Internationale Kommission zum Schutz des Rheins
Commission Internationale pour la Protection du Rhin
Internationale Commissie ter Bescherming van de Rijn

Survey of phosphorous and nitrate inputs 1996

Koblenz, November 2000

Contents

1. Introduction

High concentrations of the nutrients phosphorous and nitrogen may cause increased algae growth in standing as well as slowly flowing inland waters (lakes, dams, backwater reaches) as well as the sea.

In 1988, the considerable nutrient inputs to the North Sea resulted in great algae layers in the southern North Sea. The overfertilization phenomena of the 1980s induced the countries bordering the North Sea and the ICPR to reduce nitrogen and phosphorous inputs by 50 % each by 1995 compared to 1985.

A first survey of diffuse nutrient inputs published in 1992 was retroactively drafted for the reference year 1985.

With a view to assessing perfomances against targets and to preparing eventual supplementary measures it was necessary to take stock of the diffuse nutrient inputs in 1996 and to elaborate a more precise analysis of the quantity and the most important pathways of these inputs. Thus, an overall balance was stricken of all point source discharges of urban and industrial origin and of the most important non point source inputs.

To compare the order of magnitude of the inputs of 1985 and 1996, further to the extension of the Dutch convention area fixed by the new Rhine convention and due to the reviewed classification of the pathways to be quantified, the 1985 inputs were re-estimated.

2. Survey methods and comparability of results

Basically, the survey of diffuse nutrient inputs 1996 followed the same guidelines as that of 1985.

However, for the present survey, the choice of pathways was adjusted to the findings of the survey of diffuse priority substances 1996 (heavy metals and lindane). Annex 1, Firgure 14 gives an overview over the distribution of pathways serving as a basis for surveys and the relationship existing between the different pathways. The extension of the Dutch convention area under the new Rhine convention is part of the adjustment. While the old Dutch Rhine catchment area and thus the area covered by the old nutrient survey was limited by the sphere of influence of the tidal zone (see Annex 2, Figure 15), the new Dutch convention area is limited by the coastal zone. The technical terms used in the present report are defined in Annex 3.

Methods of estimating diffuse inputs

The diffuse nitrogen and phosphorous inputs into water bodies were quantified with the aid of the mean nutrient concentrations in the considered nutrient pathways (e.g. precipitation, drainage and groundwater, soil, farm manure, leaks of silage liquor) as well as with that of the data on soil use figuring in official statistics. The estimate of input was among others derived from test results (erosion measurements, run-off experiments, measurements of discharge and concentrations in defined running waters), taking into account the main factors influencing nutrient inputs (e.g. nutrient balance, soil use, topography).

As convened, not only the mere non point sources were quantified, but also scattered small point sources of pollution, as domestic sewage treatment plants, road runoff, farm yards etc. which are point sources of nutrient discharges to water bodies. Due to lacking data, leaking sewers and damaged domestic connections have only partly been taken into account.

The approach to the quantification of nutrients has been chosen such that the relative quantitative importance of pathways (see Figure 1) is clear for any further use of the results. The target was to create an as optimal basis as possible for the discussion of complementary measures aimed at a further reduction of substance inputs.

The methods applied to estimate the background concentration of natural compounds are summarized in Annex 4.

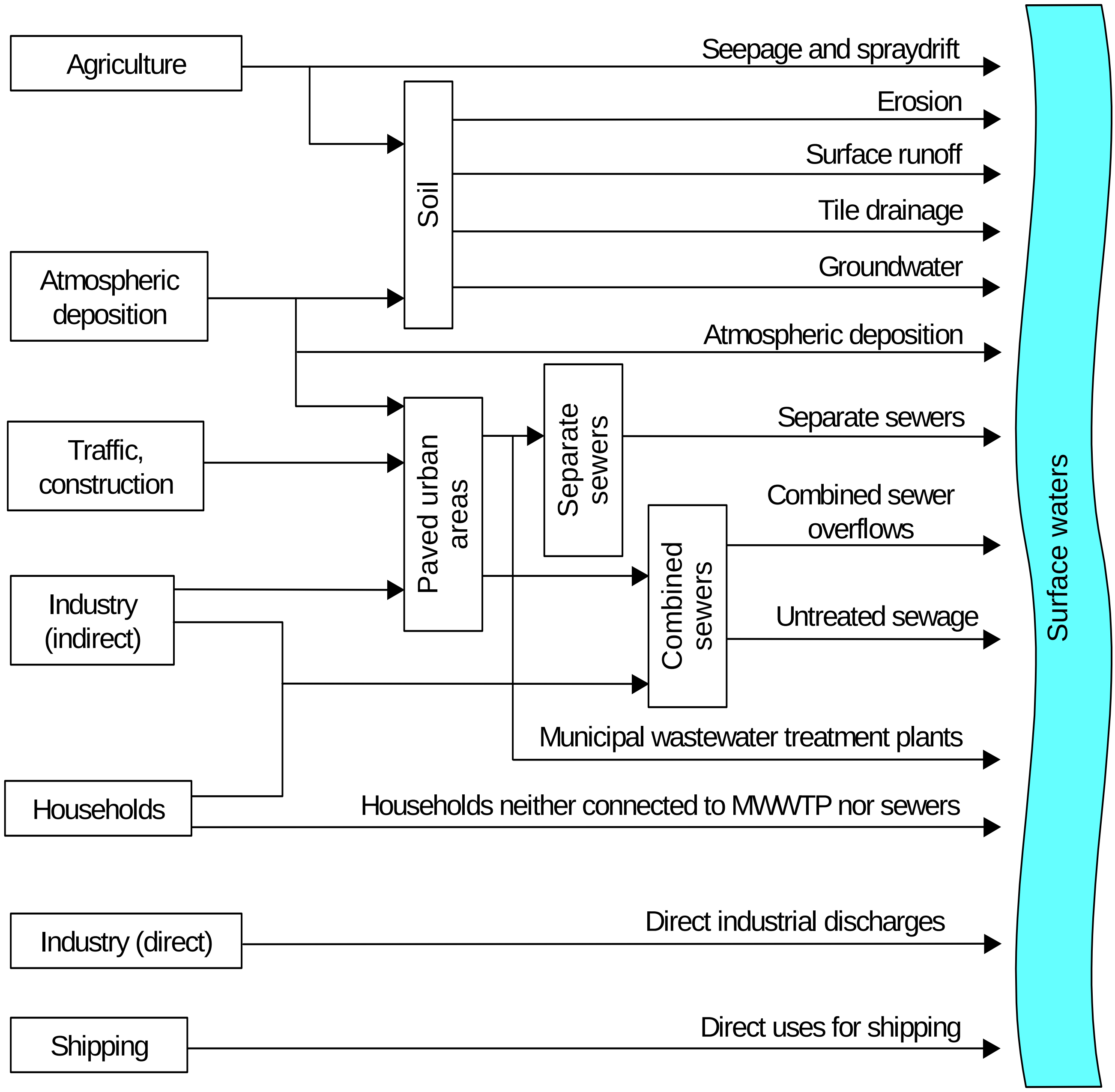
Point source discharge data

In every country, point source inputs were either established on the basis of direct discharge measurements or, if there were none, on the basis of estimations.

Direct discharges from production, processing or use of each of the substances are listed in the category „industrial inputs". These data concern discharges to the Rhine or its tributaries.

The category „urban discharges" comprises discharges from households and industries connected to the urban sewerage system (indirect dischargers). Both treated and, to a very small extent untreated effluents are taken account of. Contrary to earlier surveys, the storm sewers range among the diffuse inputs.

The apparent precision of data indicated in the table results from the calculation method, not from the measuring method.


Agriculture
Atmospheric deposition
Traffic, construction
Industry (indirect)
Households
Industry (direct)
Shipping
Soil
Paved urban areas
Separate sewers
Combined sewers
Seepage and spraydrift
Erosion
Surface runoff
Tile drainage
Groundwater
Atmospheric deposition
Separate sewers
Combined sewer overflows
Untreated sewage
Municipal wastewater treatment plants
Households neither connected to MWWTP nor sewers
Direct industrial discharges
Direct uses for shipping
Surface waters

Structure of the Rhine catchment

With its 185,000 km² the Rhine catchment extending to 9 countries ranges among Europe's greatest river basins. Five countries, Switzerland, France, Germany, Luxembourg and the Netherlands share the major parts of the catchment area along the river's more than 1,200 km long course. From a hydrological point of view, the Rhine is medium-sized. However, some 50 million people live in this area; the soil is subject to intensive use and there is a high concentration of industry. Worldwide there is hardly another river system with a comparable concentration of industry. The Rhine is intensively used for navigation, power generation, and industrial production, it provides cooling water for thermal power plants, and water for agriculture – particularly during dry periods; water works along the Rhine supply some 20 million people and the industry with drinking water.

The share each Rhine bordering country holds in the total nutrient pollution of the river must be evaluated and related against the background of the size, structure (see Table 1 and Figure 3) and the surface shares (see Figure 2) of the national catchment area, and its population density. When considering the nutrient inputs of diffuse origin, the influence of various environmental factors in the different Rhine bordering countries must also be taken account of: e.g. topography, climate/weather, kind and intensity of soil use and soil cultivation, density of the network of surface water bodies. The quantification procedure for diffuse inputs takes account of the particular conditions specific to individual countries.

The new Rhine Convention has extended the Dutch convention area. While the old Dutch Rhine catchment area was limited by the zone influenced by the tidal area (see Annex 2, Figure 15), the new convention area extends to the coastal line. Thus, the Dutch share of the entire convention area has risen from 5 % to 15 %, the share of inhabitants has risen from 7 % to 21 %. Compared to the old convention area, the recently added area has a higher density of agricultural enterprises, but a lower density of industry and population. The consequences for the surveys of 1985 and 1996 are that the share of Dutch point source discharges of urban origin and of diffuse inputs of agricultural origin rises disproportionately compared to the older inventories. Due to the differences in size and structure between the old and the new convention area, the diffuse inputs inventoried for the old Dutch convention area and published in 1992 cannot be compared with those of the current survey.

