impacts in Dflm/yr, by Case				
Pseudo-Province	C	D	E	F	G
Groningen	38	40	43	78	92
Friesland	177	176	210	405	346
Drenthe	26	56	98	181	106
Overijssel	112	112	126	181	161
Gelderland	44	44	96	163	87
Utrecht	18	18	18	35	40
Flevoland	48	49	48	79	82
Noord-Holland	25	25	25	48	51
Zuid-Holland	44	151	149	183	220
Zeeland	-	27	27	33	33
Noord-Brabant	370	438	484	751	651
Limburg	8	33	37	54	53
Net benefits	910	1169	1361	2191	1922

NOTE: Differences from the final briefing are explained in App. L.

We summarize the primary case impacts for agriculture in an extremely dry year as follows:

- Grass sprinkling accounts for 70 percent of total sprinkling and 60 percent of benefits in each case.
- Increasing the amount of sprinkling increases benefits.
- Implementation of MAXTACS provides substantial benefits.
- The Dutch government gets 40 percent of net benefits in each case.
- Noord-Brabant always gets the largest agricultural benefits.

30.3. SHIPPING IMPACTS

The shipping impacts for the primary cases in the DEX scenario are shown in Table 30.5. The impacts include total variable shipping cost for the base case; Dutch and total variable low-water losses, Highlands lock-delay losses, and dredging costs; and the value of the fleet proxy for the Dutch and total shipping fleets. The table shows total losses for the base case (A), and net benefits (relative to case A) for all other cases.

As an example to clarify the tables, consider cases D and C. In these cases, the shipping benefits have opposite signs. Case D has positive numbers in the shipping loss rows, which means that shipping losses are lower in case D than in the base case (case A). In case C the numbers are negative. This means that there is a net increase in shipping losses equal to the amounts shown. This same relation also applies to

Table 30.5

BENEFITS FOR SHIPPING: PRIMARY CASES, DEX EXTERNAL SUPPLY

	Costs and Benefits in Dflm/yr, by Case					
	Costs	Benefits Relative to Case A				
Item	A	C	D	E	F	G
Total variable shipping losses						
Low-water losses	-347.44	-29.59	3.85	2.24	-18.10	-14.76
Highland lock-delay losses	-9.72	-0.11	0.03	0.01	-2.19	0.02
Dredging costs	-0.36	-0.27	0.21	0.21	-0.09	-0.06
Total	-357.52	-29.97	4.09	2.46	-20.38	-14.80
Dutch variable shipping losses						
Low-water losses	-215.41	-18.35	2.38	1.39	-11.22	-9.15
Highland lock-delay losses	-5.93	-0.08	0.02	0.01	-1.36	0.01
Dredging costs	-0.36	-0.27	0.21	0.21	-0.09	-0.06
Total	-221.70	-18.70	2.61	1.61	-12.67	-9.20
Long-run fleet proxy annualized fixed cost						
Total fleet	-2862.1	0.2	0.2	0.2	0.0	0.0
Dutch fleet	-1758.1	0.1	0.1	0.1	0.0	0.0

NOTE: Differences from the final briefing are explained in App. L.

the long-run fleet proxy. Positive numbers mean that a smaller fleet is required than in the reference case.

Shipping losses are lower in case G than in case F because the increased basic drainage resulting from lower GW extractions in case G increases the flow in the Maas.

We summarize the primary case impacts for shipping in an extremely dry year as follows:

- Total variable shipping losses are only 20 percent of actual variable shipping costs, which include large constant costs for the routes where the depths do not vary with policy.
- In all cases, the change in shipping losses is less than 10 percent of the base case losses and less than 2 percent of the base case actual costs.
- The selected policies have little apparent impact on the size of the long-run fleet for the 90 percent proxy.
- Highland lock-delay costs do not change much except when GW use changes significantly.

- Dredging costs are always small compared with other shipping costs.

30.4. POWER PLANT IMPACTS

Imposing thermal standards imposes additional costs on power plants. We calculated these penalty costs for each case using the EPRAC model described in Chap. 9. The penalties depended strongly on the scenario and on the strictness of the standards (3 deg on rivers and 7 deg on canals, or 3 deg everywhere), but were less dependent on other factors. Thus, the penalty costs were not very different for cases A, C, D, E, F, and G.

The results are shown in Table 30.6. When a standard of 3 deg was imposed on rivers, and 7 deg on canals, the DEX cases incurred penalty costs of 15 to 20 Dflm/yr. In all cases, most of the penalty was due to the need to curtail power generation at the very efficient Amer plant (on the Maas near Geertruidenberg) and substitute power generated at less efficient plants elsewhere. Since the Amer plant is on a river, its heat discharge was constrained by the 3-deg standard.

When the 3-deg standard was applied to canals as well as to rivers, the penalty costs rose to 43-50 Dflm, an increase of about 30 Dflm. The rise from the cases with a 7-deg canal standard was due almost entirely to the need to curtail power generation at the Velsen plant on the Noordzeekanaal.

The differences in the thermal penalty across cases are due to small differences in flows, notably in the Noordzeekanaal, that we had originally thought would be of no consequence. Small changes in the managerial strategies employed in the different cases would suffice to equalize the penalties. For further information, see the discussion of sensitivity to managerial strategies in Chap. 32.

Table 30.6

PENALTY COSTS FROM IMPOSING THERMAL STANDARDS:
PRIMARY CASES, DEX EXTERNAL SUPPLY

Standards for River/Canal	Impacts in Dflm/yr, by Case					
	A	C	D	E	F	G
3-deg/7-deg	-15.0	-19.5	-17.6	-17.8	-18.0	-15.6
3-deg/3-deg (reference)	-42.8	-50.1	-47.6	-47.9	-47.8	-45.0

We summarize the primary case impacts for power plants in an extremely dry year as follows:

- Imposition of thermal standards imposes similar penalty costs in all cases.
- The stricter standards increase penalty costs about 30 Dflm/yr.
- Minor adjustments to managerial strategies can equalize penalties among cases.

30.5. INDUSTRIAL FIRMS AND DW COMPANIES AND THEIR CUSTOMERS

In this section we present the primary case impacts for the DEX scenario as they are felt by industrial firms and by DW companies and their customers. Since these groups are little affected by SW policies, and since they are allowed the same total quantity of GW in cases A through F, the same impacts accrue to these groups in all of those cases. Consequently, when discussing relative impacts near the end of the section we need only discuss the relative impacts for case G, when the GW quota is reduced to one-quarter of its value in the other cases.

First we give the impacts of the primary PAWN cases on DW companies and their customers (commercial firms, households, and industrial firms) for the DEX scenario; we also indicate which SW projects would be required and how the percentage of GW in DW would be affected. Then we discuss the full costs and benefits arising in the industrial sector. Commercial firms and households do not generally extract GW or SW, so the DW company analysis covers all of the significant direct impacts on them. But industrial firms extract appreciable amounts of GW and DW and are affected in several ways by the considered policies. We also illustrate how the Dutch markets probably would distribute the industrial benefits among the firms, their customers, competing firms, and the government.

30.5.1. Impacts in the DW Sector

DW companies convert SW and GW into high-quality piped water, suitable for drinking, cooking, and sanitary uses by households and firms, and for process and cooling uses by industrial firms. PAWN water management policies (1) affect the costs of producing and purchasing DW; (2) require the construction of new DW production facilities; and (3) affect the quality and taste of DW. We discuss each of these effects in turn.

Financial Impacts on DW Companies and Their Customers. PAWN water management policies affect the costs and revenues of DW companies, and the composition of DW. The major financial effects are shown in Table 30.7. Note that the conditions facing the DW companies are the same in cases A through F. Indeed, although agricultural GW use changes in those cases, this does not affect DW production because the priority for GW extractions is always with DW companies and industrial firms.

In case G conditions are quite different. The GW quota is reduced to one-quarter of its reference value, severely restricting the amount of

Table 30.7

FINANCIAL IMPACTS ON DW COMPANIES
AND THEIR CUSTOMERS: PRIMARY CASES

Item	Impacts in Dflm/yr, by Case: A-F	G
Revenues from		
Commercial firms	266	484
Households	362	668
Industrial firms	129	333
Total revenues	757	1485
Cost of supplying DW	616	1095
Net surplus	141	390

SOURCE: Table 4.12 of Vol. VII.

NOTES: Costs do not include local distribution and overhead. We include 4 percent value-added tax in revenues. Differences from the final briefing are explained in App. L.

GW available, and priority for that limited GW is given to agriculture. This causes large cost increases in DW production because reliance must be placed on new and costly SW facilities.

All PAWN primary cases are based on the assumption that DW companies can and do base the prices they charge for DW on marginal production costs. This ensures that DW, and GW, will be allocated in the most efficient manner. With increasing marginal costs, which in PAWN are always higher than average costs, it also means that DW revenues will be larger than total (variable plus fixed) costs, thus producing a surplus. Since DW companies are required by law to be nonprofit enterprises, we assume that this surplus will be remitted to the government as quasi-taxes.

DW Production Impacts on the Environment. DW companies strive to use GW whenever possible in producing DW because GW is usually clear, cool, good tasting, and of consistent quality. However, when GW is restricted or made too costly, DW companies must turn to SW, which is less desirable than GW (and currently much more expensive).

Using SW to produce DW requires the construction of large, costly SW projects--mainly reservoirs and infiltration projects. Table 30.8 shows the SW projects that would be required under each case and the extractions that would be made.

Cases A through F would all require a total of six SW projects: the Biesbosch and Braakman reservoirs, dune infiltration in both Noord- and Zuid-Holland, water that has infiltrated through the banks of the Lek, and the special water collection system for Amsterdam. The 1977

Table 30.8

SW PROJECTS AND EXTRACTIONS REQUIRED: PRIMARY CASES

SW Project	Extraction (mcm/yr) A-F	G
Spaarbekken Lettelbert	--	50*
Spaarbekken Twente	--	57*
Spaarbekken Maas/Waal	--	100*
Spaarbekken Ysselmeer	--	44
Spaarbekken Zuid-Flevoland	--	69
Spaarbekken Biesbosch	160**	200
Spaarbekken Markiezaat	--	31
Spaarbekken Braakman	16*	16*
Spaarbekken Itteren/Borgharen	--	51
Grindgat Heel/Panheel	--	50*
Duininfiltratie Noord-Holland	21	90
Duininfiltratie Zuid-Holland	23	110*
Oevergrondwater Lek	50*	50*
Oeverinfiltratie Maas	--	50*
Oevergrondwater Roosteren	--	25*
Plassenwaterleiding Amsterdam	60*	60*
Infiltratie Veluwe	--	205
Infiltratie Groot Heide	--	20*
Total SW extracted	330	1278
Total number of SW projects required	6	18

SOURCE: Vol. VII, p. 44.

NOTES: Blanks denote that no SW project is required.

*Extraction equals maximum capacity of SW project.

**160 mcm/yr represents forced extraction from the Biesbosch.

capacities for these projects were 160, 11, 104, 70, 0, and 30 mcm/yr, respectively, so the base case implies both the expansion of the Braakman reservoir and the construction of the Lek facility. The existing infiltration projects in Noord- and Zuid-Holland would be used at substantially less than their current capacities, and the Groot Heide infiltration project would not be used at all.

Case G, where the quota sharply reduces GW extractions, would require many more SW facilities. In all, case G requires a total of 1278 mcm/yr of SW from 18 projects.

The Percentage of GW in DW. Because SW is generally of lower quality than GW, the prospect of having to use increasing amounts of it raises the question of whether DW companies can maintain the quality of the resulting DW above the lawful level. ("Quality" here is concerned as much with taste as with the elimination of harmful pollutants from the water.[3]) We use the percentage of GW in DW as a proxy measure for DW quality and as an indicator of the susceptibility of DW supply to interruptions from shortages or accidental pollution spills. Table 30.9 shows our estimates of the percentage of GW in DW by pseudo-province for the PAWN primary cases.

In cases A through F, most DW is composed entirely of GW. Only the low-lying western provinces of Noord- and Zuid-Holland and Zeeland need to use any SW at all in their DW production. However, those three provinces contained over 40 percent of the total population of the Netherlands in 1979, and they consumed a correspondingly large portion of total DW.

When the GW extraction quota is cut to 25 percent of its value in case G, SW extractions by DW companies nearly quadruple to compensate, with the result that the proportion of GW contained in the DW drops to about one-fifth of its value in the base case. The percentage drops substantially in all provinces. In fact, Drenthe, Friesland, and the Zuid-IJsselmeer polders are the only pseudo-provinces whose DW would contain over one-third GW. Four provinces, Noord- and Zuid-Holland, Zeeland, and Limburg, would have almost no GW available for DW purposes. This could have a significant effect on public health.

Table 30.9

DW COMPOSITION BY PSEUDO-PROVINCE:
PRIMARY CASES

	Percentage of GW in DW, by Case	
Pseudo-Province	A-F	G
Groningen	100	20
Friesland	100	40
Drenthe	100	75
Overijssel	100	31
Gelderland	100	21
Utrecht	100	20
Zuid-IJsselmeerpolders	100	46
Noord-Holland	50	7
Zuid-Holland	33	7
Zeeland	67	3
Noord-Brabant	100	15
Limburg	100	0
Netherlands (avg.)	77	16

30.5.2. Impacts in the Industrial Sector

PAWN analyses of the impacts of water management policies on the industrial sector of the Dutch economy assume that industrial output will not change because of those policies. However, changes in GW costs, quality, and availability may cause firms to substantially adjust the way in which they use water. They may switch to alternative water sources, or they may reduce their total water requirements either by recirculating used water or by adopting other water-conserving cooling processes.

All of those changes cost money. They increase industrial costs, and those increased costs will increase product prices and lower profits. Increased product prices will reduce the welfare of households (and other firms) that purchase the products and increase the competitive position of competing firms and products, both Dutch and foreign.

The Impacts on Industrial Firms. Table 30.10 shows how the industrial firms will adjust their water use in response to the primary cases, and how this will affect their costs. Note again that cases A through F are equivalent for this sector. None of the tactics affects industrial firms until the GW extraction quota is cut to 25 percent of its reference value in case G. Since industrial firms incur many production costs that are not water related and hence not accounted for in our

Table 30.10

IMPACTS ON INDUSTRIAL FIRMS:
PRIMARY CASES

Impact	Impacts, by Case A-F	 G
Industrial water consumption (mcm/yr)		
GW intake	438	170
DW intake	255	318
SW intake	3705	3734
Total intake	4398	4222
Industrial cost increases (Dflm/yr)		
GW taxes	0	0
DW costs	0	204
Other	0	36
Total cost	0	240

SOURCE: IRSM output computed at DHL.