Figure 2: Catchment surface shares of the Rhine bodering countries

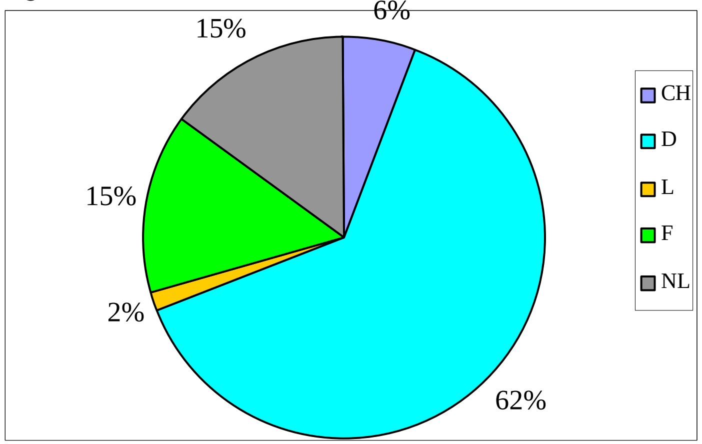
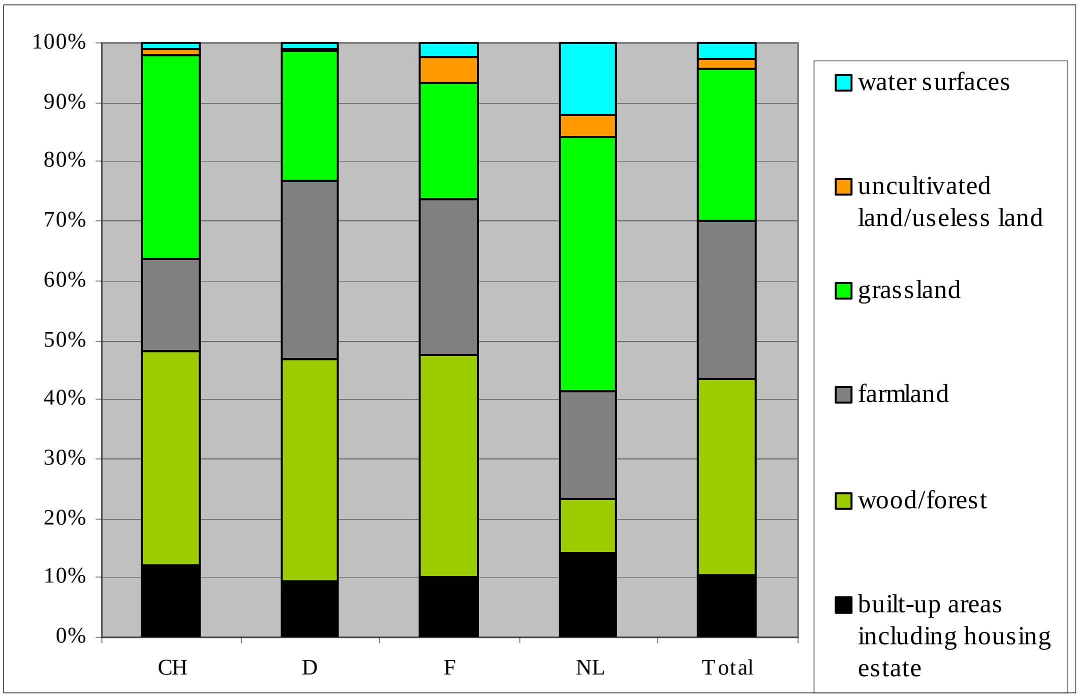


Table 1: Structure of the Rhine catchment area (for surfaces downstream the great lakes on the edge of the Alps)

Struktur des Rheineinzugsgebiets / Structure du bassin du Rhin

country (unity = Km²)	CH		D		L		F		NL		Total	
	km²	%	km²	%	km²	%	km²	%	km²	%	km²	%
surface shares of the countries in the Rhine basin	9 427	100	102.584	100	2 552	100	23 614	100	24 445	100	162 622	100
built-up areas including housing estate	1 145	12	9.421	9	306	12	2 398	10	3 479	14	16 749	10
wood/forest	3 383	36	37.703	37	884	35	8 829	37	2 165	9	52 964	33
agricultural surface (total)	4 713	50	54.189	52	1 244	48	10 798	46	14 975	61	85 919	53
farmland	1 455	15	30.220	30	543	21	6 153	26	4 435	18	42 806	26
grassland	3 257	35	21.959	22	701	27	4 645	20	10 436	43	40 998	25
uncultivated land/useless land	100	1	388	1	103	4	1 011	4	873	4	2 475	2
water surfaces	86	1	883	1	15	1	578	2	2 953	12	4 515	3

Figure 3: Structure of the Rhine catchment



3. Total phosphorous (P) inputs

Total phosphorous (P) inputs 1985

A look at the phosphorous emissions in 1985 (see Table 2 and Figure 5) immediately reveals that urban and industrial point source discharges by far prevailed the non point source inputs. In total, point source discharges account for 75 % of the total inputs, including the background concentration of natural compounds. Urban discharges were more than double the industrial ones.

In Germany, France and Switzerland erosion and surface runoff were the most important diffuse pathways of phosphorous inputs. However, in the Netherlands, most of the phosphorous flowed into the Rhine via drainage and groundwater. Summing up, similar to nitrogen, drainage and groundwater were the most important diffuse pathways of the about 4.000 t P/a of phosphorous inputs (6 % of the total inputs). Erosion (4 % of the total inputs) and surface water runoff (2 % of the total inputs) account for further 6 % of the total P inputs to the Rhine catchment. In the low-lying Netherlands, both pathways are insignificant.

Even though agriculture constituted the main non point source in all Rhine bordering countries, diffuse inputs from sewers (separate sewerage systems, combined storm-overflow, untreated wastewater from combined sewerage systems and inhabitants not connected to sewage treatment plants) amounting to about 8 % of the total inputs must also be taken account of.

Figure 4: Shares of drainage and groundwater in the respective total national inputs (in % of the total national inputs)

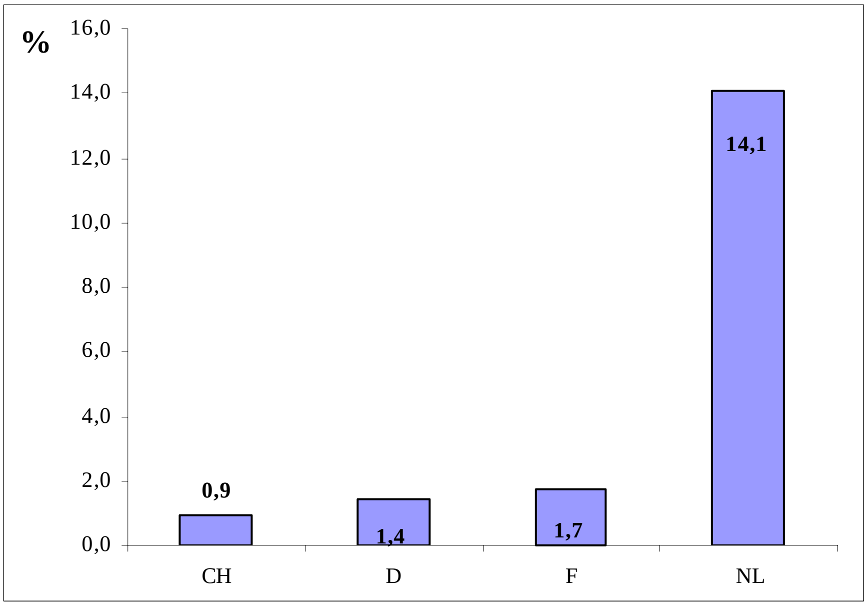


Figure 5: Total phosphorous (P) inputs in 1985

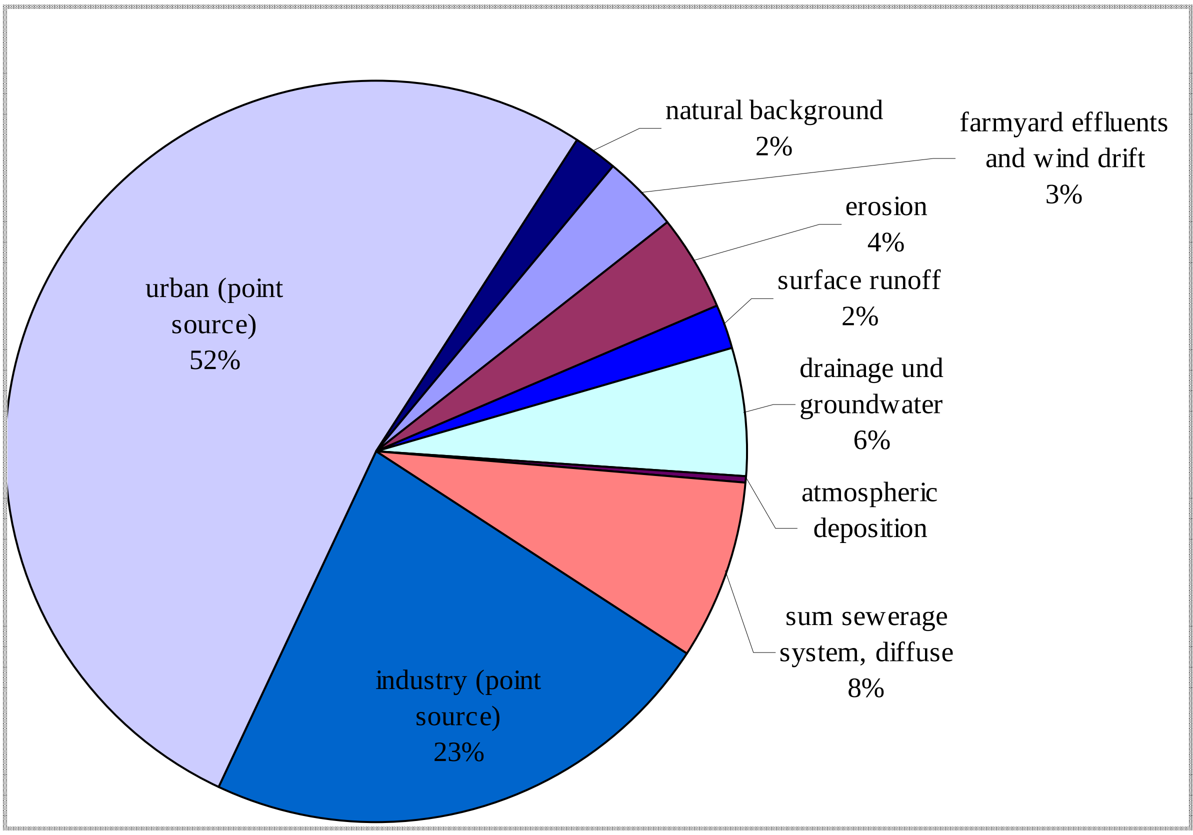


Table 2: Total phosphorous (P) inputs 1985

Phosphoremissionen 1985 neugeschätzt (neues Vertragsgebiet)