NOTES: The 4 percent value-added tax has been added to DW costs. Differences from the final briefing are explained in App. L.

analysis, we have no total cost estimate for the base case. Thus, all industry costs are reported relative to the costs incurred in case A.

Table 30.10 shows absolute levels of water use for cases A through F and case G. Industrial firms use much more SW than GW or DW, but most of this SW is low-quality, brackish water withdrawn near the North Sea. But firms also use significant amounts of GW and DW, and it is these types of water use that prove most sensitive to water management policies. When the GW quota is lowered in case G, the GW extractions of industrial firms fall by 268 mcm/yr, to less than 40 percent of their base case level. Use of DW and SW increases, but not nearly enough to make up the difference, so total water use falls by 176 mcm/yr. This net reduction in water use is a result of the nature of the two substitute sources. SW is usually of low quality and cannot be substituted for GW without undergoing extensive and expensive treatment. DW is almost always as clean and pure as GW, but it is also expensive, especially in this case, when much of the DW must be produced from (low quality) SW. Under these conditions, firms prefer to recirculate water and adopt other water-conserving cooling methods.

The lower portion of the table shows the change in costs incurred by the firms when the water management policy is changed. When the GW quota is sharply reduced, the costs of industrial firms increase substantially. Some of the cost increase is for the adoption of water-conserving equipment, but most is increased payments for DW. We have seen that the use of DW by firms increases by about 25 percent. The increase in DW costs for the firms works out to much more than that because the additional DW is not available at the old DW price. In fact, all of the DW used by the firms must now be purchased at the new, higher price. (This is also true when DW is priced according to its average cost of production, but the effect is greater under marginal-cost pricing.) Using the total change in cost and the change in GW extractions, we estimate that the cost increase experienced by the firms is about 0.87 Dfl for each cubic meter of GW that is conserved by the stricter quota.

Distribution of Costs in the Industrial Sector. The cost changes we have been referring to are incurred directly by business firms. Under some conditions, the firms absorb the full effect of the increased cost, but that is not usually the case. Even if product prices do not change and the firms' profits fall, a portion of the effect is transferred to the government because the firms will pay less profits tax. In most instances, however, product prices do change, if only slightly. This passes some of the cost increase along to domestic and foreign consumers. Competing firms will also benefit or incur losses as their price changes affect their sales and profits. And the government may notice a change in its value-added tax collections. Our procedure for estimating all of these effects was summarized in Chap. 19.

Table 30.11 shows our estimate of the distribution of the cost changes associated with case G. We estimate a "most probable" distribution by assuming that the reduction in sales caused by a price increase is

Table 30.11

DISTRIBUTION OF INDUSTRIAL BENEFITS FOR CASE G

Recipient	Benefit in Dflm/yr
Dutch	
Industrial firms	-136
Consumers	-15
Government	-89
Net Dutch	-240
Foreign	
Industrial firms	123
Consumers	-245
Government	117
Net foreign	-5
Net benefit	-245

SOURCE: Computations applying procedures from Vol. X to IRSM outputs.

NOTES: Dutch government receipts come from the value-added tax and the profits tax. Foreign government receipts come from the foreign value-added tax and profits tax.

just sufficient to maintain revenue at its former level and that the percentage increase in supply is 10 times the price increase.[4] We also assume that none of the industrial products is effectively price-supported; and finally we assume that international markets exist for most of the industrial products produced and sold in the Netherlands. This last assumption is particularly important in quantifying the estimates.

As the table shows, consumers feel only small effects from the policy changes. The EEC-wide markets that we assume have many alternative sources of supply for these industrial products. Consequently, Dutch producers faced with increased costs can raise prices only slightly or they will lose sales to foreign producers. This circumstance insulates the consumers, both domestic and foreign, from sharing significantly in the cost impacts.

The Netherlands government does share a major portion of the cost increases. Since we assume an average tax rate on profits of 40 percent, the government bears 40 percent of all the costs that firms are not able to pass along to consumers. It does, however, collect slightly more value-added tax on industrial sales because of the price increases. As we mentioned before, we assume that GW is allocated by quotas rather than price, so the government receives no revenues from GW taxes in these cases.

Foreign effects net nearly to zero, but individually they appear rather large; most of the product markets are located outside the Netherlands, so that even when the price changes are quite small, many items and many producers and consumers are involved, causing the total effects to be significant. The foreign effects result when the original cost changes for the Dutch producers induce some (small) change in EEC-wide prices. But after that there is little interaction between the Dutch and foreign effects. Foreign effects are composed almost entirely of transfers from foreign consumers to foreign producers, and those producers then pass a portion of the increased profits along to their governments through increased profits-tax payments.[5]

Thus we find that the net Dutch effect (a loss of 240 Dflm/yr in Table 30.11) is identical to the total industrial cost (in Table 30.10) and nearly equivalent to the net Dutch benefit. We find this close correspondence in all the cases we have examined, although the net Dutch benefit and total industrial cost are not always identical.

We summarize the primary case impacts on the DW sector as follows:

- Quotas severely restricting GW extraction greatly increase the cost of DW production, the percentage of SW in DW, and cost to industrial users of GW.
- The Dutch government, rather than the consumer, will bear large amounts of these increased costs.

30.6. SUMMARY OF MONETARY BENEFITS

Table 30.12 summarizes the monetary benefits discussed above. It shows the net Dutch benefit and the portion of that benefit going to the Dutch government for each of the cases C through G, relative to the base case, case A.

Table 30.12 shows that all cases have a large excess of monetary benefits over costs in an extremely dry year. (The cost of MAXTACS is shown separately in the table; all other costs--for example, sprinkling costs and the costs of waterboard plans--have been accounted for in the individual sectoral analyses.) The most impressive entries in the table are the large Dutch benefits from agriculture (the benefits of increased crop production or reduced salinity damage in each case over the base case). This sector is clearly the focus of the primary policies, and its benefits dominate our findings. Only in case G, with the GW extraction quota of 0.25, are any of the other impacts within an order of magnitude of the benefits to farmers.

Total Dutch benefits are greatest for case F, which has high sprinkler intensity with both GW and SW. Cases C and D, with medium intensity for

Table 30.12

SUMMARY OF DUTCH BENEFITS: PRIMARY CASES,
DEX EXTERNAL SUPPLY

Item	Impacts in Dflm/yr, by Case, Relative to Case A				
	C	D	E	F	G
Dutch share					
MAXTACS	--	-56.4	-56.4	-56.4	-56.4
Agriculture	891.0	1139.0	1330.0	2148.0	1879.0
Shipping	-18.7	2.6	1.6	-12.7	-9.2
Thermal penalty	-7.4	-4.8	-5.1	-5.0	-2.2
Industry	--	--	--	--	-240.0
Households	--	--	--	--	-306.0
Commercial	--	--	--	--	-218.0
DW companies	--	--	--	--	249.0
Total	865.0	1080.4	1270.1	2074.0	1296.2
Total, grass mult. of 1	533.0	698.4	807.1	1261.0	617.2
Dutch government					
MAXTACS	--	-56.4	-56.4	-56.4	-56.4
Agriculture	352.1	451.3	527.3	849.7	743.7
Shipping	-7.6	1.2	0.8	-5.1	-3.7
Thermal penalty	--	--	--	--	--
Industry	--	--	--	--	-89.0
Households	--	--	--	--	--
Commercial	--	--	--	--	-80.0
DW companies	--	--	--	--	249.0
Total	344.5	396.1	471.7	788.2	763.6

NOTE: Components may not add to total due to rounding.

SW sprinklers and low intensity for GW sprinklers, have less than half the total benefits of case F. And case E, with medium intensity for both types of sprinkling, does only slightly better.

The dominance of the agriculture sector is again evidenced by the findings in case G. This case, which has a GW quota only 25 percent of the quota used in all other cases, shows the second highest total Dutch benefits. The benefits to agriculture from the high SW sprinkling (even though GW sprinkling is low) more than outweigh the additional costs borne by the commercial, household, and industrial sectors.

Total Dutch benefits are sensitive to the use of the grass multiplier. Setting the grass multiplier to 1 typically reduces Dutch benefits by 35 to 40 percent. In case G, however, where significant costs are borne by the other sectors, reducing farm benefits by removing the grass multiplier lowers total Dutch benefits by over 50 percent.[2]

The lower portion of the table shows the revenues the Dutch government could expect to receive to offset the costs of MAXTACS. The findings shown here are nearly identical to those discussed above for the total Dutch share of benefits: (1) benefits are significantly greater than costs in all cases; (2) most benefits come from the agriculture sector; and (3) case G does surprisingly well.

We will discuss these monetary impacts further at the end of the chapter, when we introduce the summary scorecard for these primary cases.

30.7. ENVIRONMENTAL IMPACTS

In this section, we consider a range of impacts that water management policies have on the environment. First, we discuss the results of water quality standards. Next, we discuss the effects of GW extractions in the different cases; we treat GW extractions in this section because reducing GW extractions is often considered an important tool in protecting the environment. Finally, we discuss a set of special cases defined and analyzed by RIN (Rijksinstituut voor Naturbeheer, the State Institute for Nature Management).

30.7.1. Violation of Water Quality Standards in the Network

Both the terrestrial and aquatic environments, and the uses that can be made of them, are strongly affected by water quality. We have considered six parameters that are related to environmental concerns. They are:

- Salinity (indicated by the chloride concentration)
- Chromium (a prototype of all heavy metals)
- BOD (biochemical oxygen demand)
- Phosphate (a nutrient for algae)
- Thermal pollution (discussed in Sec. 30.4)
- GW levels

We cannot directly estimate the environmental effects of changes in chloride, chromium, BOD, and phosphate concentrations, but the effects of each have been considered at length by others in the setting of water quality standards. (See discussion in Chap. 16.) Our source for quality standards is the IMP 1975-1979 [30.1]. The IMP has provided two different standards for chromium, BOD, phosphate, and chloride; one is a provisional limit, and one the stricter target value. The provisional limits are the standards currently being enforced, and we have taken these to be our reference standards for PAWN. For each pollutant, we also look at three other standards, one stricter than the reference standard, the others more lenient (twice and three times the reference standard, respectively, except for chloride). The four standards for each pollutant are shown in Table 20.2.

For the amounts of phosphate, chromium, and BOD discharged into Dutch waters from internal and external sources, we use the reference assumption given in the rest of the scenario in Chap. 20.

Node-Decades, a Measure of Compliance. In our analysis, we used detailed runs of the DM to calculate how water management affects water quality at each of the 92 nodes of the PAWN network. For impact assessment, we developed an aggregate measure of compliance with a water quality standard that includes both the frequency and the geographic extent of the standard's violation. We partitioned the 92 nodes into two categories, provincial and nonprovincial. The nonprovincial nodes are those on the major, state-controlled waterways, such as the Rijn, the Amsterdam-Rijnkanaal, and the IJssel lakes. All other nodes are provincial nodes. At each node, we compare the calculated concentration of the pollutant with the standard in each decade and determine the number of decades with violations. We accumulate the number of decades with violations for provincial and nonprovincial nodes separately. The total score for each kind of node is the number of node-decades not meeting the standard.

For each kind of node, we compare the score with the worst possible score, which is the number of nodes in the group times the number of decades. Our measure of compliance is the number of node-decades in violation, expressed as a percentage of the worst possible score. The lower the percentage, the better.

Chromium. For the primary cases, the results for chromium are easy to describe: None of the standards is ever violated at any node.

Phosphate. The results for phosphate are shown in Table 30.13. For the provincial nodes, even the most lenient standard (3 x Reference) is violated more than 50 percent of the time, and the IMP provisional limit and target value (the two strictest standards) are violated virtually all of the time. For the nonprovincial nodes, the two more lenient standards are rarely violated, the provisional limit is violated about half the time, and the target value is almost always violated. Thus, phosphate concentrations in excess of twice the reference standard appear to be confined largely to provincial nodes.

Water management policies essentially have no effect on the degree of compliance. There is no significant difference among the six cases.

BOD. The results for BOD are shown in Table 30.14. For the provincial nodes, the two most lenient standards are violated with moderate frequency, while the stricter standards (the IMP provisional limit and target value) are violated about half the time. For the nonprovincial nodes, violations of the more lenient standards rarely occur, but the two stricter standards are violated nearly as often as at provincial nodes. Thus, very high BOD concentrations are confined for the most part to provincial nodes. As with phosphate, the cases hardly differ in their violation frequencies.

Table 30.13

PHOSPHATE STANDARD VIOLATION FREQUENCY:
PRIMARY CASES, DEX EXTERNAL SUPPLY

	Violations in Percent, by Case					
Item	A	C	D	E	F	G
Provincial nodes						
Reference x 3 = 0.9 mg/l	55	53	53	53	51	52
Reference x 2 = 0.6 mg/l	72	70	69	69	67	68
Reference x 1 = 0.3 mg/l	92	91	92	92	91	92
Target = 0.05 mg/l	98	99	99	99	99	99
Nonprovincial nodes						
Reference x 3 = 0.9 mg/l	3	5	5	5	5	5
Reference x 2 = 0.6 mg/l	7	10	10	10	10	10
Reference x 1 = 0.3 mg/l	51	51	52	52	51	52
Target = 0.05 mg/l	96	96	96	96	96	96

NOTE: Differences from the final briefing are explained in App. L.

Table 30.14

BOD STANDARD VIOLATION FREQUENCY:
PRIMARY CASES, DEX EXTERNAL SUPPLY

	Violations in Percent, by Case					
Item	A	C	D	E	F	G
Provincial nodes						
Reference x 3 = 15 mg/l	11	11	9	9	10	11
Reference x 2 = 10 mg/l	22	21	20	20	20	22
Reference x 1 = 5 mg/l	47	46	45	44	44	45
Target = 3 mg/l	73	72	70	70	71	72
Nonprovincial nodes						
Reference x 3 = 15 mg/l	1	1	1	1	1	1
Reference x 2 = 10 mg/l	5	5	4	4	4	4
Reference x 1 = 5 mg/l	38	40	39	39	40	40
Target = 3 mg/l	67	66	66	66	66	66

Chloride. The results for chloride are shown in Table 30.15. For the provincial nodes, the 200 mg/l standard (PAWN's reference standard) is violated nearly half the time. Water management policies make a significant difference in level of compliance for provincial nodes. Moving from left to right, the cases transport progressively more water from nonprovincial to provincial nodes, both because the capacity to do so has been increased by adding MAXTACS, and because the demand for water has increased (especially agricultural demand). Nonprovincial water is generally more saline, so the increase in the supply of nonprovincial water to provincial nodes results in an increase in their chloride concentration. This is seen to some degree in violations of all the standards, but is most striking for the strictest standards. For nonprovincial nodes, however, there are no differences among cases. The reference standard is violated about 70 percent of the time; the other standards, with a greater or lesser frequency depending on whether they are stricter or more lenient.