Country		**CH**	**D**	**F**	**NL**	**total**
		t / a	**t / a**	**t / a**	**t / a**	**t / a**
diffuse inputs						
1	farmyard effluents and wind drift	18	1 660	200	602	2 480
2	Erosion	126	2 480	380		2 986
3	surface runoff	235	925	270		1 430
4.a	Drainage	15	95	63		
4.b	groundwater [1]	12	460	60		
4	**drainage and groundwater** [4]	27	555	123	3 480	4 185
5	atmospheric deposition	6	42	10	37	95
6	separate sewerage system [2]	6	110	7		
7	combined sewerage stormwater overflow	[3]	2 010	500	78	
8	combined sewerage system, untreated discharges	0	1 130	600	828	2 558
9	inhabitants, not connected	30	75	100	405	610
6 - 9	**sum sewerage system, diffuse**	36	3 325	1 207	1 311	5 879
1 - 9	**sum diffuse 1-9**	448	8 987	2 190	5 430	17 055
point source discharges						
10	industry (point source)	150	3 370	1 280	11 989	16 789
11	urban (point source)	2 300	25 970	3 520	6 749	38 539
10 - 11	**sum point source**	2 450	29 340	4 800	18 738	55 328
1 - 11	**sum diffuse and point source**	2 898	38 327	6 990	24 168	72 383
12	natural background	98	625	108	524	1 355
1 - 12	**sum diffuse, point source and natural background**	2 996	38 952	7 098	24 692	73 738

1) CH: including grassland in built-up areas 2) CH: only rural areas taken account of
3) CH: included in urban (point source) 4) NL: including 3 "surface runoff"

Total phosphorous (P) inputs 1996

In 1996, the diffuse inputs (see Table 3) of 12,800 t P/a correspond almost exactly to the point source discharges of 12,600 t P/a if the diffuse background concentration of natural compounds which man cannot influence is left aside. The point source industrial discharges amount to about half the point source discharges of municipal sewage treatment plants.

As in case of nitrogen, drainage and groundwater are the most important pathways and account for 4,400 t P/a (16 % of total inputs). Erosion (11 % of total inputs) and surface runoff (5 % of total inputs) account for about 16 % of the total P inputs to the Rhine catchment. Both these pathways are insignificant in the low lying Netherlands, where other pathways are of greater importance. In the Netherlands, some specific agricultural causes (drainage and groundwater) account for a distinctly different image of the relevant pathways than what is the case in the other Rhine bordering countries.

Diffuse inputs from sewers (separate sewerage systems, combined storm-overflow, untreated wastewater from combined sewerage systems and inhabitants not connected to sewage treatment plants) amounting to about 9 % of the total inputs must also be taken account of.

Figure 6: Total phosphorous (P) inputs 1996

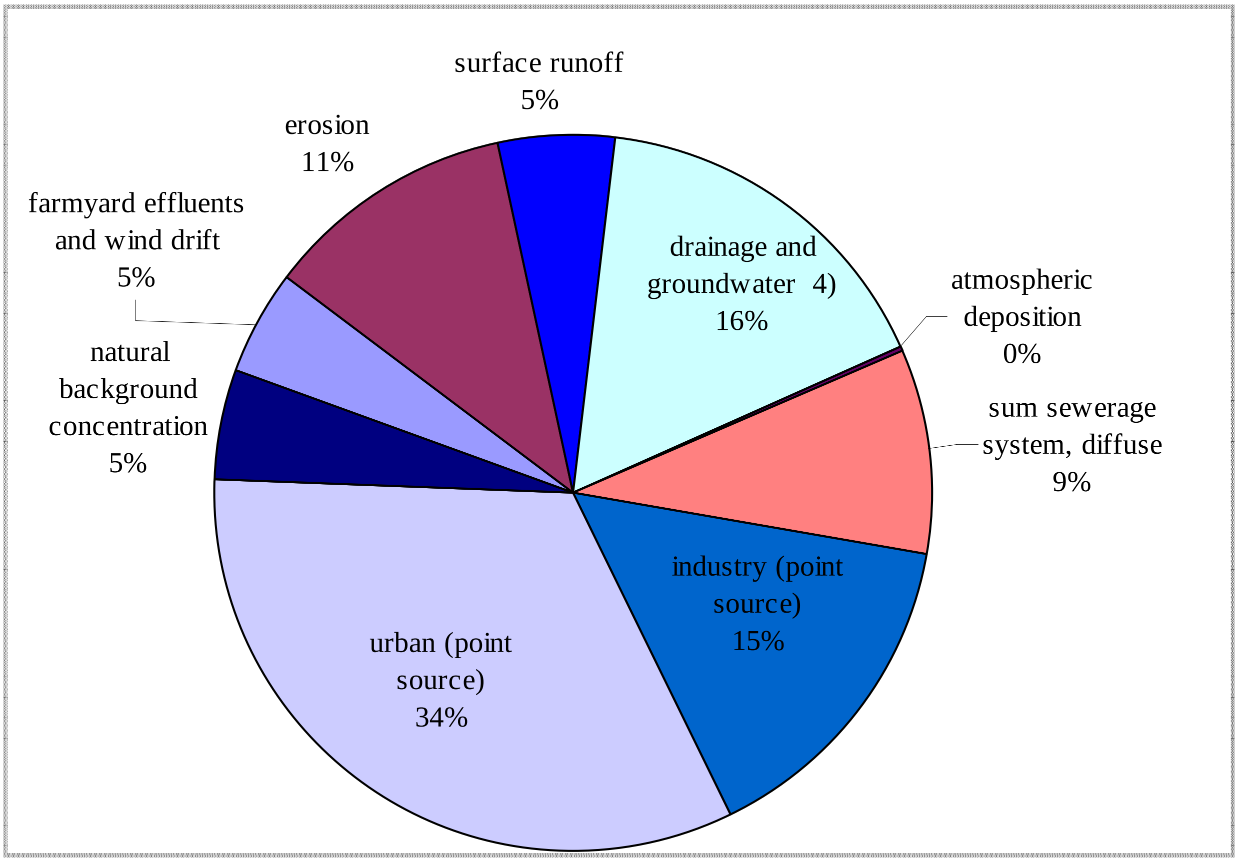


Table 3: Total phosphorous (P) inputs 1996

Phosphoremissionen 1996 (neues Vertragsgebiet)

Country		**CH**	**D**	**F**	**NL**	**total**
		t / a	**t / a**	**t / a**	**t / a**	**t / a**
diffuse inputs						
1	farmyard effluents and wind drift	5	830	140	289	1 264
2	Erosion	55	2 685	340	0	3 080
3	surface runoff	156	995	240		1 391
4.a	Drainage	39	100	60		
4.b	Groundwater 1)	17	460	60		
4	**drainage and groundwater 4)**	56	560	120	3 641	4 377
5	atmospheric deposition	5	40	10	56	111
6	separate sewerage system 2)	10	135	7		
7	combined sewerage stormwater overflow	152	990	265	83	1 490
8	combined sewerage system, untreated discarges	0	195	330	99	624
9	inhabitants, not connected	10	22	75	61	168
6 - 9	**sum sewerage system, diffuse**	172	1 342	677	243	2 434
1 - 9	**sum diffuse 1-9**	449	6 452	1 527	4 229	12 657
point source discharges						
10	industry (point source)	35	590	410	3 000	4 035
11	urban (point source)	900	4 925	830	2 071	8 726
10 - 11	**sum point source**	935	5 515	1 240	5 071	12 761
1 - 11	**sum diffuse and point source**	1 384	11 967	2 767	9 300	25 418
12	natural background	138	605	108	524	1 375
1 - 12	**sum diffuse, point source and natural background**	1 522	12 572	2 875	9 824	26 793

1) CH: including grassland in built-up areas 2) CH: only rural areas taken account of
3) NL: including 3 "surface runoff"

Comparison of the total phosphorous (P) inputs 1985 and 1996

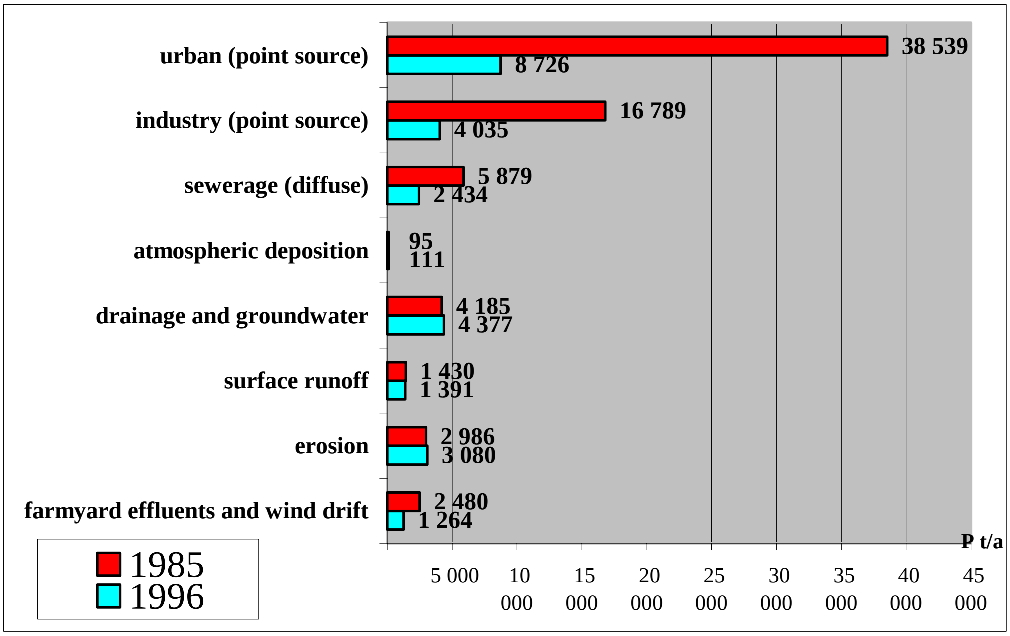
During 1985 to 1996, the total inputs deriving from human activities (see Table 4 and Figure 7) have decreased from about 72,400 t P/a to about 25,400 t P/a. This 65 % reduction is far above the targeted 50 % reduction of all phosphorous inputs. The decline in total emissions of the Rhine catchment is almost exclusively due to a 77 % (urban origin), respectively 76 % (industrial origin) reduction of point source discharges. Thus the share of point source discharges in the total inputs dropped from 75% (1985) to 49% (1996). Diffuse inputs from sewerages (separate sewerage systems, combined storm-overflow, untreated wastewater from combined sewerage systems and inhabitants not connected to sewage treatment plants) were equally reduced by considerable 59 %. However, due to their small share in the total inputs this reduction makes little difference.