Table 30.15

CHLORIDE STANDARD VIOLATION FREQUENCY:
PRIMARY CASES, DEX EXTERNAL SUPPLY

	Violations in Percent, by Case					
Item	A	C	D	E	F	G
Provincial nodes						
Reference x 3 = 300 mg/l	21	23	24	24	26	25
Reference x 2 = 250 mg/l	30	31	32	33	37	36
Reference x 1 = 200 mg/l	35	39	42	43	47	46
Target = 150 mg/l	39	46	51	52	57	56
Nonprovincial nodes						
Reference x 3 = 300 mg/l	47	48	47	47	47	47
Reference x 2 = 250 mg/l	61	60	60	60	60	60
Reference x 1 = 200 mg/l	70	69	69	69	69	69
Target = 150 mg/l	74	73	74	74	74	73

GW Extractions. Total GW extractions for the primary cases for the DEX scenario are shown in Table 30.16. These estimates are collected from a number of sources: Agricultural extractions came from the DM; DW company extractions came from RESDM; and the estimates of industrial extractions came from IRSM.

GW extractions by industrial firms and DW companies are constant for cases A through F, as noted before. They differ only in case G when the quota is reduced to 25 percent of its value in the other cases. Agricultural extractions show a different pattern. They are nearly constant in cases A, C, D, and G, where the GW sprinkler intensity is low; significantly higher in case E, which has a medium GW sprinkler intensity; and over twice the base case value in case F, which has high GW sprinkler intensity. Total GW extractions, therefore, are the same in cases A, C, and D, increase in case E and again in F, and decline substantially in case G.

The estimates for remaining GW can be elaborated upon. In analyzing GW extractions, we took RID's estimates of "extractable amounts"--how much GW could be extracted in various provinces of the Netherlands without unduly risking serious consequences from the accompanying drop

Table 30.16

GW EXTRACTIONS IN PRIMARY CASES:
DEX EXTERNAL SUPPLY

	Extractions in mcm/yr, by Case					
Item	A	C	D	E	F	G
GW extractions						
Agricultural	275	275	278	445	625	275
DW companies	1102	1102	1102	1102	1102	250
Industrial	438	438	438	438	438	154
Total	1815	1815	1818	1985	2165	679
GW quota	2038	2038	2038	2038	2038	510
Remaining GW	223	223	220	53	-127	-169
GW quota (fraction of RID)	1.0	1.0	1.0	1.0	1.0	0.25

in the DW level--and broke them down by PAWN district and pseudo-province. This gave us many individual quotas. Our models then estimated GW extractions by district (or by pseudo-province) and compared the extractions for each case with the appropriate quota.

In cases A, C, D, and E total GW extractions are less than the aggregate quota. However, this does not mean that there is a surplus of GW in every district, or even in every pseudo-province. Some regions may be extracting their full quota of GW, and some may even be using more than the quota supposedly allows them.

We usually limited extractions to the amount of the quota. In runs where industry and DW companies have priority, they could extract all the GW they wished, up to the quota for that run; the remainder was available for agricultural extraction. In runs where agriculture had priority, it was allowed to extract the average amount of GW it would need, up to the quota for that run, and industry and DW companies were limited to extracting no more than was left. We permitted one exception to the priority scheme: Currently installed GW sprinklers continue to operate, even if their extractions cause the quota to be violated. This occurs in case G.

Case F is slightly more complex. To comply with the quotas, cutbacks in the actual GW sprinklers (that is, cutbacks from the sprinklers implied by the specified intensity) were determined on the basis of the average year. But in DEX the demand for GW sprinkling is so great that the currently installed sprinklers use sufficient GW to exceed the quotas. However, the quotas are designed to be long-term limits and, on the average, they are not exceeded. (In Chap. 31, we show that the GW quota for case F is not exceeded by the average extractions.)

30.7.2. RIN's Special Environmental Analysis

Six Special Environmental Cases. RIN analyzed some of the environmental impacts of water management. To do this, RIN defined six special cases, in consultation with PAWN, which we designate RIN1 through RIN6. These cases are defined in Table 30.17. The six cases have different external supply scenarios, sprinkling scenarios and policies, and infrastructures (RIN5 has MAXTACS, the other cases the current infrastructure). The context for all cases is 1976, the assumptions used in the rest of the scenario are the reference assumptions, and no charges are included. Unlike all other PAWN cases, the open-air GW sprinkler intensity is reduced below the specified levels if necessary to meet GW quotas in cases RIN1, RIN2, and RIN3. Such reductions apply to all open-air crops and can reduce their intensities below current levels. In all RIN cases, glasshouse crops are kept at current intensities.

Table 30.17

DEFINITION OF THE SIX SPECIAL CASES

	Case					
Item	RIN1	RIN2	RIN3	RIN4	RIN5	RIN6
External supply	1967	DEX	DEX	DEX	DEX	1967
New tactics	None	None	None	None	MAXTACS	None
GW quota	1.0	1.0	1.0	.25	.25	.25
Waterboard plans	None	None	None	All	All	All
Sprinkler intensity						
SW	Low	Low	High	High	High	High
GW (glasshouse)	Curr	Curr	Curr	Curr	Curr	Curr
GW (open air)	Low	Low	High	None	None	None

With our models, we calculated GW levels averaged over the entire year in each of 28 different areas. The 28 areas were formed by further dividing each of 17 drainage regions into "high" and "low" Highlands areas, depending on the average GW level in the years 1953-1959.

Tables 30.18 and 30.19 show the results of these calculations for the low Highlands and high Highlands areas, respectively. The GW levels are generally higher in all areas in cases RIN1 and RIN6 than in the other cases. (Higher GW levels are reflected in lower numbers because the water is closer to the surface.) These two cases have the external supply scenario of a year of average dryness (1967), which has more rain (and hence less extraction of GW for sprinkling) than the DEX scenario used in the other four RIN cases. In many areas, RIN6 has higher levels than RIN1, because the quota for GW extractions is 0.25, rather than 1.0.

Table 30.18

GW LEVELS BY DRAINAGE REGION: LOW HIGHLANDS

Region	GW Level in cm Below Surface, by RIN Case 1	2	3	4	5	6	Mean Level, 1953-59
3	62	83	83	82	81	60	71
5	88	107	111	103	103	83	67
6	114	140	154	129	129	101	81
7	55	70	70	69	69	55	47
8	73	90	90	87	87	70	69
9	69	85	87	83	83	67	68
11	90	115	144	78	78	60	82
12	81	94	102	69	69	57	74
13	74	85	91	71	71	61	84
14	89	105	110	86	85	74	82
15	96	106	112	98	97	87	87
16	129	149	161	142	142	120	78

Table 30.19

GW LEVELS BY DRAINAGE REGION: HIGH HIGHLANDS

Region	GW Level in cm Below Surface, by RIN Case 1	2	3	4	5	6	Mean Level, 1953-59
1	188	203	213	199	198	183	167
2	177	195	204	194	194	175	156
3	197	213	218	205	205	189	184
4	237	249	254	237	237	225	219
5	232	245	253	238	238	225	209
6	189	205	209	197	197	183	177
7	143	161	167	160	160	142	130
8	376	393	400	373	373	356	391
9	687	703	711	699	699	683	685
11	252	273	290	232	232	214	216
12	189	205	214	184	183	168	171
13	198	212	218	192	192	180	191
14	162	180	188	160	159	142	141
15	285	298	308	272	272	261	245
16	352	363	374	350	350	341	327
17	849	858	868	844	844	835	837

As for the other cases, in both the low and the high Highlands, RIN2 and RIN3 deplete the GW more in the Northeast Highlands (regions 5 and 6) and the Southern Highlands (regions 11, 12, 13, 14, and 15) than do RIN4 and RIN5. The latter cases have a reduced quota for GW extractions.

Finally, only in the Northeast Highlands (regions 5 and 6) does the GW level appear to drop relative to the average of the years 1953 through 1959, even in the cases with the mean level external supply (RIN1 and RIN6). One expects the levels to drop in a dry year, so this comparison is not so meaningful for the other cases. But the fact that the levels have dropped in a year of roughly average dryness suggests that there would be a long-term, persistent drop in these areas in these cases. Since RIN6, at least, extracts less GW than is extracted currently, we should be observing such a drop even now.

Nothing quantitative can be said about the environmental consequences of these changes in GW levels for nature areas. (RIN would have liked the levels on a finer geographic scale than was available from the PAWN models.) RIN proposed the mean levels from the early 1950s as GW level standards; after comparing these standards with levels in case RIN1, which approximates the current situation, RIN concluded that this standard is met in about 35 percent of the areas. RIN6 is closest to the standards, and hence must be judged most favorable, but even here the GW levels do not always meet the standards. However, many environmentalists are convinced that the levels of the 1950s will not be reached again and thus that comparing other cases with these standards is of questionable value.

RIN Water Quality Standards. RIN has proposed alternative water quality standards to those of the IMP that we gave earlier. Their standards are: for phosphate, 0.05 mg/l, the same as the IMP target level; for BOD, 5 mg/l, the same as the IMP provisional limit; for nitrate-nitrogen, 0.5 mg/l, a pollutant we did not consider earlier; for chromium (or any heavy metal), 0 mg/l; for excess temperature, 0 deg C; and for chloride, various standards depending on location (shown in Fig. 4.10 of Vol. V). The chromium standard of 0 mg/l and the excess temperature standard of 0 deg C reflect RIN's view that reductions in these pollutants are beneficial, regardless of how low the levels from which the reductions are made.

RIN has examined the six special cases, and notes the following. The phosphate standard is violated in all of the cases at virtually every node in every decade. The BOD standard in cases RIN1 and RIN6 is met at about 20 percent of the nodes. Chromium always violates its standard. The excess temperature standard is met at some nodes, but violated wherever there are heat discharges from power plants or industries. At best, the chloride standard is met in 22 percent of the PAWN districts.

RIN Assessment of MAXTACS. RIN has roughly estimated the environmental impact of each of the major technical tactics in MAXTACS. Their assessments are summarized in Table 30.20. RIN judged the tactics in terms of the scope of their effects. For example, the decreased minimum level in the IJssel lakes was judged to have "an important negative influence" because this tactic affects multiple regions. Making the Grevelingen fresh was judged to have a "very important negative influence" because its effect on migratory birds was considered international in scope.

Table 30.20

ENVIRONMENTAL IMPACTS OF MAXTACS (RIN ESTIMATES)

Tactic	Impact
New policy for flushing Markermeer	0
Decrease minimum level of IJsselmeer and Markermeer in summer by 10 cm (to NAP = 50 cm)	**
Expand Twenthekanaal route by 15 m^3/s	***
Increase throughput capacity of Van Starkenborghkanaal at Gaarkeuken to 25 m^3/s	***
Expand capacities of Zuid-Willemsvaart (section 2), Noordervaart, Kanaal Wessem-Nederweert, and Wilhelminakanaal by 5 m^3/s	***
Maintain portable pumping capacity of 5 m^3/s on the Julianakanaal at Maasbracht	0
Make the Grevelingen fresh	***
Build a pipeline from the Maas to Delfland with a capacity of 8 m^3/s	+
Construct groin in Nieuwe Waterweg	0

Impact codes:

+	Positive impact
0	No influence
*	Negative influence--affects regional values
**	Important negative influence--affects national values
***	Very important negative influence--international values

RIN Assessment of SW Projects. We used RESDM to analyze the impacts of imposing a strict quota on GW extractions, and, as one impact, RESDM selected projects for supplying additional SW to use in making DW. In Table 30.21 we show RIN's assessment of the environmental impacts of these projects, again judging the tactics by the scope of their effects. Note, however, that this assessment does not consider any beneficial effects of the higher GW level caused by a reduced quota. In the PAWN analysis, cases other than the primary cases were considered in sensitivity analyses.

30.8. SUMMARY SCORECARD

Table 30.22 summarizes the extreme impacts of the primary cases for those factors identified at the beginning of this chapter as particularly important parameters in our assessment. We feel they span

Table 30.21

ENVIRONMENTAL IMPACTS OF SW PROJECTS (RIN ESTIMATE)

	Impacts, by Case			
	Primary Cases		Sensitivity Cases(a)	
SW Project	A-F	G	M,P	Q
SBB Biesbosch	***	***	***	***
SBR Braakman	*	*	*	*
OGL Lek	*	*	*	*
DNH Duin Noord-Holland	***	***	***	
DZH Duin Zuid-Holland	***	***	***	
PLW Amsterdam	**	**	**	
GHP Heel/Panheel		*	*	
OGR Roosteren		*	*	
SLT Lettelbert	***			
SLT Twenthe	***			
SLT Maas/Waal	**			
SMA Markiezaat	**			
IVE Veluwe	**			
IGH Groot Heide	**			
OGM Maas	*			

Impact codes
(blank) Project not included in case
`*` Negative influence (regional values)
`**` Important negative influence (national values)
`***` Very important negative influence (international values)

(a) Sensitivity cases H-Q are defined in App. D. Cases H-L have the same impacts as primary cases A-F.

the range of concerns of various groups. The scorecard clearly shows that there is no dominant water management policy--one that is best for all impacts. Instead, selecting the preferred policy will depend on the relative importance that decisionmakers assign to the different impacts as they consider the effects on various sectors and groups.

We summarize our observations about the summary scorecard as follows:

- Case C, with the smallest policy changes from the current policy, has the smallest net benefits but the best environmental and public health impacts.

- Cases C and D have similar public health and environmental impacts, but implementing MAXTACS in D increases net benefits by 220 Dflm and significantly lowers the minimum IJsselmeer summer level.

- Cases D and E have similar public health and environmental impacts, but medium GW sprinkling gives E 200 Dflm more net benefits while taking more GW.

Table 30.22

SUMMARY SCORECARD: PRIMARY CASES, DEX EXTERNAL SUPPLY

Item	Effects, by Case				
	C	D	E	F	G
Dutch net benefits (Dflm)	■ 865.0	▨ 1080.4	▨ 1270.1	☐ 2074.0	▨ 1296.2
Minimum summer lake level (cm)	☐ -37	▨ -45	▨ -47	■ -49	■ -49
Percent GW in DW	☐ 77	☐ 77	☐ 77	☐ 77	■ 16
Pollution (% violation frequency)					
BOD					
Provincial nodes	46	45	44	44	45
Nonprovincial nodes	40	39	39	40	40
Total phosphate					
Provincial nodes	91	92	92	91	92
Nonprovincial nodes	51	52	52	51	52
Chloride					
Provincial nodes	☐ 39	▨ 42	▨ 43	■ 47	■ 46
Nonprovincial nodes	69	69	69	69	69
GW extraction (mcm/yr)	▨ 1815	▨ 1818	▨ 1985	■ 2165	☐ 679
DW projects (number)	☐ 6	☐ 6	☐ 6	☐ 6	■ 18
MAXTACS (env. impacts)	☐ NO	■ YES	■ YES	■ YES	■ YES

Rankings: ☐ Best ▨ Intermediate ■ Worst

NOTE: Differences from the final briefing are explained in App. L.

- Case F has the highest net benefits, but also the highest GW extraction and the worst minimum IJsselmeer summer level.

- Case G, designed to provide maximum protection for the environment, has the second highest net benefits--because of the high SW sprinkling. However, it also entails by far the worst public health effects (percent of GW in DW) and the largest adverse environmental impacts from constructing DW projects.

Of course, it is not intended that a policy decision be made solely from these extreme impacts. Rather, in combination with the average impacts given in the next chapter, they are intended to give each decisionmaker an idea of the range of impact magnitudes that might result from each policy so as to enable him to factor into his decision whatever degree of risk aversion he deems appropriate.

NOTES

1. In preparing the Nota Waterhuishouding, the Dutch extended the approach by splitting up the benefits for a sector into two parts, the first resulting from the growth of the sector, and the second from water management tactics needed for other sectors.

2. The results would be different had we rerun the complete analysis with a grass multiplier of 1. In such an analysis, the optimal sprinkler intensities would have been recomputed, resulting in fewer sprinklers in both the high and medium sprinkler scenarios. With fewer sprinklers, the cases would have more crop damage and hence smaller benefits for a multiplier of 1 than we have calculated. This qualification applies whenever we present results for a multiplier of 1.

   In making our calculations, we did not recompute the sprinkler intensities but merely recalculated the benefits using a crop price scenario with a multiplier of 1.

3. We realize that GW from different locations has different quality, as does SW (e.g., Maas water is much less saline than Rijn water), and that our proxy measure of quality is therefore quite crude. However, to calculate more sophisticated measures would have required a separate, complex study.

4. In economics terminology, we assumed a demand elasticity of -1.0 and a supply elasticity of 10.0.

5. Similar procedures were used in allocating the increased DW costs for the commercial firms among the owners, customers, and competitors of those firms and among the Dutch and foreign governments. The contribution of the commercial sector to the Dutch share of net benefits and to the monetary benefits accruing to the Dutch government is shown later in this chapter. Volume X discusses the full allocation of benefits for the commercial sector.

Chapter 31

AVERAGE IMPACTS OF THE PRIMARY CASES

31.1. INTRODUCTION

This chapter considers the average annual impacts of water management policies embodied in the primary cases. As explained in Chap. 5, these are approximated by the impacts in the 1943 external supply scenario. We will discuss financial impacts on agriculture, shipping, power plants, and industrial firms and DW companies; then we will present environmental impacts and the summary scorecard. We also consider two additional topics: the total economic impacts of major infrastructure investments and the ultimate monetary effects of the primary cases on typical Dutch households. As in Chap. 30, where table entries differ from those in the final PAWN briefing, the differences are explained in App. L.

31.2. AGRICULTURE

The average net agricultural benefits of the primary cases are only about 17 percent of the benefits in an extremely dry year, but they are still significant. (Recall that as net benefits to the agricultural sector they do not reflect the 56.4 Dflm annual cost of MAXTACS, an expenditure by the national government affecting many sectors.) The benefits are shown in Table 31.1. Dutch benefits of 154 Dflm result from the implementation of waterboard plans and a medium level of surface water (SW) sprinklers in case C. An additional 39 Dflm of Dutch benefits are possible in case D by implementing MAXTACS, which helps alleviate the problem of too much salt in water sprinkled on glasshouse crops. High sprinkler intensities in cases F and G produce large benefits; benefits are slightly lower in case G because groundwater (GW) sprinkler intensities are low. However, the benefit difference is partially made up by the aid agriculture receives from low GW extraction by industry and drinking-water (DW) companies.

Dutch net benefits make up about 97 percent of total benefits in each of the primary cases. Dutch government benefits are about 39 percent of that total. Dutch consumer benefits are small because the changes in crop prices are small.

As in the DEX external supply scenario, a major portion of the net benefits come from grass--about 70 percent of the benefits in case C, and 60 percent in the other cases. If the grass multiplier is set to 1 in the benefit calculations, Dutch net benefits drop significantly; however, the benefits are still positive.[1]

Another way to test the sensitivity of the benefit results to assumptions regarding grass is to leave grass sprinkling at its current level. This implies that benefits on current grass production will be

Table 31.1

TOTAL AND DISTRIBUTED ANNUAL BENEFITS FROM THE AGRICULTURAL SECTOR: PRIMARY CASES, 1943 EXTERNAL SUPPLY

	Impacts in Dflm/yr, by Case				
Item	C	D	E	F	G
Gross benefits					
Grass	195	203	249	446	372
Non-grass	98	137	160	239	204
Sprinkling cost					
Variable cost	-56	-60	-78	-154	-109
Fixed cost	-58	-58	-77	-140	-103
Waterboard plan costs	-22	-22	-22	-22	-22
Net benefits	157	200	232	369	342
Net benefits, grass mult. of 1	59	98	107	145	154
Division of net benefits					
Dutch					
Producer	89	111	131	210	193
Consumer	5	7	8	12	11
Government	60	75	87	138	129
Total	154	193	226	360	333
Total Dutch, grass mult. of 1	56	91	101	137	147
Total Dutch, w/o new grass	44	78	90	131	119
Foreign					
Producer	-22	-38	-40	-52	-50
Consumer	42	73	76	99	96
Government	-17	-28	-29	-38	-37
Total	3	7	7	9	9

NOTES: Differences from the final briefing are explained in App. L. The annual cost of MAXTACS is not included.

retained but no benefits will be gained from increased production. When we restrict grass sprinkling in this way, the resulting net benefits are only slightly lower than the benefits that occur when we set the multiplier to 1. However, this simple procedure, which involved no DM runs, may underestimate monetary benefits. It is possible that in new runs, water previously used by grass might be used productively elsewhere, thereby adding benefits.

The case rankings are identical when we ignore the benefits of new grass sprinkling and when we use a grass multiplier of 2: F is first, G is second. When the multiplier is set to 1, the top two cases switch rankings, but their benefits remain very close.

Except for grass and open-air vegetables, average net benefits for the primary cases are relatively low for all crops, as can be seen in Table 31.2. Glasshouse crops benefit in cases D through G from the implementation of MAXTACS. Increased sprinkling of consumption potatoes and trees yields respectable net benefits.

Table 31.2

BENEFITS FROM AGRICULTURE BY CROP:
PRIMARY CASES, 1943 EXTERNAL SUPPLY

	Impacts in Dflm/yr, by Case				
Crop Type	C	D	E	F	G
Grass	110	115	136	229	214
Consumption potatoes	11	11	12	17	17
Milling potatoes	2	3	7	12	9
Seed potatoes	2	2	3	5	4
Sugar beets	4	4	6	9	6
Cereals	4	4	6	9	7
Cut corn	2	2	2	3	3
Bulbs	2	2	2	3	3
Vegetables, open air	32	33	34	48	48
Fruits	4	4	4	5	5
Trees	9	9	10	20	17
Vegetables, under glass	-1	15	15	14	15
Flowers, under glass	-1	18	17	17	16
Subtotal	179	222	254	391	364
Waterboard plan costs	-22	-22	-22	-22	-22
Total	157	200	232	369	342

Table 31.3 shows net agricultural benefits by pseudo-province in the 1943 external supply scenario. The regional distribution of benefits is similar to that achieved in the extremely dry year (see Table 30.4).

Table 31.3

BENEFITS FROM AGRICULTURE BY PSEUDO-PROVINCE:
PRIMARY CASES, 1943 EXTERNAL SUPPLY

	Impacts in Dflm/yr, by Case				
Item	C	D	E	F	G
Groningen	8	8	9	17	21
Friesland	34	34	40	74	70
Drenthe	5	10	19	35	20
Overijssel	24	23	25	34	34
Gelderland	6	6	16	25	11
Utrecht	3	3	3	5	5
Flevoland	9	9	9	14	15
Noord-Holland	3	3	3	5	6
Zuid-Holland	3	38	38	43	48
Zeeland	-	1	1	1	1
Noord-Brabant	55	57	60	101	96
Limburg	7	8	9	15	15
Total	157	200	232	369	342

We summarize the primary case average impacts for agriculture as follows:

- Grass accounts for 60 to 70 percent of net benefits in each case.
- Setting the grass multiplier to 1 cuts benefits by about 75 percent, but the net benefits remain positive for all cases.
- The largest increase in benefits is for grass and open-air vegetables.
- The Dutch government gets 40 percent of net benefits in each case.

31.3. SHIPPING

The impacts on shipping are shown in Table 31.4. The table shows total losses for the base case (A), and net benefits (relative to case A) for all other cases. When we compare these results with those from the DEX supply scenario (Table 30.5), we see the following differences:

- Total shipping losses have fallen to 7 percent of actual variable costs, most of which do not vary with policy.
- The change in shipping losses is less than 1 percent of base case losses and less than 0.1 percent of base case variable costs.
- Some policies which damaged shipping in an extremely dry year benefit it in a moderately dry year, and thus are beneficial on average.
- Highlands lock-delay losses have become almost negligible.

All costs and differences observed in the primary cases under the DEX scenario have been considerably reduced. The policies have very little effect on shipping costs, one way or the other. This is somewhat surprising, because 1943 was not a good year for shipping. In a ranking of years in terms of potential shipping losses, 1943 would be the eighth driest year since 1930 (thus a 17 percent year). Still, water levels are much higher than in DEX.

As in the DEX scenario, the cases have no effect on the size of the long-run fleet proxy because the proxy value does not depend on scenario. (The proxy is determined by a specific Rijn flow and decade, so it depends only on the water management policy.)

We summarize the primary case impacts for shipping as follows:

- The average value of all losses is greatly reduced from their extremes in DEX.
- Policies have little effect on average shipping costs.
- Policies have no effect on average size of long-run shipping fleet.

Table 31.4

BENEFITS FOR SHIPPING: PRIMARY CASES,
1943 EXTERNAL SUPPLY

	Benefits and Costs in Dflm/yr					
	Costs	Benefits Relative to Case A				
Item	A	C	D	E	F	G
Total variable shipping losses						
Low-water losses	-113.02	-0.04	0.62	0.58	0.42	0.25
Highlands lock-delay losses	-0.12	-0.10	0.03	0.03	0.04	0.04
Dredging costs	-0.12	0.09	0.12	0.12	0.06	0.12
Total	-113.26	-0.05	0.77	0.73	0.52	0.41
Dutch variable shipping losses						
Low-water losses	-70.07	-0.02	0.38	0.36	0.26	0.16
Highlands lock-delay losses	-0.08	-0.07	0.02	0.02	0.02	0.02
Dredging costs	-0.12	0.12	0.12	0.12	0.06	0.12
Total	-70.27	0.06	0.52	0.50	0.34	0.30
Long-run fleet proxy annualized fixed cost						
Total fleet	-2862.1	0.2	0.2	0.2	0.0	0.0
Dutch fleet	-1758.1	0.1	0.1	0.1	0.0	0.0

NOTE: Differences from the final briefing are explained in App. L.

31.4. POWER PLANTS

The penalty costs of imposing thermal standards were calculated for these cases using the EPRAC model described in Chap. 9. The penalties depend primarily on the strictness of the standards (3 deg on rivers and 7 deg on canals, or 3 deg everywhere), but were less dependent on the water management policies. Thus, the penalty costs were much the same for cases A, C, D, E, F, and G (the 1943 cases).

The results are shown in Table 31.5. When a standard of 3 deg was imposed on rivers, and 7 deg on canals, the DEX cases suffered a penalty of roughly 20 Dflm. For the 1943 cases, with their higher river flows, the penalty dropped to 3 to 5 Dflm/yr. In all cases, most of the penalty resulted from the need to curtail power generation at the very efficient Amer plant (on the Maas near Geertruidenberg), and substitute power generated at less efficient plants elsewhere. Since the Amer plant is on a river, its heat discharge was always constrained by the 3-deg standard.

Table 31.5

PENALTY COSTS FROM IMPOSING THERMAL STANDARDS:
PRIMARY CASES, 1943 EXTERNAL SUPPLY

Standards for River/Canal	Impacts in Dflm/yr, by Case					
	A	C	D	E	F	G
3-deg/7-deg	-3.2	-4.6	-4.4	-4.5	-4.8	-3.8
3-deg/3-deg	-20.6	-23.5	-22.0	-22.0	-22.1	-21.0

When the 3-deg standard was applied to canals as well as to rivers, the penalty costs rose. In these cases, the penalty costs became 20 to 24 Dflm/yr, about 17 to 19 Dflm larger than with the 7-deg standard applied to canals. The rise from the cases with a 7-deg canal standard was due almost entirely to the need to curtail power generation at the Velsen plant on the Noordzeekanaal. (The DEX penalties were about 25 Dflm larger.)

We summarize the primary case impacts for power plants as follows:

- Stricter standards increase average penalties about 18 Dflm/yr.
- Average penalties are 25 Dflm/yr lower than the extreme penalties in DEX because of higher river flows.

31.5. INDUSTRIAL FIRMS AND DW COMPANIES AND THEIR CUSTOMERS

The impacts on industrial firms and on DW companies and their customers are independent of the external supply scenario because GW extractions remain the same, as explained in Sec. 31.7.2 below. Hence, the impacts for the 1943 external supply scenario are identical to those reported in the previous chapter for DEX.

31.6. SUMMARY OF MONETARY BENEFITS

Table 31.6 summarizes the average monetary effects associated with the primary cases. It differs from Table 30.12, which contains the extreme monetary effects, in the following ways:

- Average benefits to agriculture are much smaller: 150 to 360 Dflm/yr in contrast to 890 to 2150 Dflm/yr in DEX.
- Other impacts are small or unchanged, so net Dutch benefits are reduced by the full amount of the decrease in agricultural benefits.

Table 31.6

SUMMARY OF DUTCH BENEFITS: PRIMARY CASES,
1943 EXTERNAL SUPPLY

Item	Impacts in Dflm/yr, by Case				
	C	D	E	F	G
Dutch share					
MAXTACS	--	-56.4	-56.4	-56.4	-56.4
Agriculture	153.5	193.2	225.7	360.5	330.1
Shipping	0.1(a)	0.5	0.5	0.3	0.3
Thermal penalty	-2.9	-1.4	-1.4	-1.6	-0.4
Industry	--	--	--	--	-240.0
Households	--	--	--	--	-306.0
Commercial	--	--	--	--	-218.0
DW companies	--	--	--	--	249.0
Total	150.6	136.0	168.4	302.9	-238.4
Total, grass mult. of 1	53.1	33.8	43.7	79.4	-421.5
Dutch government					
MAXTACS	--	-56.4	-56.4	-56.4	-56.4
Agriculture	58.8	74.6	87.0	138.2	128.6
Shipping	0.1	0.3	0.3	0.2	0.2
Thermal penalty	--	--	--	--	--
Industry	--	--	--	--	-89.0
Households	--	--	--	--	--
Commercial	--	--	--	--	-80.0
DW companies	--	--	--	--	249.0
Total	58.9	18.5	30.9	82.0	152.4

NOTES: Components may not add to total due to rounding. Differences from the final briefing are explained in App. L.