Inputs deriving from farmyard runoff and wind drift have declined. All other inputs, mainly influenced by agriculture, have slightly increased. However, since point source discharges have been heavily reduced, the diffuse share in the total inputs has considerably increased.

Table 4: Comparison of phosphorous (P) inputs (in t P/a) during 1985 to 1996

	1985	1996	changes in %
farmyard effluents and wind drift	2 480	1 264	- 49
erosion	2 986	3 080	+ 3
surface runoff	1 430	1 391	- 3
drainage and groundwater	4 185	4 377	+ 5
atmospheric deposition	95	111	+ 17
sewerage (diffuse)	5 879	2 434	- 59
industry (point source)	16 789	4 035	- 76
urban (point source)	38 539	8 726	- 77
sum diffuse and point source	72 383	25 418	- 65

Figure 7: Reduction of total phosphorous (P) inputs during 1985 to 1996 in t P/a



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4. Total nitrogen (N) inputs

Total nitrogen (N) inputs 1985

The re-estimation of nitrogen inputs in 1985 (see Table 5 and Figure 9) points out that in 1985, point source discharges amounting to about 284,000 t N/a slightly dominated the 249,000 t N/a of non point source inputs as long as the background concentration of natural compounds not to be influenced by human activities is not taken account of.

In all ICPR member states, agriculture (drainage and groundwater, farmyard effluents and wind drift) is the most important source of diffuse nitrogen inputs. The most important nitrogen pathway passed by groundwater and drainage. In the Netherlands it is not possible to differentiate between drainage and groundwater. Compared to phosphorous inputs, nitrogen surface runoff only plays a minor role.

The 4 % of diffuse nitrogen inputs from sewerages (separate sewerage systems, combined storm-overflow, untreated wastewater from combined sewerage systems and inhabitants not connected to sewage treatment plants) were irrelevant.

Among others, the insignificant 1 % nitrogen share in direct deposition (deposition of air-borne substances due to rainfall, dew, fog, dust or gas) on water bodies depends on the surface share of water bodies in the total surface and on the deposed amount of nitrogen. Compared to the other countries, the Dutch surface share of water bodies is comparatively high (12 %) and consequently deposition as a source of diffuse nitrogen pollution is slightly more important.

Due to great amounts of precipitation in the alpine region, background concentrations of natural compounds (nutrients reaching the water bodies without being influenced by man; pristine state) are of considerable importance in Switzerland. There is almost no difference in the shares of the background concentration of natural compounds in Germany and France.

Figure 8: Shares of background concentration of natural compounds in the respective total national inputs (in per cent of total national inputs)

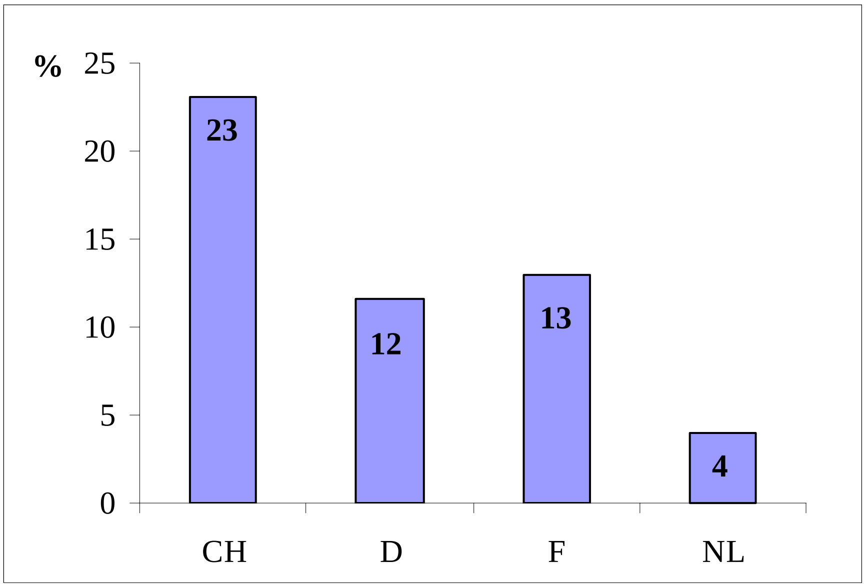


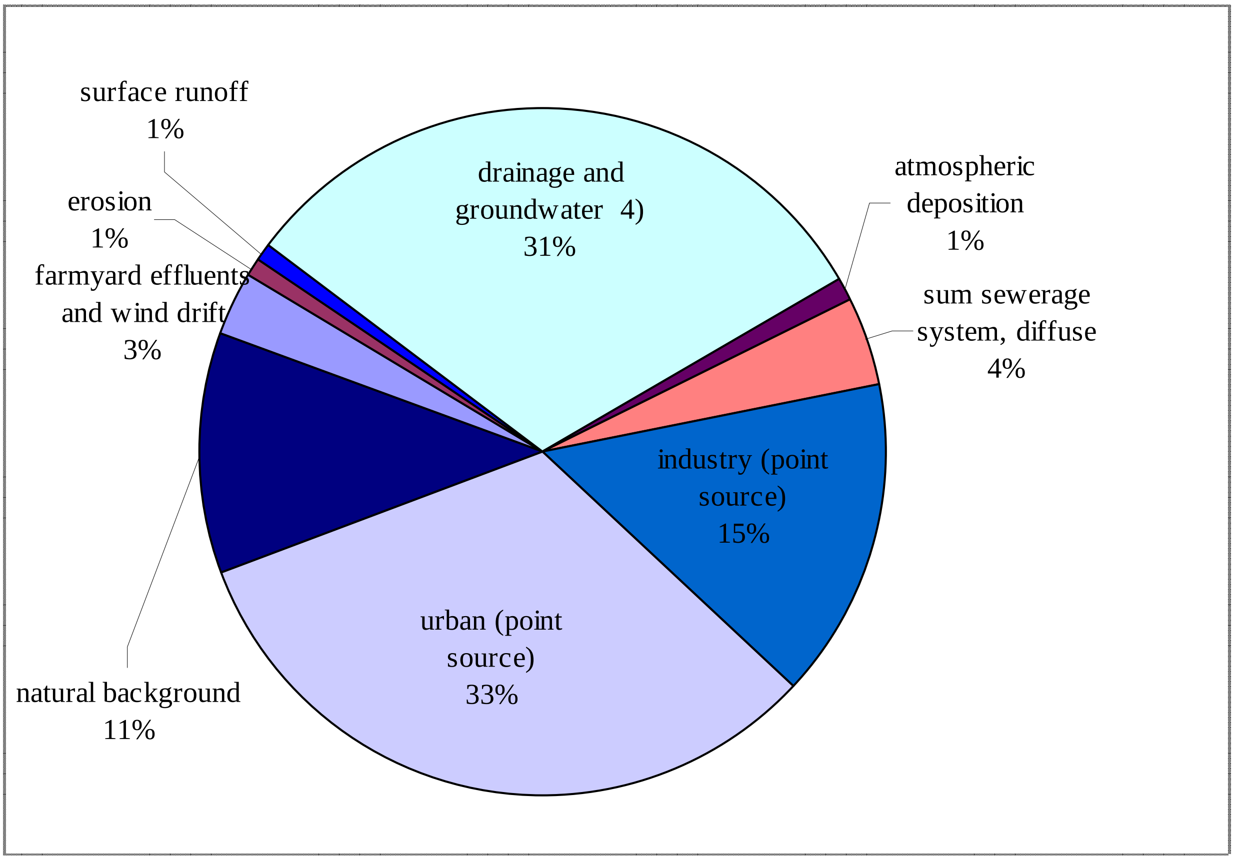
Table 5: Total nitrogen inputs (N) 1985

Stickstoffemissionen 1985 neugeschätzt (neues Vertragsgebiet)

Country		CH	D	F	NL	total
		t / a	t / a	t / a	t / a	t / a
diffuse inputs						
1	farmyard effluents and wind drift	96	8 500	1 500	7 732	17 828
2	Erosion	279	4 500	300	0	5 079
3	surface runoff	265	5 060	500	213	6 038
4.a	Drainage	1 955	23 800	2 200		
4.b	groundwater 1)	8 771	88 670	16 000		
4	**drainage and groundwater** 4)	10 726	112 470	18 200	45 786	187 182
5	atmospheric deposition	206	2 460	150	4 597	7 413
6	separate sewerage system 2)	40	1 340	600	709	2 689
7	combined sewerage stormwater overflow	3)	6 870	1 600	653	
8	combined sewerage system, untreated discharges	0	4 260	2 200	3 461	
9	inhabitants, not connected	300	850	400	1 696	3 246
6 - 9	**sum sewerage system, diffuse**	340	13 320	4 800	6 519	24 979
1 - 9	**sum diffuse 1-9**	11 912	146 310	25 450	64 847	248 519
point source discarges						
10	industry (point source)	1 000	69 450	15 000	5 221	90 671
11	Urban (point source)	19 500	135 220	15 800	22 780	193 300
10 - 11	**sum point source**	20 500	204 670	30 800	28 001	283 971
1 - 11	**sum diffuse and point source**	32 412	350 980	56 250	92 848	532 490
12	natural background	9 726	45 860	8 400	3 794	67 780
1 - 12	**sum diffuse, point source and natural background**	42 138	396 840	64 650	96 642	600 270

1) CH: including grassland in built-up areas
2) CH: only rural areas taken account of
3) CH: included in urban (point source)

Figure 9: Total nitrogen (N) inputs 1985



Total nitrogen (N) inputs 1996

In 1996, the 230,000 t N/a diffuse nitrogen inputs largely prevailed over the about 162,000 t N/a point source discharges, even if the background concentration of natural compounds not to be influenced by man is not taken account of. Point source industrial discharges only amount to a fraction of the point source discharges of municipal sewage plants.

In 1996, as in the preceding years, agriculture (drainage and groundwater, farmyard effluents and wind drift) was one of the major sources of diffuse nitrogen pollution in all ICPR member states. Groundwater and drainage are the by far most important diffuse pathways of nitrogen pollution. In the Netherlands it is not possible to differentiate between drainage and groundwater. Compared to phosphorous, nitrogen plays a minor part in surface runoff.

Diffuse inputs from sewerages (separate sewerage systems, combined storm-overflow, untreated wastewater from combined sewerage systems and inhabitants not connected to sewage treatment plants) amounting to only about 3 % were irrelevant.

With insignificant 1 %, the nitrogen share in direct deposition (deposition of air-borne substances due to rainfall, dew, fog, dust or gas) on water bodies depends among others on the surface share of water bodies in the total surface and on the deposed amount of nitrogen. Compared to the other countries, the Dutch surface share of water bodies is relatively high (12 %) and consequently deposition as a source of diffuse nitrogen pollution is slightly more important.

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Compared to 1985, and due to a new method of estimation, Swiss data concerning the order of magnitude of background concentrations of natural compounds (nutrient flows into water bodies not influenced by human activities; pristine state) have changed.

Figure 10: Total nitrogen (N) inputs 1996

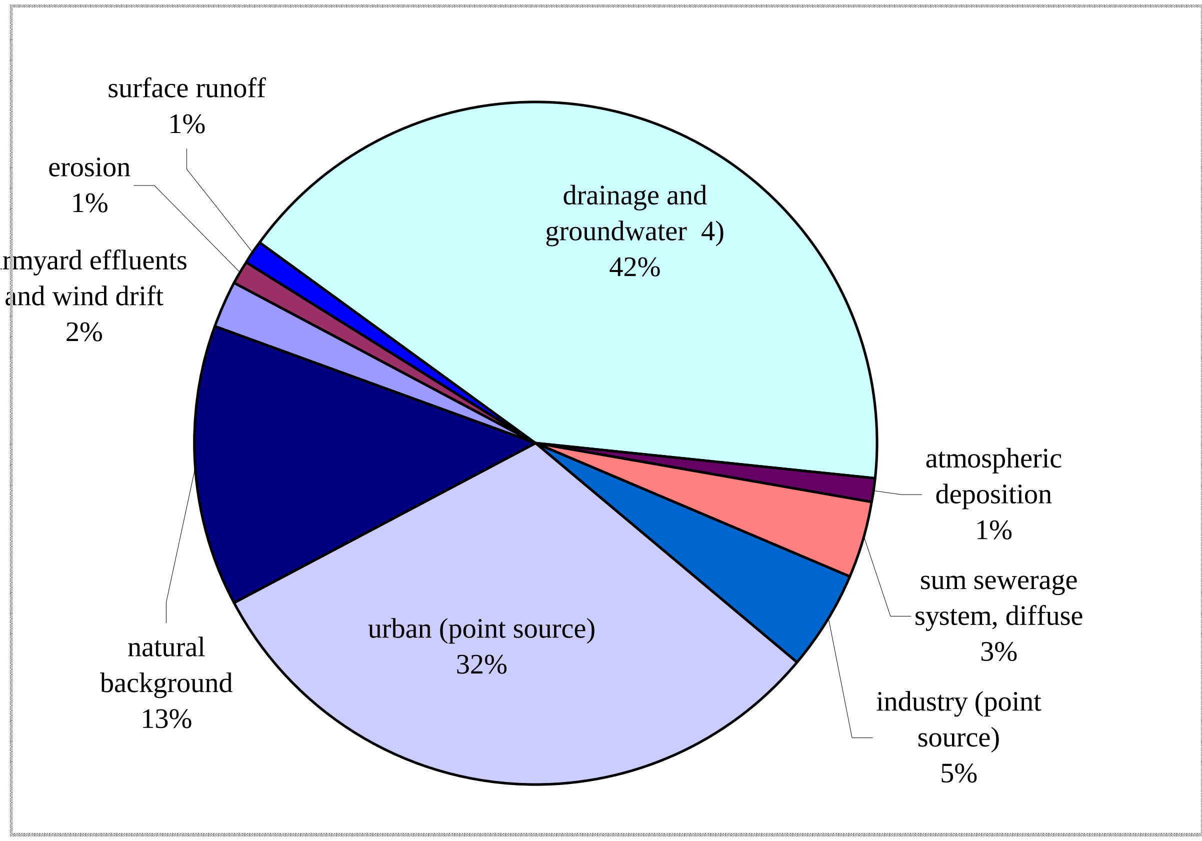


Table 6: Total nitrogen (N) inputs 1996

Stickstoffemissionen 1996 (neues Vertragsgebiet)

Country		CH	D	F	NL	Total
		t / a	t / a	t / a	t / a	t / a
diffuse inputs						
1	farmyard effluents and wind drift	23	4 200	1 000	4 545	9 768
2	Erosion	150	4 540	300	0	4 990
3	surface runoff	224	4 540	600	254	5 618
4.a	Drainage	2 264	17 450	2 500		
4.b	groundwater [1)]	10 075	82 090	18 500		
4	**drainage and groundwater** [4)]	12 339	99 560	21 000	54 699	187 598
5	atmospheric deposition	162	2 070	150	3 688	6 070
6	separate sewerage system [2)]	75	1 600	600	759	3 034
7	combined sewerage stormwater overflow	716	4 830	1 070	699	7 315
8	combined sewerage system, untreated discharges	0	1 700	1 310	928	3 938
9	inhabitants, not connected	100	520	310	577	1 507
6 - 9	**sum sewerage system, diffuse**	891	8 650	3 290	2 963	15 794
1 - 9	**sum diffuse 1-9**	13 789	123 560	26 340	66 149	229 838
point source discharges						
10	industry (point source)	1 000	13 740	4 400	2 160	21 300
11	urban (point source)	14 300	95 760	9 510	21 377	140 947
10 - 11	**sum point source**	15 300	109 500	13 910	23 537	162 247
1 - 11	**sum diffuse and point source**	29 089	233 060	40 250	89 686	392 085
12	natural background	4 729	43 120	8 400	3 794	60 043
1 - 12	**sum diffuse, point source and natural background**	33 818	276 180	48 650	93 480	452 128

1) CH: including grassland in built-up areas 2) CH: only rural areas taken account of

Comparison of total nitrogen (N) inputs during 1985 to 1996

During 1985 to 1996, the total inputs deriving from human activities (see Table 7 and Figure 11) have decreased from about 532,000 t N/a in 1985 to 392,000 t N/a in 1996. This 26 % reduction is far behind the 50 % reduction target set for the total inputs.

The decrease of total inputs has mainly been reached by reducing point source discharges, in particular those of industrial origin. The industrial share in the total discharges has fallen from 15 % (1985) to 5 % (1996).

The almost unchanged inputs via drainage and groundwater are a substantial reason for the comparatively insignificant reduction of the total inputs. But even if this important pathway (31 % of the total inputs in 1985 and 42 % of the total inputs in 1996) is left aside, the reduction of the total inputs amounts to 40 % and is thus behind the minimum target of 50 %.

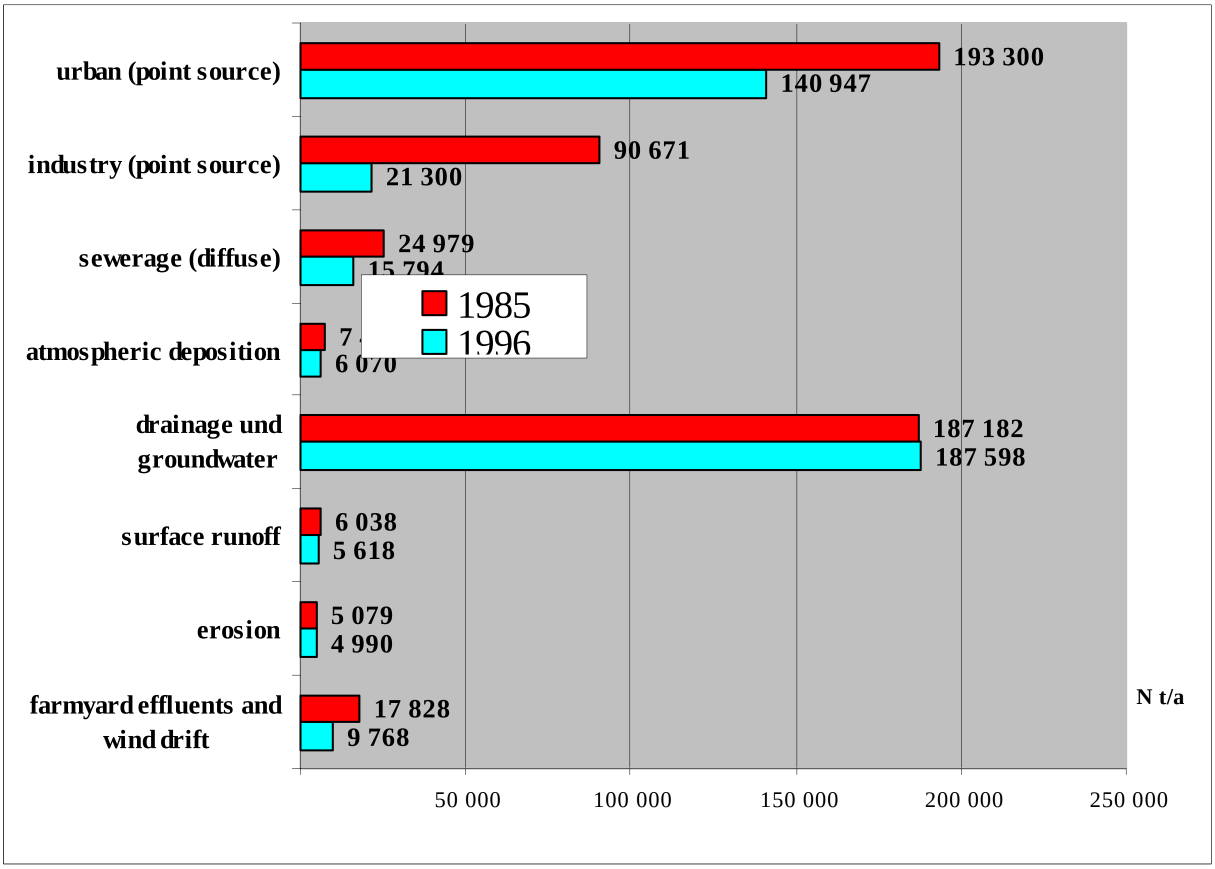
The consequence of the many years' time lag between the implementation of reduction measures in agriculture and their effects upon groundwater and drainage water (1985 and 1996 about 187,000 t N/a), particularly the heavily delayed transport of nitrate nitrogen via groundwater or drainage water to the Rhine is that estimates of these inputs are too imprecise for any survey of the effects of reduction measures in agriculture. A better tool reflecting present changes in inputs would e.g. be to determine changes in the nutrient surplus.