(a) Less than 0.05 Dflm.

- Setting the grass multiplier to 1 reduces net Dutch benefits by 75 to 85 percent. (In DEX, setting it at 1 reduced benefits by only 35 to 40 percent.) Nevertheless, the average net benefits are positive for cases C through F.
- For case G, designed for environmental protection, the average effects are large losses, over 200 Dflm/yr with a grass multiplier of 2 and 400 Dflm/yr with the multiplier set to 1. These losses result from the large cost increases that the GW quota causes for industrial firms, commercial entities, and households.

31.7. ENVIRONMENT

31.7.1. Violations of Water Quality Standards in the Network

Going from the DEX external supply scenario to the wetter 1943 scenario makes no significant difference in the frequency of violations for chromium or phosphate. BOD shows a slight increase in violations of the strictest standard, because when there is more water in the Rijn, the residence time of BOD in river sections is reduced, and hence there is less BOD decay. Chloride violations decrease in the wetter year, except for the strictest standard at nonprovincial nodes. The decreases are caused by the increased rainfall, which dilutes water everywhere and makes it unnecessary to use as much Rijn water for sprinkling in many areas. The nonprovincial nodes have such high flows through them that rain cannot significantly dilute the water there; hence, not much change in violations is observed.

31.7.2. GW Extractions

GW extractions for the primary cases in the 1943 external supply scenario are shown in Table 31.7. Many of the entries in this table are identical to those for the DEX scenario in Table 30.18; only the agricultural extractions and the estimates of remaining GW differ.

Average industrial and DW company extractions of GW are not sensitive to the external supply scenario for three reasons: (1) there is sufficient GW available for all users (cases A, C, and D); (2) firms and DW companies are given priority over farmers and, hence, can use all they desire at all times (cases E and F); or (3) agriculture is given priority but the amount of GW allocated to firms and DW companies is based on the average anticipated use by farmers and does not change with the actual amount of rain and SW available (case G).

In terms of average extractions, the RID quotas allow sufficient GW for all users in every case but G. In case G the quotas are cut back to only 25 percent of their values in the other cases, thus severely restricting industrial firms and DW companies. Farmers are always allowed sufficient GW to supply their current level of sprinkling, so they are affected less and total GW extractions exceed the quotas.

Table 31.7

GW EXTRACTIONS IN PRIMARY CASES:
1943 EXTERNAL SUPPLY

	Extractions in mcm/yr, by Case					
Item	A	C	D	E	F	G
GW extractions						
Agricultural	167	167	167	272	379	164
DW companies	1102	1102	1102	1102	1102	250
Industrial	438	438	438	438	438	154
Total	1707	1707	1707	1812	1919	568
GW quota	2038	2038	2038	2038	2038	510
Remaining GW	331	331	331	226	119	-58
GW quota (fraction of RID)	1.0	1.0	1.0	1.0	1.0	0.25

31.8. SUMMARY SCORECARD

Table 31.8 contains the summary scorecard for the 1943 external supply scenario. These results are of interest because they represent the "average" impacts of the water management policies.

Policy C, with waterboard plans and medium sprinkler intensity, always dominates policy D, which adds MAXTACS. When the grass multiplier is set to 1, C also dominates policy E, which adds medium GW sprinkler intensity to D.

Policy F, with waterboard plans, MAXTACS, and high SW and GW sprinkler intensity, always yields 100 Dflm/yr greater expected net benefits than policies C, D, and E; but it extracts 150 to 250 mcm/yr more GW.

Table 31.8

SUMMARY SCORECARD: PRIMARY CASES,
1943 EXTERNAL SUPPLY

	Effects, by Case				
Item	C	D	E	F	G
Dutch net benefits (Dflm)	150.6	136.0	168.4	302.9	-238.4
Minimum summer lake level (cm)	-20	-23	-23	-25	-25
Percent GW in DW	77	77	77	77	16
Pollution (% violation frequency)					
BOD					
Provincial nodes	45	46	46	45	46
Nonprovincial nodes	49	49	49	49	49
Total phosphate					
Provincial nodes	90	90	90	90	90
Nonprovincial nodes	55	54	54	54	54
Chloride					
Provincial nodes	27	27	27	28	28
Nonprovincial nodes	54	54	54	54	54
GW extraction (mcm/yr)	1707	1707	1812	1919	568
DW projects (number)	6	6	6	6	18
MAXTACS (env. impacts)	NO	YES	YES	YES	YES

Rankings: □ Best ▨ Intermediate ■ Worst

NOTE: Differences from the final briefing are explained in App. L.

Policy G, which reduces GW sprinklers to the current level and GW extractions to 0.25 of the current quota, was intended to improve the environment. It reduces GW extractions by 1100 mcm/yr, but:

1. It always entails an expected net loss of more than 200 Dflm/yr (more than 400 Dflm/yr with the grass multiplier set at 1).
2. It jeopardizes public health by reducing the percentage of GW in DW from 77 percent to 16 percent.
3. It entails a much larger negative environmental impact from the construction of many more SW projects.

The policies produce little difference in the minimum summer IJsselmeer level. Of course, its average (1943) value is substantially higher than the extreme (DEX).

All policies fail to improve the average water quality. Compared with the extreme values, average chloride violations are significantly lower everywhere, whereas BOD violations are somewhat higher at nonprovincial nodes.[2]

31.9. TOTAL ECONOMIC IMPACT OF MAJOR INFRASTRUCTURE INVESTMENTS

Thus far our discussion has concentrated on the long-run (annual) impacts of the PAWN cases, but there may also be some important short-term effects. In particular, we investigated the full economic effects associated with the implementation of MAXTACS.

These tactics represent major investments of money within the Netherlands and will usually require some domestically produced industrial outputs, some direct employment of labor, and some imports from other nations. They will also induce a number of indirect or secondary effects. The sum of the direct and indirect effects might easily stress available resources, especially if the projects require specialized inputs or are located in remote regions of the country.

We considered two types of short-term effects:

- Changes in the industrial sector--changes in production, imports, wage payments, and employment.
- Changes in governmental receipts from the value-added, business-profits, and personal-income taxes.

Appendix E contains a complete discussion of our findings. Here we present only a brief summary.

31.9.1. Impacts on the Private Economy

None of the projects evaluated here has impacts large enough to stress the Dutch economy, although, of course, some local shortages may occur. Even if all of the projects were implemented at the same time, and if they all incurred peak expenditures in the same year, they would increase national production by less than 0.1 percent in that year. Imports and employment would be affected even less.

The Maas-Delfland pipeline has the most substantial impacts; it is responsible for nearly half of the total effects we have computed. We estimate that it would employ over 1600 workers in its peak (third) year of construction; therefore, it could stress the economies of the regions in which it was located. However, it would probably draw workers and supplies from throughout the Netherlands, and in relation to the national economy, its effects would be small.

31.9.2. Effects on the Government

The government spends money to finance the construction of the projects, but it also receives some of that money back. A value-added tax is charged on all items produced in the Netherlands, including those purchased by the government. And wages and business profits are taxed at rather high rates. We estimated the net financial impact on the government by subtracting the estimated receipts from these three types of taxes from the actual investment expenditures.

We find that the peak-year cost of all of the projects taken together would be about 177 Dflm, plus 31 Dflm for the value-added tax. From the three tax sources listed above, the government would get back about 25 percent of that amount--about 50 Dflm. The net cost to the government would thus be about 155 Dflm.

In summary, we find that construction of all of the major PAWN projects concurrently might produce slight dislocations in a few industries or in small regions of the Netherlands, but the total economic impact on the country would be small.

31.10. MONETARY EFFECTS ON HOUSEHOLDS

Ultimately, the burdens or benefits that result from water management policies will fall on individual Dutch families. For this reason, we considered the long-term monetary effects the primary cases would have on the household budgets of average farm and nonfarm families. These estimates represent the true net domestic effects of the policies. A more complete overview of this work is given in App. F; full details can be found in Vol. X. We present both qualitative and quantitative findings.

First, because the Netherlands is a small country that produces, consumes, and trades a large number of different products with its neighboring nations, but has little control over the prices of those products, it will retain most of the benefits (and costs) of water management policies implemented within its borders. Shipping benefits are an obvious exception: Projects that lower shipping costs bring substantial benefits (equivalent to about half the Dutch benefits) to foreign carriers and also to the foreign owners and consumers of the products that are carried.

Second, domestic price changes are trivial for most internationally traded products and for products whose prices are controlled or supported by governmental agencies. Policies affecting the supply of those products will have little effect on household budgets.

Third, efficiency pricing, in the form of marginal-cost prices for DW and GW, will initially affect the production sectors where they are applied. Their ultimate effects on household budgets depend crucially on the tax assumptions. If the surpluses earned by DW companies charging marginal-cost prices are used to offset personal taxes, imposing efficiency pricing will benefit average- and low-income households. If the surpluses are used to offset business taxes, most of the benefits would be diverted to higher-income households.

Finally, the primary water management policies would benefit mainly farm households, and mainly those in Friesland, Drenthe, and Noord-Brabant. The average-income farm household in those provinces would probably benefit by more than 200 Dfl/yr; benefits accruing to most other farm households would be perhaps half that size. Benefits, if any, to most nonfarm households would be trivial, perhaps negative. Low-income households would probably be affected slightly less in absolute terms than average-income households.

Limitations on GW extractions may benefit the environment or future generations but they lower current monetary benefits. Severe restrictions impose high costs on most groups except farmers.

We are confident that the patterns of benefits described above are correct. Although the benefits are relatively small, their actual size depends strongly on the use of the grass multiplier and on the taxes selected to finance or to be subsidized by the projects. Furthermore, the benefits in an extremely dry year would be larger than in the average one, and more biased in favor of farmers.

NOTES

1. The results would be different had we rerun the complete analysis with a grass multiplier of 1. In such an analysis, the optimal sprinkler intensities would have been recomputed, resulting in fewer sprinklers in both the high and medium sprinkler scenarios.

With fewer sprinklers, the cases would have more crop damage and hence smaller benefits for a multiplier of 1 than we have calculated. This qualification applies whenever we present results for a multiplier of 1.

In making our calculations, we did not recompute the sprinkler intensities but merely recalculated the benefits using a crop price scenario with a multiplier of 1.

2. The remaining concentrations are quite similar to their extreme counterparts. This is a consequence of the assumption we made about foreign sources of pollution in the future context, which, as discussed in Sec. 20.5.6, we believe to be quite reasonable.

Chapter 32

SENSITIVITY CASE IMPACTS

32.1. INTRODUCTION

The primary cases used in impact assessment were selected to provide a wide range of impacts, both in the aggregate and in distribution among users and regions. In addition to these primary cases, we conducted a number of sensitivity studies to investigate the effect of:

- Different managerial strategies
- Increasing surface water (SW) sprinkling
- Increasing groundwater (GW) sprinkling
- Changing the GW extraction quota, priority, and charges
- Decreasing the Rijn BOD load
- Increasing the Rijn salt load

In this chapter, we discuss the effect of altering the managerial strategy, the Rijn BOD load, and the Rijn salt load. We summarize analyses of changing the GW quota, priority, and charges, and of changing sprinkler intensities and priorities. These topics are covered in more detail in Apps. G, H, and I.[1] For readers desiring further details, additional impact tables are grouped in App. K.

32.2. EFFECTS OF MANAGERIAL STRATEGY

We used runs of the DM to compare the effects of three alternative managerial strategies:

- RWS strategy: Used in screening, this is our modification of the current Dutch practice. It incorporates the new policy for flushing the Markermeer. (The RWS strategy is defined more fully in Chap. 22.)
- The SIMPLE MSDM strategy: This differs from the RWS strategy by trading off shipping losses due to low water on the IJssel for decreased salt damage to agriculture due to the Rotterdam salt wedge, and by drawing cooling water for the Noordzeekanaal power plants from the IJssel lakes instead of from the Waal at Tiel. (The SIMPLE MSDM strategy and its differences from the full MSDM strategy are defined in Chap. 26.)
- The Velsen strategy: This differs from the RWS strategy by drawing more cooling water for the Noordzeekanaal power plants from the IJssel lakes than from the Waal or Neder-Rijn. (The Velsen strategy is defined in Chap. 26.)

As implemented in the DM, all three strategies are intended to cool the Noordzeekanaal power plants only to meet a 7-deg standard, which is the current requirement.

Table 32.1 defines the cases designed to test the effects of the alternative management strategies. Table 32.2 shows the results of the comparison.

Table 32.1

DEFINITION OF CASES FOR EFFECT OF MANAGERIAL STRATEGIES

	Cases					
Item	A	B	J	H	F	K
Managerial strategy	RWS	MSDM	VEL	RWS	MSDM	VEL
Waterboard plans	No	No	No	Yes	Yes	Yes
MAXTACS	No	No	No	Yes	Yes	Yes
SW sprinklers	Low	Low	Low	Hi	Hi	Hi
GW sprinklers	Low	Low	Low	Hi	Hi	Hi
GW extraction quota	1.0	1.0	1.0	1.0	1.0	1.0
GW priority above current sprinklers	-	-	-	I/D	I/D	I/D
GW charge on IND and AGR (Dfl)	0	0	0	0	0	0
Rijn salt dump	Ref	Ref	Ref	Ref	Ref	Ref
External pollution	Ref	Ref	Ref	Ref	Ref	Ref

NOTE: I/D = industry/DW companies; IND = industry; AGR = agriculture. MSDM indicates the SIMPLE MSDM strategy.

Table 32.2 compares the average (1943 scenario) and the extreme (DEX scenario) effects of the three strategies with both the current infrastructure and sprinkling scenario, and with the MAXTACS infrastructure and maximum sprinkling scenario. When we compare the cases with the current infrastructure and sprinkler scenario (cases A, B, and J), the RWS strategy appears to be the best of the three, because of an unintended difference between the strategies: The RWS strategy sent an average of about 5 m^3/s more cooling water past the Velsen power plant than did the other two strategies. Since we have imposed a 3-deg thermal standard everywhere in these cases, the additional cost of generating electric power under the other strategies more than cancels the benefits to other sectors. If a 3-deg standard had not been imposed at IJmuiden (recalling that the strategies were implemented in the DM to meet a 7-deg, not a 3-deg, standard), or if all the strategies had been adjusted to cool Velsen with the same amount of water, the SIMPLE MSDM and VEL strategies would have had average net benefits of approximately 0.5 Dflm/yr more than the RWS strategy. Under the DEX scenario, both SIMPLE MSDM and VEL are preferable to RWS, and become moreso if the amounts of water for cooling Velsen are equalized among the three strategies.