While industry can refer to a 77 % reduction of its point source discharges, those of urban sewage treatment works have only decreased by 27 %. As far as diffuse sewerage inputs (separate sewerage systems, combined storm-overflow, untreated wastewater from combined sewerage systems and inhabitants not connected to sewage treatment plants) are concerned, an insatisfactory 37 % reduction has been obtained.

Table 7: Comparison of the total nitrogen (N) inputs (in t N/a) during 1985 to 1996

	1985	1996	changes in %
farmyard effluents and wind drift	17 828	9 768	- 45
erosion	5 079	4 990	- 2
surface runoff	6 038	5 618	- 7
drainage und groundwater	187 182	187 598	
atmospheric deposition	7 413	6 070	- 18
sewerage (diffuse)	24 979	15 794	- 37
industry (point source)	90 671	21 300	- 77
urban (point source)	193 300	140 947	- 27
sum diffuse and point source	532 490	392 085	- 26

Figure 11: N input reductions via the different pathways during 1985 to 1996 in t N/a



6. Plausibility analysis of total phosphorous and total nitrogen inputs

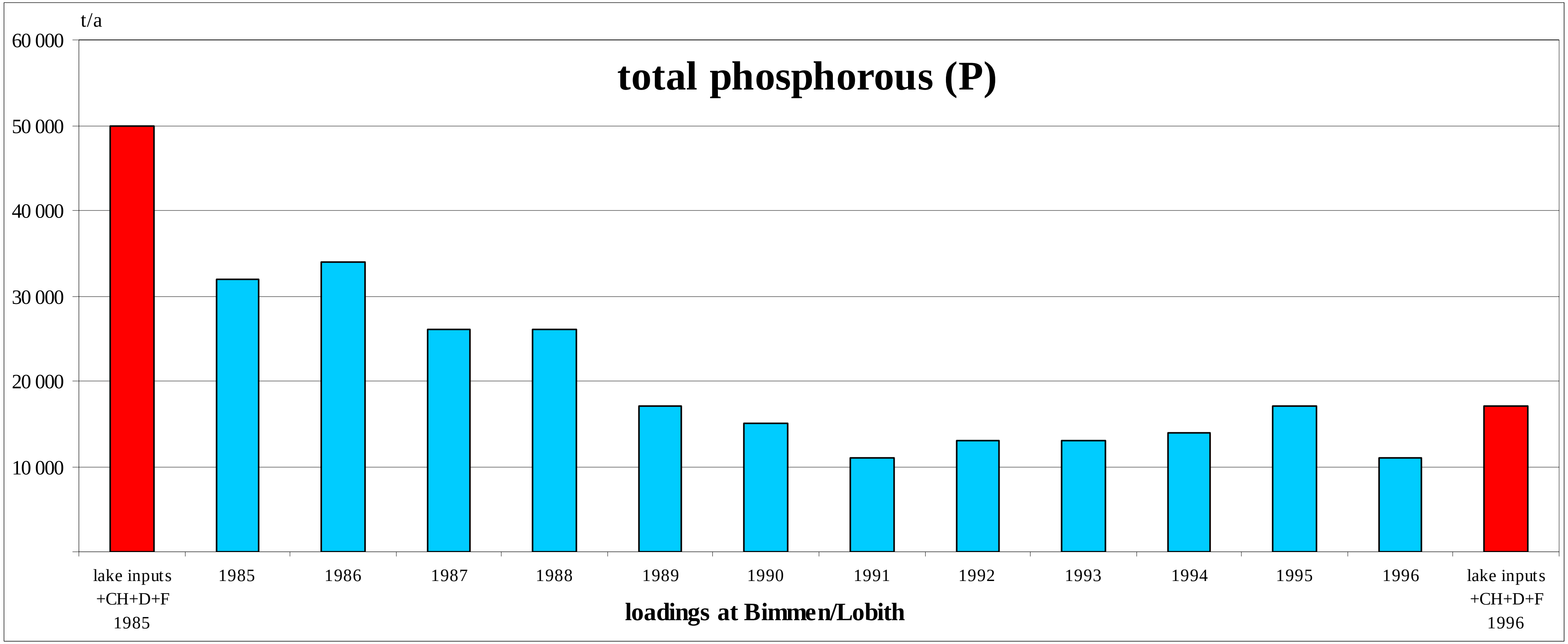
With a view to analysing the plausibility of the total phosphorous and total nitrogen inputs, the Swiss, French and German inputs in 1996 were compared to the estimated concentrations in the Rhine at Bimmen/Lobith during 1985 to 1996. This analysis of plausibility targets at estimating the reliability of the quantification particularly of diffuse inputs. The plausibility analysis was only carried through for the Bimmen/Lobith monitoring station.

When using loading data for statements on trends, for verifying reduction quota and for comparing point source discharges and diffuse inputs upstream the relevant monitoring station, it should be taken account of that

- loadings are heavily dependant on river flow and that statements on trends may only be made for loadings in years with comparable river flow;
- 1991 and 1996 were comparatively dry years (mean average river flow at Lobith over many years = 220 m^3/s)
  1987, 1988, 1994 and 1995 on the other hand were very wet years with a mean river flow of about 2.800 m^3/s, leading to high loadings. If river flow drops, the loading is equally expected to drop. This is the case in 1991 and 1996.
- a concentration of 1 µg/l over one year in the Rhine at Bimmen/Lobith corresponds to a loading of 70 t.

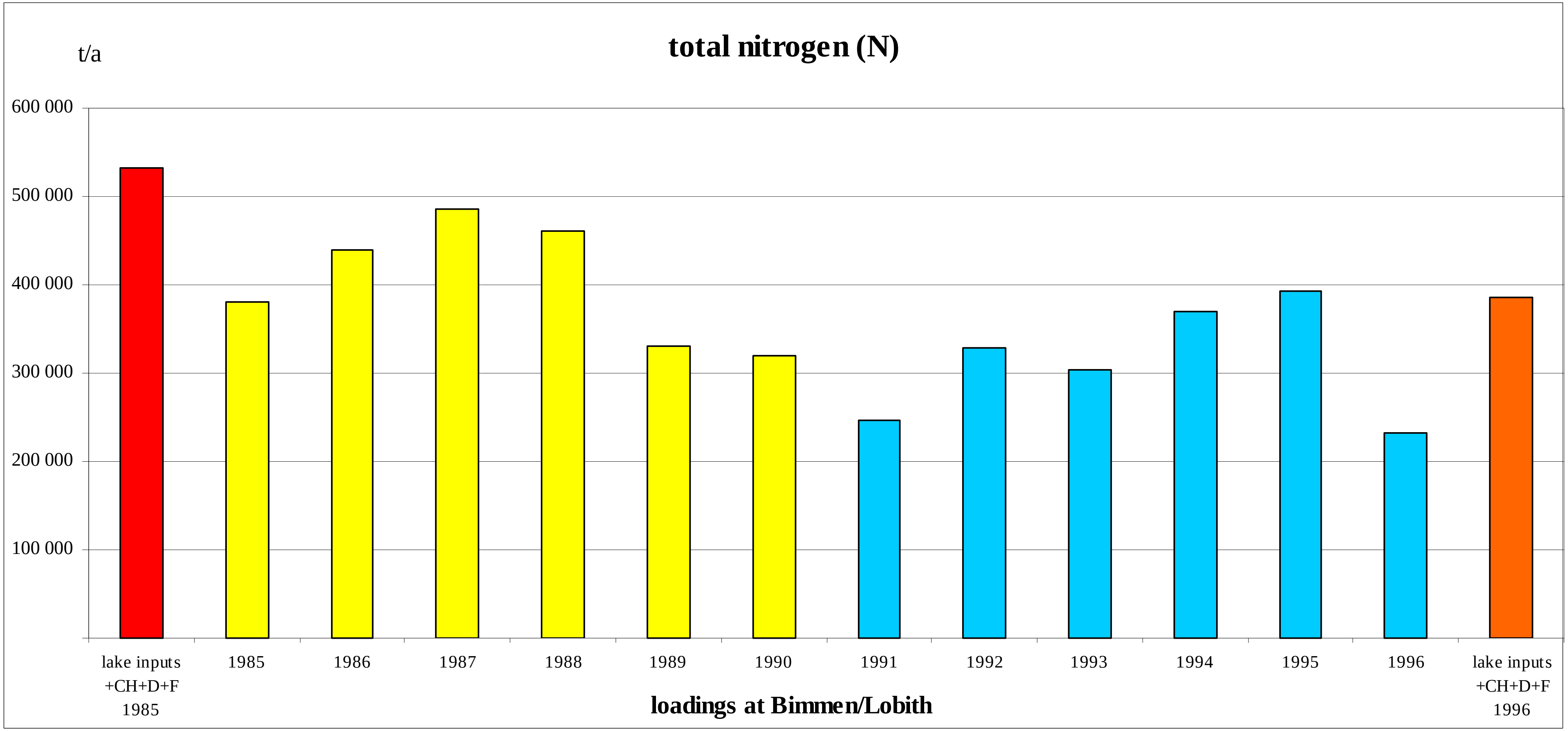
Plausibility analysis for total phosphorous (P)

Figure 12: Total phosphorous loadings at Bimmen/Lobith and total discharges up to Bimmen/Lobith



Plausibility analysis for total nitrogen (N)

Figure 13: Total nitrogen (N) loadings at Bimmen/Lobith and total discharges up to Bimmen/Lobith [1]



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Due to sometimes long travel times (in particular as far as nitrogen is concerned) the reduction of nutrient inputs to the Rhine will only show its effects in some years/decades.

Diffuse nitrogen inputs largely leach into deeper layers of soil and reach surface waters and thus the Rhine where sources crop out or due to groundwater seepage. On the one hand, this long travel time makes an estimate of nitrogen emissions to the Rhine difficult, as, on its way, interactions are many and partly still unknown. On the other hand, long travel times bring about time lags difficult to estimate. In the unsaturated soil zone and in groundwater in the lowlands of Northeast Germany, residence time for water may be up to 500 years. The question with what time lag diffuse nitrogen inputs reach the Rhine is thus decisive for the estimate of the effects of reduction measures taken in connection with the 50 % reduction target. The first very careful estimates for the German Rhine catchment seem to point to a time lag of 2 to 10 years between changes of nitrogen surplus on agricultural surfaces and changes in the nitrogen concentrations in the Rhine (Behrendt, 1999).

The following conclusions may be drawn from the results of the plausibility analysis:

- The total phosphorous and nitrogen inputs surveyed in 1996 are of the same order of magnitude as the corresponding phosphorous and nitrogen loads in the Rhine.
- The methods of estimating the point and non point nutrient inputs lead to results which well serve the target of the survey of nutrient inputs to the Rhine.
- The method developed for estimating the diffuse nitrogen inputs to the Rhine is an appropriate tool in order to point out the relative importance of the many sources and pathways of these substances.

7. Summary and perspective

Phosphorous is of prime importance for the eutrophication of the Rhine, in particular of its impounded parts and the great Dutch lakes charged by the Rhine, e.g. the IJsselmeer; this means that, contrary to the North Sea, these water bodies are phosphorous limited.

During 1985 to 1996 the total phosphorous inputs derived from human activities decreased from about 70,000 t P/a to about 25,000 t P/a. This 65 % reduction is far above the 50 % reduction target fixed for the total inputs. The decrease of the total inputs of the Rhine catchment was almost exclusively reached by a 77 % (urban origin), respectively 76 % (industrial origin) reduction of point source discharges. This considerable reduction led to a decrease of the share of point source discharges in the total inputs from 75 % (1985) to 49 % (1996).

Nitrogen pollution is of major importance for the eutrophication of shallow seas, such as the North Sea. Following the symptoms of overfertilization apparent in the 1980s, the countries bordering the North Sea and the ICPR decided to reduce nitrogen inputs by 50% between 1985 and 1995.

During 1985 to 1996, the total nitrogen inputs derived from human activities decreased from about 530,000 t N/a in 1985 to about 390,000 t N/a in 1996. This 26 % reduction is far behind the 50 % reduction target fixed for the total inputs. Total inputs mainly decreased due to a reduction of point source discharges, in particular of industrial origin.

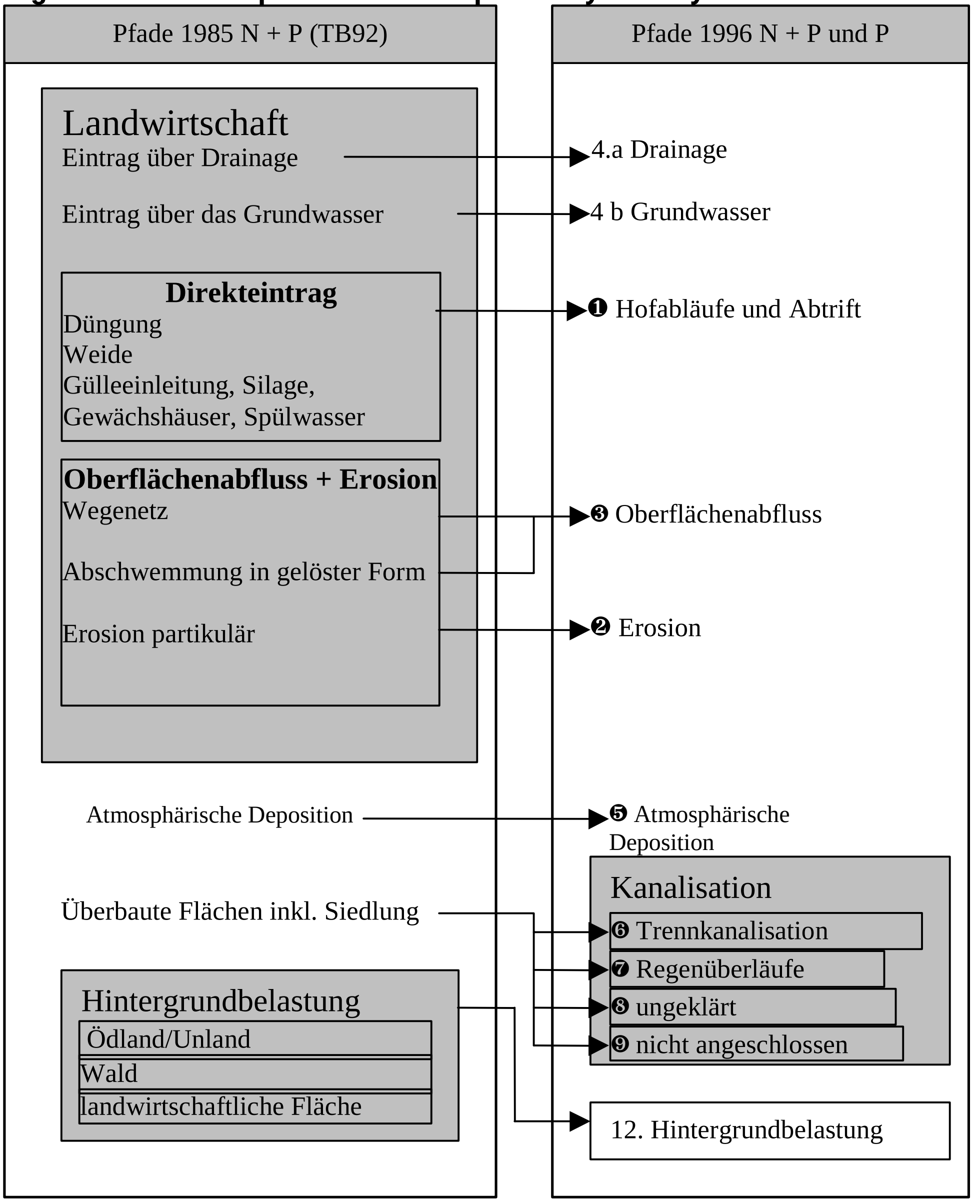
One of the main reasons for the comparatively low reduction of the total inputs is the almost unchanged amount of inputs via drainage and groundwater. The consequence of the many years' time lag between reduction measures taken in agriculture and their effects upon groundwater and drainage water (1985 and 1996 about 187,000 t N/a) and in particular of the heavily retarded transport of nitrate nitrogen via groundwater or drainage water to the Rhine is that the estimates of these inputs are too imprecise in order to be able to verify present effects of the reduction measures taken in agriculture.

In part due to long travel times, the reduction of nitrogen inputs will only show its effects in the Rhine in some years/decades.

The **plausibility analysis** established that the methods used for determining nutrient inputs of point and non point sources deliver results which entirely fulfil their purpose within the survey of nutrient inputs to the Rhine.

Annex 1

Figure 14: Comparison of the pathways analysed under the different surveys



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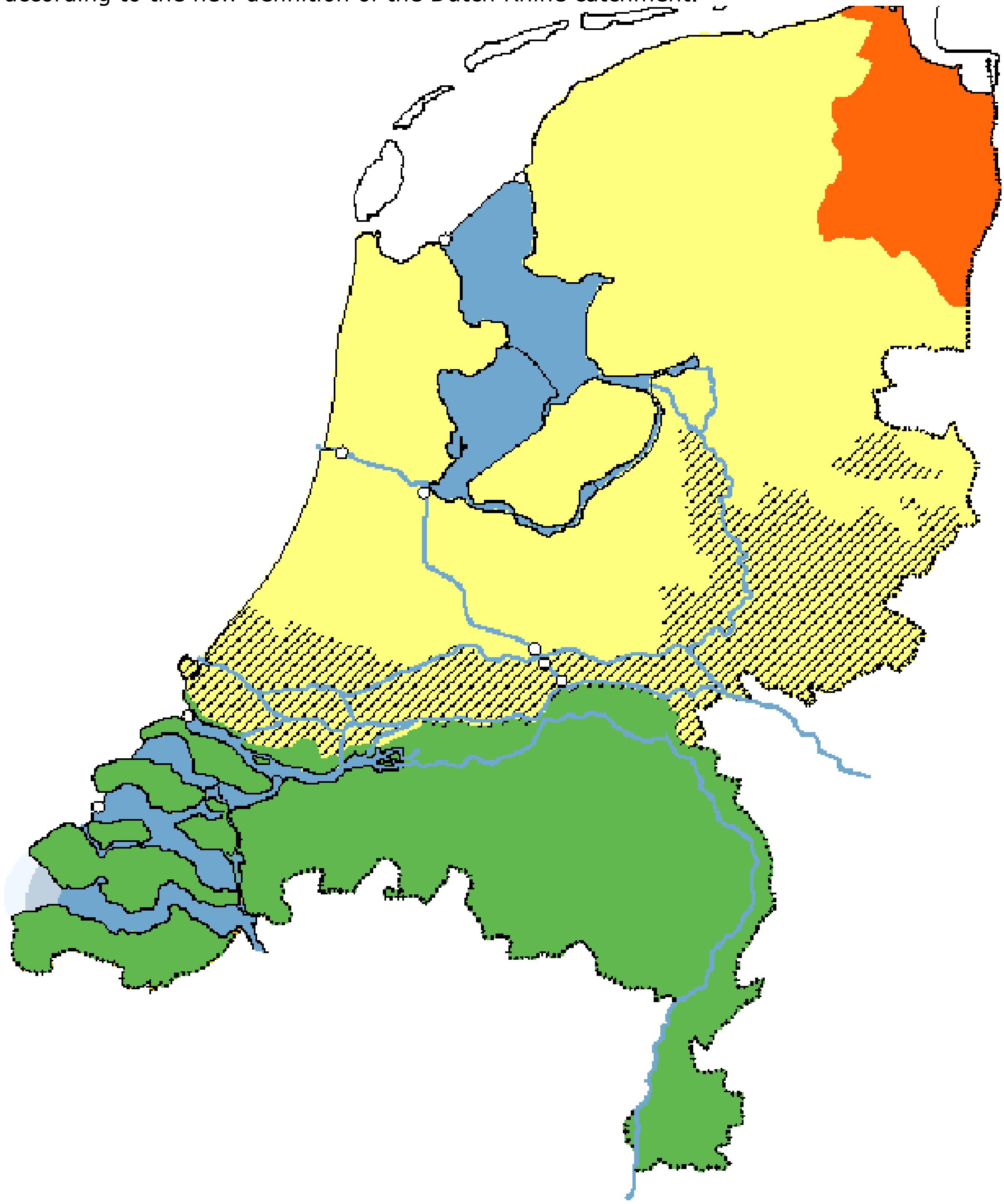
Annex 2

Figure 15: Zonation of the Dutch Rhine catchment area

Catchment areas of the rivers Ems, Rhine, Meuse and Scheldt in the Netherlands. The hachured part is the (smaller) area according to the old, the yellow (bigger) is the area according to the new definition of the Dutch Rhine catchment.