Table 32.2

EFFECT OF MANAGERIAL STRATEGIES IN 1943 AND IN DEX EXTERNAL SUPPLY SCENARIOS

	Effect, by Case					
Managerial Strategy	A (RWS)	B (MSDM)	J (VEL)	H (RWS)	F (MSDM)	K (VEL)
Dutch Net Benefits (Dflm/yr), 1943 External Supply						
MAXTACS	--	--	--	-56.4	-56.4	-56.4
Agriculture	--	0.3	0.2	360.5	360.5	360.5
Shipping	--	0.1	0.4	0.2	0.3	0.3
Thermal (a)	--	-2.0	-1.8	0.4	-1.6	-1.4
Total	0.0	-1.6	-1.2	304.7	302.9	303.0
Dutch Net Benefits (Dflm/yr), DEX External Supply						
MAXTACS	--	--	--	-56.4	-56.4	-56.4
Agriculture	--	7.2	4.0	2154.0	2148.0	2150.0
Shipping	--	1.9	5.6	-10.2	-12.7	-12.5
Thermal (a)	--	-4.5	-3.7	-0.7	-5.0	-4.0
Total	0.0	4.8	5.9	2086.7	2074.0	2077.4
Minimum Summer Lake Level (cm relative to NAP)						
1943 external supply	-20	-21	-20	-24	-25	-24
DEX external supply	-31	-35	-32	-50	-49	-49

NOTE: Compared with the final briefing, Dutch net benefits in cases H, F, and K have dropped nearly 7 Dflm, primarily because of the increased cost of MAXTACS.

(a) In these cases, we have imposed a 3-deg standard on excess temperature. If the standard were 7 deg, the thermal benefits would be essentially zero.

The SIMPLE MSDM and VEL strategies give essentially identical results in both the 1943 and DEX external supply scenarios. VEL sent more water past Velsen than did SIMPLE MSDM, so the thermal penalty under VEL is smaller. SIMPLE MSDM appears to have favored agriculture, and VEL shipping.

We now turn to a comparison of the strategies in the cases with the MAXTACS infrastructure and maximum sprinkling scenario (cases H, F, and K). In terms of average (1943) net benefits, except for the differences in the cooling of Velsen, both SIMPLE MSDM and VEL are slightly preferable to RWS, and equal to each other. In the DEX scenario, both SIMPLE MSDM and VEL appear to be worse for agriculture and shipping than RWS. The reason for this is that both VEL and SIMPLE MSDM pull water from the IJssel lakes to cool the Noordzeekanaal power plants. This practice draws the lakes down to their minimum level, and large cutbacks in sprinkling are necessary. However, it is risky to compare policies when this happens because PAWN did not analyze the question of what to do when lake levels reach their minima.

The external supply scenario is the most significant determinant of Dutch net benefits under alternative strategies. Although benefits are very large in the extremely dry year, they are small on average: Most of the time, there is ample water available for all users, of all priority classes. The salt wedge rarely intrudes as far as the mouth of the Hollandsche IJssel. The Rijn flow is usually large enough to minimize shipping costs. The lakes are ordinarily at or near their target (maximum) levels, as can be seen from the bottom section of Table 32.2. In fact, there is usually a need to discharge water from the lakes to prevent them from rising above their target levels. This excess water might as well be used to cool power plants or flush the boezems of North Holland. Thus, the DM estimates the SIMPLE MSDM strategy to be an improvement over current practice only a small fraction of the time.

As is usual in studies of this nature, estimates of costs and benefits are likely to be uncertain. The monetary differences between strategies that we quote here rely on numerous assumptions and approximations made throughout the study. It appears, however, that the SIMPLE MSDM strategy is sufficiently promising to merit further investigation, especially if more of the components of the full MSDM strategy are incorporated.

32.3. EFFECTS OF SPRINKLER INTENSITY AND PRIORITY ON AGRICULTURE

In Apps. H and I we detail the separate effects on agricultural benefits of increasing the intensity of GW and SW sprinklers. Here we summarize the combined effects of increasing both sets of sprinklers and, simultaneously, changing the GW extraction priority.

Figure 32.1 illustrates the effects of sprinkler intensity on net agricultural benefits. Sprinkler intensity is measured along the horizontal axis, increasing from left to right. Note that the low intensity does not include waterboard plans or MAXTACS, corresponding to the current situation, while the other intensities do. We show both the average (1943) and the extreme (DEX) effects of increasing SW sprinklers only and of increasing both SW and GW sprinklers. But we show only the extreme effects of changing GW priority from industry and DW companies to agriculture.

The curves in Fig. 32.1 indicate that increased sprinkling has enormous effects on agricultural net benefits in an extremely dry year and much smaller, though perhaps still significant, average effects. For example, increasing only SW sprinkling to high intensity from current levels nets about 1900 Dflm/yr in benefits in DEX, and 350 Dflm/yr in 1943. Adding GW sprinklers also has a major impact on benefits, though less than adding SW sprinklers. With high intensity and industry/DW company priority, adding GW sprinklers produces nearly 300 Dflm/yr in agricultural net benefits in DEX, but less than 50 Dflm/yr in 1943. If agriculture has priority the increase is greater; in that case, in DEX, increasing both GW and SW sprinkling produces nearly 600 Dflm/yr more than when only SW sprinkling is increased.

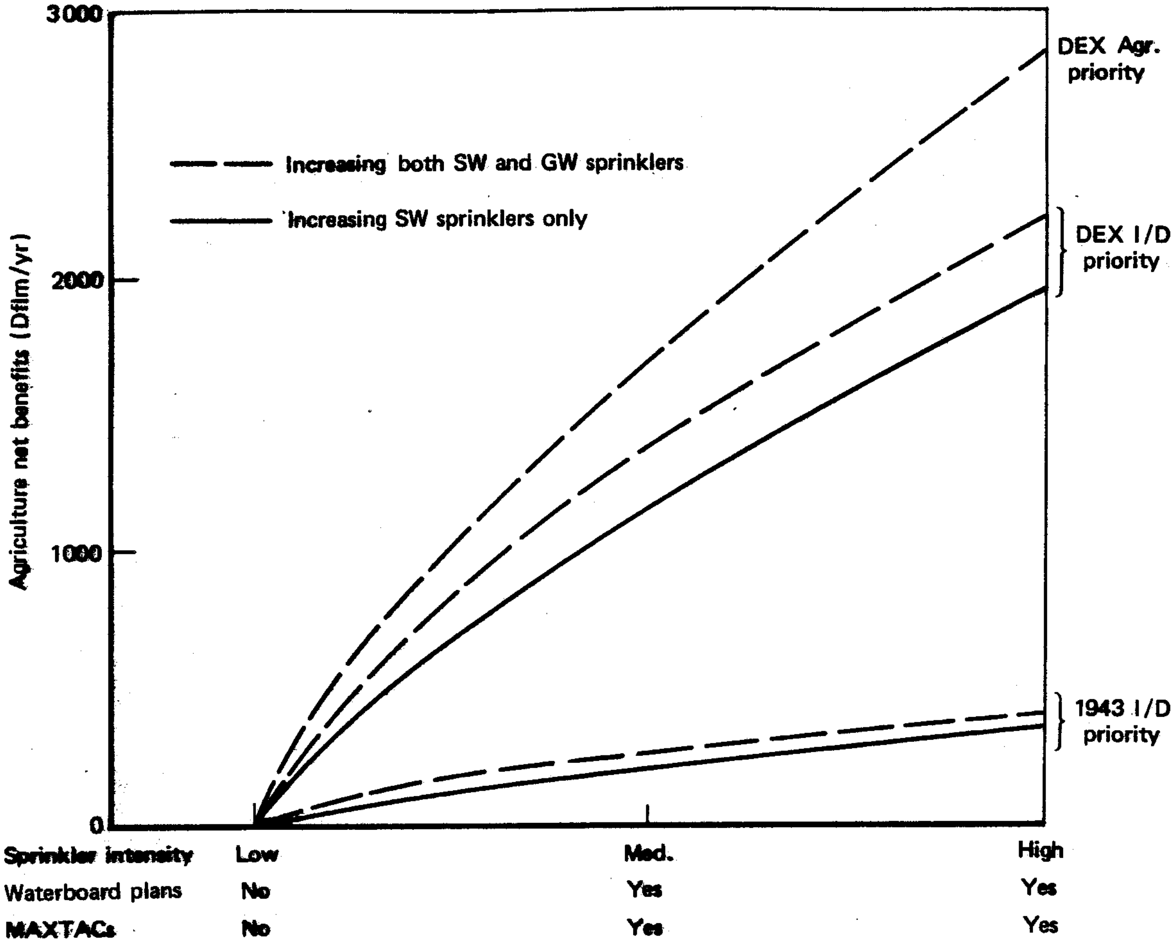


Fig. 32.1--Effect of sprinkler intensity on agricultural net benefits

The agricultural benefits of increased GW sprinkling come at the cost of increased agricultural GW extractions, which threaten nature preserves and the long-run supply of GW. To complement Fig. 32.1, Fig. 32.2 shows the corresponding GW extractions. Regardless of the intensity, by far the largest extractions occur in DEX when agriculture has GW priority, and the smallest in 1943 with industrial/DW company priority. Significantly, the average extractions with agricultural priority are similar to the extractions in an extremely dry year with industrial/DW company priority.

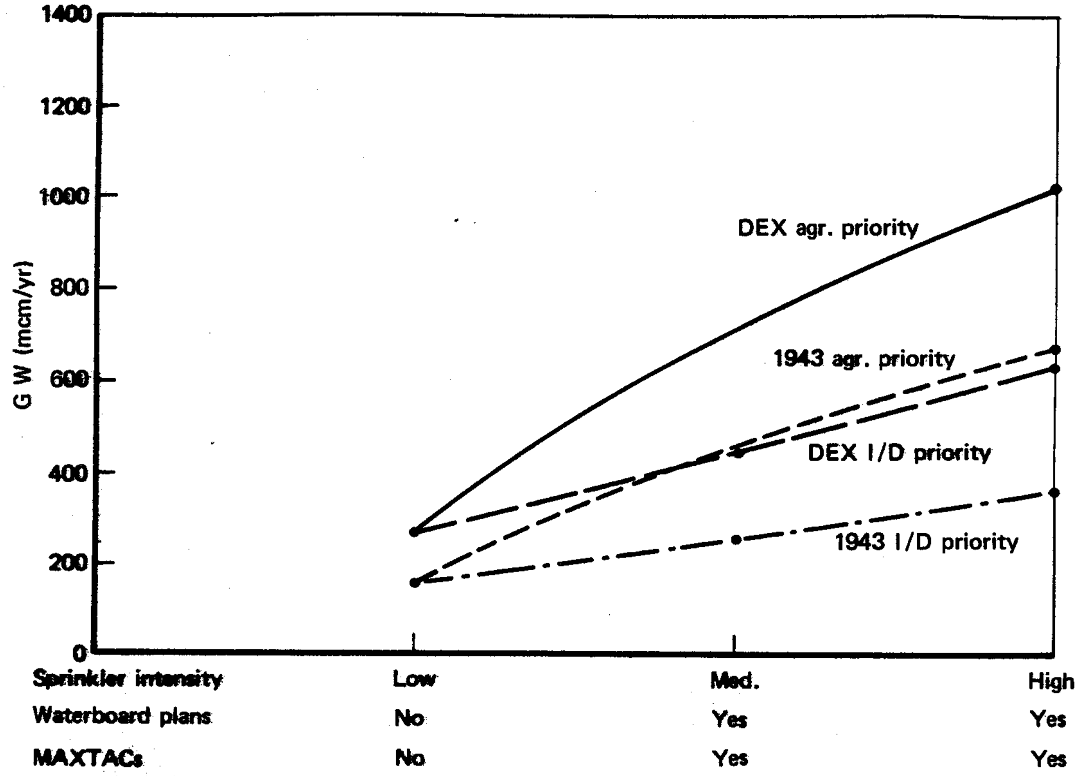


Fig. 32.2--Agricultural GW extractions

32.4. EFFECT OF GW QUOTA, PRIORITY, AND CHARGES

In this section we summarize the effects of three policy variables relating to GW: extraction quota, priority, and use charge. To do so we use six impact assessment cases; they are defined in Table 32.3. The cases differ in the following ways:

- GW sprinklers: Level is high except in case G, where it is low.
- GW extraction quota: Usually 1.0. In case G it is 0.25; in case Q it is 1.5.
- Extraction charge for GW: No charge except in cases M and L, where it is 0.20 Dfl/m^3. (This is an arbitrarily imposed tax, not a shadow price used to induce optimal allocation of GW.)
- Priority for GW: Agriculture has priority in cases G, P, and M. Industry and DW companies have priority in cases F, L, and Q.

Table 32.3

DEFINITION OF CASES FOR EFFECT OF GW QUOTA, PRIORITY, AND CHARGES

	Cases					
Item	G	P	F	M	L	Q
Managerial strategy	MSDM	MSDM	MSDM	MSDM	MSDM	MSDM
Waterboard plans	Yes	Yes	Yes	Yes	Yes	Yes
MAXTACS	Yes	Yes	Yes	Yes	Yes	Yes
SW sprinklers	Hi	Hi	Hi	Hi	Hi	Hi
GW sprinklers	Low	Hi	Hi	Hi	Hi	Hi
GW extraction quota	.25	1.0	1.0	1.0	1.0	1.5
GW priority above current sprinklers	AGR	AGR	I/D	AGR	I/D	I/D
GW charge on IND and AGR (Dfl)	0	0	0	.20	.20	0
Rijn salt dump	Ref	Ref	Ref	Ref	Ref	Ref
External pollution	Ref	Ref	Ref	Ref	Ref	Ref

NOTE: I/D = industry/DW companies; IND = industry; AGR = agriculture. MSDM indicates the SIMPLE MSDM strategy.

Changes in policy variables relating to the cost of and priority for GW extractions have a large impact on Dutch benefits in an extremely dry year. The average impacts are smaller but still impressive. Table 32.4 summarizes the impacts for DEX. (The 1943 scorecard and discussions of financial impacts arising in the agricultural, DW, and industrial sectors are contained in App. G.)

As expected, case G, with a low level of GW sprinkling, yields the smallest Dutch benefits. Increasing the GW quota to 1.0 and increasing the sprinkling level to high substantially increases benefits. Benefits increase by over 1300 Dflm/yr when agriculture has GW priority (case P) and by considerably less, about 780 Dflm/yr, when priority is shifted to industry and DW companies (case F) because fewer new GW sprinklers are permitted than implied by the specified intensity. The imposition of GW charges in case L as opposed to case F lowers Dutch benefits by 164 Dflm/yr; because the charge makes sprinkling more expensive, farmers consider fewer sprinklers to be optimal. A comparison of cases P and M, which also differ only by the imposition of a GW charge, shows much lower benefits in the case with the charge (case M) for the same reason; benefits are 366 Dflm/yr lower although the Dutch government's share drops less than 50 Dflm/yr. In case Q, where the GW quota is 1.5, benefits increase more than 330 Dflm/yr over case F, where the quota is 1.0, because the higher quota permits many more GW sprinklers.

The minimum summer lake level is not affected by these cases. And there are hardly any differences in the percent of pollution violations except for chloride at provincial nodes, where there are small differences. This is mainly because changes in GW extractions produce only moderate changes in the amount of basic drainage into the SW system.

Table 32.4

EFFECT OF GW QUOTA, PRIORITY, AND CHARGES:
DEX EXTERNAL SUPPLY

Item	Effect, by Case					
	G	P	F	M	L	Q
Dutch net benefits (Dflm)	1296.2	2609.4	2074.0	2243.4	1910.4	2407.5
Min. summer lake level (cm)	-49	-49	-49	-49	-49	-49
Percent GW in DW	16	74	77	75	77	87
Pollution (% violations)						
BOD						
Provincial nodes	45	45	44	46	45	45
Nonprovincial nodes	40	40	40	40	40	40
Total phosphate						
Provincial nodes	92	89	91	90	90	89
Nonprovincial nodes	52	50	51	51	51	50
Chloride						
Provincial nodes	46	52	47	50	47	49
Nonprovincial nodes	69	69	69	69	69	70
GW extractions (mcm/yr)	679	2576	2165	2115	1904	2626
DW projects (number)	18	8	6	8	6	3
MAXTACS (env. impacts)	YES	YES	YES	YES	YES	YES

NOTE: Compared with the final briefing, Dutch net benefits have dropped in all cases by 6 to 7 Dflm due primarily to the increased cost of MAXTACS. GW extractions are now based on IRSM rather than on RESDM estimates of industrial GW use.

We again use the percentage of GW in DW as a proxy for DW quality and the susceptibility of DW supply to interruptions. Case G, as we have seen before, is the difficult case. When the GW quota is cut to 25 percent of its usual value, SW use by DW companies nearly quadruples to make up the large deficit. The percentage of GW in DW drops substantially in all provinces. In the other cases the situation is less severe, but the composition of DW is still less than ideal. In the cases with a 1.0 quota, only the low-lying western provinces of Noord- and Zuid-Holland and Zeeland need to use SW in their DW production. But, as noted before, these three provinces contain over 40 percent of the total population, and they consume a correspondingly large portion of total DW, so the national average makeup of DW contains about 25 percent SW in these cases. When the GW quota is increased to 1.5, the nationwide percentage of GW in DW increases to more than 85 percent.

GW extractions depend on the allowed extractions (the quota), the priority, and the presence of GW charges. The charge is particularly significant when agriculture has priority: Extractions fall by more than

400 mcm/yr in moving from case P to case M. This is because the increased sprinkling costs produced by the charge considerably reduce the number of GW sprinklers that farmers consider optimal, even though with priority they can effectively have as many as they want.

We saw above that financial benefits were over 500 Dflm/yr greater in case P than in case F. But now we see that the negative environmental impacts associated with cases P and M are significantly larger than those associated with cases F and L. The two groups of cases are nearly the same for lake level, percentage of GW in DW, and pollution violations. But GW extractions are significantly greater in case P, and both it and case M require two additional SW projects. Agricultural priority on GW means not only greater overall GW extractions, but also more new projects for producing DW to meet the increased industrial demands.

Case F would require a total of six SW projects: the Biesbosch and Braakman reservoirs, dune infiltration in both Noord- and Zuid-Holland, water that has infiltrated through the banks of the Lek, and the special water collection system for Amsterdam. Case L would require virtually the same projects and capacities. Case M would require those plus water from the Roosteren; and case P would also require water from the Heel/Panheel project. Case G, where GW extractions are reduced sharply, is entirely different; it would require all 18 projects. Case Q, on the other hand, has almost an excess of GW. Only three SW projects would be required, and the major one, the Biesbosch reservoir, is needed only because RESDM requires it (see Sec. 25.4.3).

32.5. EFFECT OF CHANGING RIJN BOD

We considered the effect of reducing the BOD load in the Rijn in two cases. Case F is described in Table 32.1; case T differs from it only in that the BOD load in the Rijn has been reduced fivefold from the reference load to a "low" load of 2 mg/l, to reflect the possible effect of German or French cleanup programs. Regardless of the external supply (we ran cases for the extremely dry year DEX and for the extremely wet year 1967), BOD violations were reduced significantly at provincial nodes, and spectacularly at nonprovincial nodes. Violations of the reference standard (IMP provisional limit of 5 mg/l), for example, were reduced in frequency from 40 to 30 percent at provincial nodes, and from 40 percent (or more in the wet year) to less than 10 percent at nonprovincial nodes (See Table 32.5).

32.6. EFFECT OF CHANGING RIJN SALT LOAD

Here we present a series of five cases in which we examine the effect of increasing the salt load in the Rijn. This increase can be interpreted as a failure to implement a treaty by 1985 under which the French would agree to reduce the amount of salt dumped into the Rijn from their potash mines in Alsace. Table 32.6 defines the cases. The first, case A, is the base case for all comparisons. In the next two, B and R, the

Table 32.5

EFFECT OF CHANGING RIJN BOD FOR DEX AND 1967 EXTERNAL SUPPLY

	Effects, by Case			
	DEX		1967	
Item	F	T	F	T
Dutch net benefits (Dflm)	2074.0	2074.0	-56.7	-56.7
Minimum summer lake level (cm)	-49	-49	-20	-20
Percent GW in DW	77	77	77	77
Pollution (% violation frequency)				
BOD				
Provincial nodes	44	34	41	32
Nonprovincial nodes	40	9	58	6
Total phosphate				
Provincial nodes	91	90	87	87
Nonprovincial nodes	51	51	55	55
Chloride				
Provincial nodes	47	47	15	15
Nonprovincial nodes	69	69	16	16
GW extraction (mcm/yr)	2165	2165	1777	1777
DW projects (number)	6	6	6	6
MAXTACS (Env. impacts)	YES	YES	YES	YES

NOTE: Compared with the final briefing, Dutch net benefits have dropped in all cases by 6 to 7 Dflm due primarily to the increased cost of MAXTACS. GW extractions are now based on IRSM rather than on RESDM estimates of industrial GW use.

infrastructure and sprinkling are at their current levels. The cases differ only in that one uses the reference salt load in the Rijn (311 kg/sec: case B) while the other uses the high salt load (365 kg/sec: case R). The final two cases, F and S, use the MAXTACS infrastructure and high sprinkling demand. Again, one (case F) uses the reference Rijn salt load, and the other (case S) the high salt load. All cases except the base use the SIMPLE MSDM managerial strategy.

32.6.1. Impacts on Water Quality Standards

To find a conservative lower bound on the improvements in salt concentration that the treaty might bring, we examine the cases for the extremely dry year (DEX) when there would be the least water to dilute the salt. As can be seen in Table 32.7, going from the reference to the high salt load makes little difference at provincial nodes (compare B with R, and F with S), but it makes a large difference at nonprovincial

Table 32.6

DEFINITION OF CASES FOR EFFECT OF CHANGING RIJN SALT LOAD

	Case				
Item	A	B	R	F	S
Managerial strategy	RWS	MSDM	MSDM	MSDM	MSDM
Waterboard plans	No	No	No	Yes	Yes
MAXTACS	No	No	No	Yes	Yes
SW sprinklers	Low	Low	Low	Hi	Hi
GW sprinklers	Low	Low	Low	Hi	Hi
GW extraction quota	1.0	1.0	1.0	1.0	1.0
GW priority above current sprinklers	-	-	-	I/D	I/D
GW charge on IND and AGR (Dfl)	0	0	0	0	0
Rijn salt dump	Ref	Ref	Hi	Ref	Hi
External pollution	Ref	Ref	Ref	Ref	Ref

NOTE: I/D = industry/DW companies; IND = industry; AGR = agriculture. MSDM indicates the SIMPLE MSDM strategy.

Table 32.7

SALT STANDARD VIOLATION FREQUENCY FOR CASES SHOWING EFFECT OF RIJN SALT TREATY IN DEX SCENARIO

	Violations in Percent, by Case			
Item	B	R	F	S
Provincial nodes				
Reference x 3 = 300 mg/l	21	25	26	32
Reference x 2 = 250 mg/l	29	30	37	41
Reference x 1 = 200 mg/l	35	36	47	50
Target = 150 mg/l	39	40	57	59
Nonprovincial nodes				
Reference x 3 = 300 mg/l	46	55	47	57
Reference x 2 = 250 mg/l	60	65	60	65
Reference x 1 = 200 mg/l	69	71	69	71
Target = 150 mg/l	73	74	74	75

nodes. This is because many nonprovincial nodes are on the Rijn, or receive most of their water from the Rijn. On the other hand, as we saw earlier, increasing the sprinkling demand and improving the infrastructure causes a significant increase in chloride violations at provincial nodes, but little difference at nonprovincial nodes (compare B with F, and R with S).

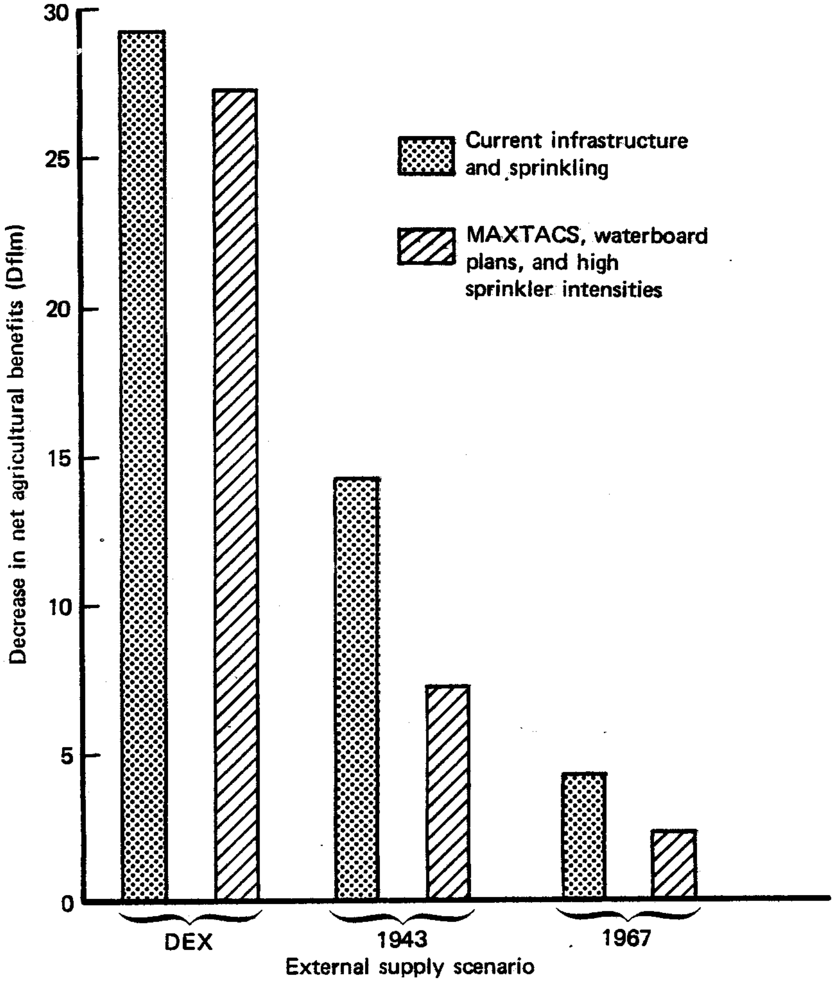


Fig. 32.3--Decrease in Dutch net agricultural benefits caused by increasing Rijn salt load from reference to high

32.6.2. Impacts on Monetary Benefits

The increased salt in the Rijn has economic consequences, especially for farmers, since Rijn water is used to supply salt-sensitive glasshouse crops in the Midwest and elsewhere. In the extremely dry year, the lack of a treaty costs the Netherlands about 30 Dflm in lost benefits, essentially all of it lost by agriculture, regardless of the infrastructure and sprinkler scenario. The average (1943) agriculture losses are smaller: about 14.7 Dflm/yr with the current infrastructure and sprinkling, decreasing to about 7.1 Dflm/yr with the maximum expansion of infrastructure and sprinkling. (Impact tables for these cases are contained in App. K.)

The magnitude of the losses depends on both the external supply scenario and the water management tactics we investigate. As one would expect, increasing the salt concentration in the Rijn increases agricultural damage, thereby reducing agricultural net benefits. This can be seen in Fig. 32.3, in which the decrease in Dutch net benefits is displayed for each of the above pairs of cases under three external supply scenarios. In the DEX external supply, expansion of the infrastructure and sprinkling do little to alter the decrease in benefits; it remains nearly 30 Dflm/yr. (The effect is minimal because the pipeline from the Biesbosch to Delfland contained in MAXTACS is forced to carry Rijn water in extremely dry years, since Maas water, which has much lower salinity, is unavailable; delivering high-salinity water to the extremely valuable glasshouse crops in Delfland produces large losses from salt damage.) In contrast, under the 1943 (moderately dry) and 1967 (extremely wet) external supply scenarios, these expansions halve the losses of benefits, mainly because the pipeline is carrying low-salinity Maas water. In all circumstances, the decrease in benefits is nearly all explained by a change in glasshouse crop benefits.

NOTE

1. A final sensitivity study concerning the effects of managerial strategy, sprinkling scenario, GW quota, and GW priority on shipping costs was found to produce only small impacts. That analysis is summarized in App. J.

Chapter 33

CONSEQUENCES OF PAWN

PAWN accomplished its tasks successfully. First, it defined the scope of the problem, identified the key parameters, and then developed a methodology for assessing the multiple impacts of water management policies. Second, it applied the methodology to design alternative water management policies for the Netherlands and to assess and compare their impacts. Finally, it created a Dutch capability for further such analyses by training Dutch analysts and by documenting and transferring methodology developed at Rand to the Netherlands.[1] Indeed, Dutch analysts, trained in PAWN, have used the PAWN methodology for considerable additional analysis[2] in support of the Nota Waterhuishouding (the new national policy document on water management) and for several additional studies as well.

Because this volume already has a summary, we will not attempt to summarize PAWN's substantive results here. Rather, we will summarize the consequences of PAWN for the Netherlands' national water management policy contained in the Nota and for the general field of policy analysis.

33.1. CONSEQUENCES FOR THE DUTCH NATIONAL WATER MANAGEMENT POLICY

Unlike many analyses, PAWN did not conclude by recommending a particular alternative. Rather, it compared the alternatives in terms of their many impacts, but left the choice to the Dutch political process, where the responsibility properly resides.

The RWS combined some of the PAWN results with the results of its own additional analysis to draft its Nota Waterhuishouding, the new national policy document on water management. This policy document--scheduled for publication in mid-1983, after extensive review and consultation with other government ministries, the provinces, and local waterboards--provides a new water management policy for the Netherlands. Although the policy presented in the Nota specifies a number of actions, it provides only guidelines for dealing with certain issues and defers or delegates some decisions entirely. Most of the policy components adopted or recommended in the Nota arose from the PAWN analysis or the additional RWS analysis done with the PAWN methodology. In this section we will attempt to identify these components and indicate their genesis.[3]

33.1.1. Policy Components Adopted

In the Nota, several existing components of the national water management policy were changed, and several new ones were adopted.

First, with the exception of the Merwedekanaal expansion, no major new national water management infrastructure will be built by the RWS.[4] This decision was based on the PAWN results that showed that the upper bound on the expected benefits for such tactics was generally less than their fixed costs. Many of them had investment costs of several hundred million guilders. The decision to expand the Merwedekanaal, which is relatively inexpensive, was based largely on the PAWN screening results.

Second, the new policy for flushing the Markermeer, developed in PAWN, has already been implemented. Its expected annual benefits of between 0.7 and 2.5 Dflm per year should alone repay the costs of the PAWN study in less than a generation.

Third, a new policy for flushing the Zoommeer, once its construction is complete, has been adopted. (The policy is to flush the Zoommeer with no more than 100 m^3/s as long as salt intrusion in the Hollandsche IJssel is not occurring. The particular flushing rate will be chosen on the basis of ongoing research on its environmental effects in the Oosterschelde and Westerschelde.) The new policy is based on analysis by the RWS using the PAWN methodology, although the general question was investigated in PAWN's screening analysis.

Fourth, a new rule for extractions at Tiel has been implemented. PAWN demonstrated that it was unnecessary to extract large amounts of water at Tiel. The RWS then used the DM to make additional calculations and develop the details of the new policy.

Fifth, the RWS had adopted a policy permitting dredging below Tiel, but requiring that special precautions be taken to minimize the risk of shipping accidents and that special types of dredging vessels be used. The implementation decision about when and how to dredge was left to the RWS Directorate of Upper Rivers.

Finally, a thermal standard of 3 deg C has been adopted for canals. (Besides being more stringent, this standard also differs from the current law by specifying that the excess temperature must be measured after a suitable "mixing zone.") This decision was based largely upon the fact that PAWN showed that the cost of the more stringent standard was considerably less than had been feared, and that redistributing the generating load was sufficient to meet even the more stringent standard under future levels of demand.

33.1.2. Policy Components Recommended

The Nota presents recommendations on a number of policy components. For all but the first recommendation mentioned below, the ultimate decisions would be made in the provincial or local water management planning process. This posture is consistent with the philosophy of decentralization decisionmaking that has been the cornerstone of Dutch governance since the Netherlands was founded with the original union of seven provinces. When provincial or local governments decide to implement one of these tactics, they are responsible for part of its cost, with the central government paying part through subsidies or some other mechanism of cost sharing.

First, the RWS recommended that the increase in the summer target level of the IJsselmeer and Markermeer found promising by the PAWN screening analysis be deferred until it became clear whether substantial growth in surface water (SW) sprinkling was occurring. If substantial growth was occurring, as anticipated in PAWN, then the level increase would be adopted (unless recently begun research concludes that there would be significant adverse consequences for nature).

Second, the 46 waterboard plans that survived PAWN screening analysis, plus a few others that the RWS considered attractive from a groundwater (GW) perspective, were recommended for consideration by the provinces. The decision and implementation was left to local planning, where it should be possible to more closely examine possible effects on nature preserves and other local issues.

Third, a number of regional technical and managerial tactics were recommended. Many of these were identical with those identified as promising in the PAWN screening analysis. However, some were different, either because of a modification of the design or because the additional analysis by the RWS reached a somewhat different conclusion. Here the decision and implementation were left to the provinces.[5]

Fourth, the RWS has recommended a slight variation on the tactic that uses portable pumps during periods of low flows on the Julianakanaal to recycle water at the Maasbracht lock. The PAWN screening analysis found that tactic promising with portable pumps rather than a permanent pumping station. However, the RWS has found that it is possible to put a new permanent pumping station in an existing structure, and thereby get greater pumping capacity than the portable pumps would provide at nearly the same cost. Although the tactic is slightly modified, its recommendation is based on the PAWN analysis.

Fifth, to deal with diminishing GW supplies and falling GW levels, the RWS has recommended quotas to limit agricultural extractions of GW. This recommendation is based in part on an RWS analysis of the effect of extractions on future GW levels, using the PAWN models. (Although not based on it, the recommendation is consistent with the PAWN finding that, from the standpoint of the nation, it is more beneficial to give priority for extracting GW to industry and DW companies if their demands are expected to increase significantly and if agricultural demand for GW is expected to become much higher.) The recommendation does not specify the exact amounts of the quotas to apply in different areas, but rather leaves this determination to the provincial planning process.

Sixth, the RWS implicitly recommended a regional approach to pollution problems. This appears to be based on the PAWN finding that "dilution is no solution to pollution"; that is, no national policy to redistribute the water will appreciably improve water quality nationwide, although there might be highly localized changes.

Finally, in addition to the recommendation above, the RWS explicitly recommended a regional approach to eutrophication. The RWS recommended adding complementary tactics to the current national policy of phosphate control, which it plans to continue. As recommended by PAWN, the combination of tactics would be tailored to each individual lake, and would be chosen on the basis of analysis with the PAWN/WABASIM eutrophication methodology and experimental testing.

33.2. CONSEQUENCES FOR THE FIELD OF POLICY ANALYSIS

Besides the consequences mentioned above, PAWN produced models, techniques, and a case study example that can be useful for policy analysis not only in other locations, but in other policy problems as well.

The PAWN volumes provide a thoroughly documented case study for government officials, engineers, regional planners, and others in fields outside water resource and environmental analysis who wish to learn how a policy analysis of complex natural resource and environmental questions can be carried out. Moreover, for specialists in these fields, it introduces an operational methodology that is more comprehensive than others and that employs several useful new models and techniques.

For some PAWN models such as the DM, only the general approach and concepts can be used in other locations because their logical structure is specific to the Netherlands. But many PAWN models can be transferred to other locations with appropriate changes to their databases and, sometimes, minor modifications in structure. Such models include EPRAC, IRSM, RESDM, and various agricultural and eutrophication models.

One of the useful new techniques introduced by PAWN is the measure of compliance for the violation of water quality standards. This measure, which could be applied to other kinds of environmental standards as well, is particularly valuable because it integrates the frequency and geographic extent of the standard's violation into a compact and easily understood metric.

Another innovation introduced by PAWN is the use of goal programming to design minimum-cost strategies, both short-run and long-run, that satisfy environmental standards and various other constraints.[6] (Goal programming is a branch of mathematical programming concerned with finding the combination of variables that minimizes an objective function subject to constraints, where the constraints or the components of the objective function represent different goals.) In PAWN, and elsewhere, this technique is a powerful and efficient way to design "optimal" strategies when the strategy has many possible ingredients and when the multiple goals are mostly nonmonetizable and incommensurate. Thus, MSDM finds the mix of (short-run) managerial tactics that minimizes the relevant costs and economic losses while satisfying constraints in the form of different water quality standards, requirements, and limits on lake levels. And RESDM finds the most economically efficient mix of long-run responses by industrial firms and DW companies while satisfying constraints reflecting the permissible amount of GW extractions (quotas), capacity of DW company reservoirs, and provincial DW demands.

But PAWN has relevance beyond water resource and environmental analysis. For those concerned generally with the analysis of public policy decisions, either as producers or consumers, it offers a comprehensive description of the approach and results of a study that contributed directly and substantially to the making of a major public policy design.

Several techniques and features of the approach should be useful in a wide range of policy problems. First, the distinction between policy, strategy, and tactics, and among the four kinds of tactics (technical, managerial, pricing, and regulation), is helpful when dealing with alternatives that are numerous and diverse.

Second, the criterion that the set of impact measures chosen should span the full range of objectives held by different interest groups, and reflect both equity and efficiency considerations, is important when dealing with problems with complex physical and social effects; so also is the related criterion that the impact measures are best expressed in natural physical units, which are not always monetary.

Third, the "insurance viewpoint," which separates monetary costs and benefits into annual fixed cost and annual net benefits, is a powerful and natural way of dealing with time-streams of random costs and benefits.

Fourth, the technique we employed to estimate upper and lower bounds on the expected annual net benefits is very cost-effective in comparison with the common technique of running many cases so as to be able to calculate a reasonably accurate average value.

Fifth, diagrams like the PAWN system diagram that divide the problem into parts and show their interrelations are valuable aids for designing, managing, and explaining the research.

Sixth, when considering policies that are implemented by different levels of government and by different private institutions, and impacts that are experienced by widely different groups, it is essential to employ a methodology such as we have developed for distributing the monetary benefits and costs calculated in the different sectors among producers, consumers, and the government. Otherwise some benefits or costs may be neglected and others double-counted.

Seventh, the stages of analysis (screening, policy design, impact assessment) afford an effective way to deal with the curse of dimensionality by performing explicit hierarchical design and evaluation of alternatives. Screening usually works best by applying classical cost-effectiveness analysis; policy design by using goal programming in combination with considerable art; and impact assessment by considering a set of cases that span the range of promising tactics and provide a varying mix of impacts.

Eighth, in impact assessment it is important to pay attention to different attitudes toward risk. We found that comparing the average impacts from a set of policies with the extreme values that would occur in extremely rare circumstances gives the decisionmakers an idea of the range of annual impacts that might result from a policy and allows them to factor into their decision whatever degree of risk aversion they wish.

Ninth, rather than combining the various impacts into a single measure of performance, which may lose information and substitute the analysts' values for those of the decisionmakers, the scorecard technique provides an effective method for comparison of cases and decisionmaking. (It can sometimes also be useful in screening.)

Finally, rather than concentrating on the aggregate impacts to society as practically all other studies do, the PAWN approach gives equal attention to distributional impacts, which consider the uneven distribution of impacts among different groups or locations. In this way it can treat the objectives of many groups and reflect equity as well as efficiency considerations.

Despite these useful techniques and features, PAWN's greatest value may be as a case study for training new analysts and for designing new studies. Few, if any, studies have been undertaken of comparable breadth and complexity. Few studies have been as successful in terms of having their methodology institutionalized for national and regional planning and their substantive results incorporated in a new national policy. And, to our knowledge, no study of comparable complexity has been more carefully and thoroughly documented.

NOTES

1. In PAWN, and in the two previous policy analysis projects Rand conducted with the RWS--POLANO [33.1], which was concerned with alternatives to protect the Oosterschelde from floods, and BARCON [33.2], which was concerned with storm-surge barrier control strategies--an explicit goal was to help the Dutch learn policy analysis and help them establish policy analysis institutions in the Netherlands. The primary way of helping them learn policy analysis was by conducting joint research projects. Considering all three joint research projects, about two dozen Dutchmen received intensive training for a year or more, and nearly another dozen received extensive part-time training.

Although most of them have remained with the RWS or DHL, some have gone on to policy analysis positions in the Ministry of Health and Environment, the Ministry of Internal Affairs, the Ministry of Finance, the province of Noord-Holland, and the municipalities of Amsterdam and Dordrecht. One has been appointed as first professor of policy analysis in the Netherlands.

A policy analysis department for the entire RWS has been established, with the Dutchman who did his Ph.D. work at the Rand Graduate Institute as its first head; moreover, a systems management department, with a major policy analysis function, was established in the Delta Service of the RWS. At DHL, a systems analysis department for water management has been established, with a Dutchman who was in residence at Rand for 18 months working on PAWN as its deputy head; and a mathematical biology department was founded with the primary task of performing and extending the WABASIM (water basin modeling). Finally, a quasi-independent policy analysis institute (SIBAS) has been formed to serve the entire Dutch government, with the Dutchman who led the Dutch part of the POLANO project as its first director.

2. The research supporting the Nota is described in a Dutch language report called "the White Nota" [33.3]. Emphasizing methodology, this report summarizes all the research for the Nota, whether done with Rand or in the additional analysis by the Dutch. It details all the Dutch calculations and the relevant Rand calculations for the policy results in the Nota.

3. This chapter is being written after most, but not all, of the review and consultation on the Nota has taken place. Thus it is conceivable that the components we identify may be treated somewhat differently in the final published Nota.

4. The Nota raises but leaves open the question of whether the Grevelingen should remain salt or become fresh, as was found to be promising in the PAWN analysis. The second Oostvaardersdijk was ruled out as a water management tactic in the Nota. If the Markerwaard is done, that will be reconsidered. The official policy of the Dutch Cabinet is that the Markerwaard will be done when the money becomes available.

5. When the RWS knows which regional tactics and waterboard plans have been chosen for implementation, they plan to use the PAWN methodology to investigate the potential effects on the national system. A recent investigation assumed all the recommended waterboard plans and regional tactics were implemented; it concluded that, from a national perspective, there appeared to be enough SW.

6. A similar approach was used by several of the authors in the early 1970s. Although the formulation was similar, the earlier approach used heuristic search rather than mathematical programming to find the least costly strategy subject to various

air quality standards. (See Refs. 33.1 and 33.2.) We know of no comparable applications of goal programming, although mathematical programming has been used for years to select short-run strategies for operating a network of reservoirs and long-run strategies for picking a mix of capital investment projects.

REFERENCES

33.1. Goeller, B. F., et al., San Diego Clean Air Project: Summary Report, The Rand Corporation, R-1362-SD, 1973.

33.2. Mikolowsky, W. T., J. H. Bigelow, B. F. Goeller, and J. K. Ives, A Tradeoff Model for Selecting and Evaluating Regional Air Quality Control Strategies, The Rand Corporation, R-1367-SD, December 1973.

33.3. Pulles, J. W., et al., Een beleidanalyse voor de Waterhuishouding van Nederland (PAWN), Rijkswaterstaat, 1983.