Annex 3

Table 8: Definition of terms used in the report

Farmland	Open farmland including particular cultures such as fruit, vegetables, wine and hop, excluding meadows and pastures
Wind drift	Spread by the wind during application (scattered spray mist)
Runoff	See **surface runoff**
Atmospheric deposition	Wet: deposition of air pollutants due to rain or dew Dry: deposition of air pollutants by dust Gaseous: deposition of air pollutants by gases
Soil erosion	See erosion
Diffuse inputs	Pollutant inputs which cannot be captured in a point source (agriculture, forest, low density built-up areas, atmosphere). Furthermore discharges from separate sewerage systems, combined storm overflows and inhabitants not connected to any sewer.
Drainage	Artificial drainage using slit pipelines and/or open ditches
Fertilizer	Manure and inorganic fertilizer
Erosion	Amount of soil transported per unit of time from a defined surface by surface water runoff, including the fixed pollutants
Geogenous sources	Substance inputs due to contact of runoff water with living rock
Farmyard effluents	Runoff reaching surface waters directly from the farm
Combined sewer	Sewer transporting domestic and industrial effluents including rainwater from roofs and traffic ways to municipal sewage plants
Combined storm overflow	Relief of mixed canalisation during storm events
Surface runoff	Transport of dissolved pollutants together with water running off at the soil surface (also known as runoff)
Surface water body	Running waters and lakes in the Rhine catchment area.

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Annex 4

Method of estimating the background concentration

Swiss method of estimation

Indications on the calculation of the background concentration of natural compounds in the Swiss Rhine catchment downstream the lakes (Volker Prasuhn (FAL 2000))

Background concentration of natural compounds

The background concentration of natural compounds is determined by natural substances in precipitation which are thus not due to air pollution derived from human activities as well as by substance concentrations in runoff water under natural vegetation (forest, unproductive vegetation and surfaces without any vegetation) conditioned by the properties of soil and stone layers. Thus, the **anthropogenic diffuse pollution** is a result of all changes to transport ways, runoff rates and substance concentrations in water compared to a state with a potentially natural vegetation. This comprises all interferences with natural vegetation due to agricultural use of soil (e.g. tilling of soil, fertilization and soil vapour concentration), uses due to forestry, construction works and air pollution derived from human activities.

Calculation of water flows

The calculation of the background concentration of natural compounds is based on the assumption that, in all catchment areas, the potentially natural vegetation below the forest line is forest. Thus forest was assumed for all present surfaces covered by meadows, farmland and urban areas. Apart from forests there are surfaces with unproductive vegetation lying above the forest line, surfaces without any vegetation and water bodies. These three categories have been drawn from surface statistics and are identical with the data of the main calculation. Water flows have been re-calculated accordingly, with unchanged precipitation rates. However, due to the retention behaviour of the forest (greater evapotranspiration), less water runs off. Apart from in alpine regions and in the pre-alpine highlands, there is no surface runoff under the forests, which means that almost all water percolates.

Calculation of material flows

The material flows of the background concentration of natural compounds were calculated parallel to the main calculation but are based on the following assumptions or modifications:

- Modified soil use (forest instead of grasslands, farmland and housing estate) and resulting water flows are taken account of.
- Nitrogen concentrations in seepage water under woods and improductive vegetation were reduced by 50 % compared to the values used for the main calculation. Thus, air pollution derived from human activities and uses by forestry were taken account of. The same values as those underlying the main calculation for seepage water in forests and on improductive vegetation were used for phosphorous concentrations in seepage water. It was thus assumed that man-made air pollution and uses by forestry do not influence phosphorous concentrations in seepage water in forests and on improductive vegetation.

- Compared to the main calculation and due to air pollution derived from human activities, phosphorous and nitrogen inputs to waters from atmospheric depositions were reduced by 50 % in all areas. The values applied are rough estimates.
- Apart from atmospheric deposition, the only other direct input to waters is defoliation. The high inputs of leaves and the resulting dissolved phosphorous and nitrogen were taken account of in so far, as the entire surface, deduction made of surfaces without vegetation and improductive surfaces are refered to and that the values of the „other non point source inputs" of the main calculation were taken over.
- Water flow beneath improductive vegetation and surfaces without vegetation was determined according to the same terms as in the main calculation, as far as concentrations of substances are concerned, the changed atmospheric deposition was taken account of.
- The figures for ‚natural erosion' figuring in the main calculation were applied, and extended by the surface share of housing estate areas. Then a 20 % reduction was made in all catchment areas. This insinuates that 20 % of the erosion refered to as ‚natural erosion' is man-made (e.g. erosion on ski slopes, dirt tracks, etc.).

German method of estimation

All German nutrient input estimates are based on the MONERIS model system (Behrendt et.al.: Nährstoffbilanzierung der Flussgebiete Deutschlands. German: UBA texts, 75/99; English: UBA texts 23/00; Internet: http://193.174.169.36/npbilanz). In MONERIS, background concentrations of natural compounds are estimated for those pahtways which, under natural circumstances, presumably also led to inputs to surface waters. Estimates were carried out on the following basis:

- As far as erosion is concerned, only that in high mountain ranges was considered to be natural. However, there are no high mountain ranges in the German part of the Rhine catchment.
- For the snow melt share of surface runoff, natural concentrations of 10 µg/l phosphorous and 1 mg/l nitrogen were assumed. For the rest of the surface runoff, the basis assumed was that of today's concentrations in forest areas amounting to about 50 µg/l phosphorous and 1 mg/l nitrogen. Due to their high degree of water saturation, drained areas formerly probably drained via the surface, therefore background concentrations of natural compounds were also taken into account.
- 2 mg/l nitrogen in seepage water were assumed when determining the background concentration of natural compounds in groundwater. According to conditions of denitrification, this value decreases to groundwater concentrations between 0.2 and slightly above 1 mg/l. For phosphorous, a uniform concentration of 10 µg/l P in groundwater was assumed. It was not taken account of the fact that higher values are to be expected in the marshy lowlands.
- With respect to deposition, concentrations of 10 µg/l phosphorous were assumed in rainwater. Half of today's nitrogen deposition was assumed. This value is probably a bit too high, but due to the few water surfaces of no importance.

French method of estimation

On the basis of concentrations for forests, the natural inputs have been estimated to 1.3 mg/l N and 0.015 mg/l P. Taking into account the total volume, this would lead to the values listed below.

	Volume in $10^6 m^3/a$	N t/a	P t/a
Pathway 12a fallow land	230	300	3
Pathway 12b forests	3.200	4.200	48
Pathway 12c farmland	3.100	4.200	46
Total		8.500	97
Data entered		8.400	108

Calculations were made for each sub-catchment and, as a matter of principle, they are more precise than the total assessment indicated above. These data have been entered into the tables for N for the years 1985 and 1996.

Dutch method of estimation

Old definition (progress report 1992)

According to the progress report for 1992, the background concentration for natural compounds is defined as follows:
„Nutrient flows reaching the water bodies without any human influence (land use, incineration, etc.) (pristine state)."

Situation in the Netherlands

So far, it has not been possible to find any information on natural N or P compounds in atmospheric depositions.

As it is assumed that the nutrient loading caused by erosion has a very low share and is indicated as „nil", the natural component of erosion is equally indicated as „nil".

In the Netherlands, nutrient loadings originating from groundwater and surface runoff to surface waters are mainly determined by river flow. Today, groundwater levels are not natural but artificially controlled. Without man's interference the level of groundwater in the Netherlands would lie immediately under the soil surface and large drained areas would be flooded. Another modification of great importance for the Rhine catchment is the construction of a dike (Afsluitdijk) turning the enclosed water surface into a great inland water body (the IJsselmeer).

Applying the above definition for background concentration of natural compounds to Dutch conditions gives rise to two problems. Firstly, there is no hydrological model permitting to calculate nutrient inputs under natural circumstances (no human influence). Secondly, such calculations are of little importance, as these data make no indications on the background concentration of natural compounds under the present river flow.

Data transmitted

Due to the particular conditions in the Netherlands, data on the background concentration of natural compounds differ from the official definitions. The present survey reports on the following:

- Atmospheric deposition is indicated as a total number, comprising nutrients of human as well as of natural origin.
- The data on the pathways 3 and 4 represent the total loading from groundwater and runoff from agricultural surfaces and thus also comprise nutrients of natural origin.
- For the pathways 12a and 12b, a value is indicated comprising the nutrient loading in groundwater as well as the runoff from surfaces without any agricultural activities which more or less correspond to the definition „ uncultivated land/useless land" or „forest".

New definition

As far as the Dutch Rhine catchment is concerned, the definition of the background concentration of natural compounds figuring in the progress report 1992 cannot be applied. However, the total nutrient inputs into surface water bodies comprise a share of natural origin, not influenced by man. Data on the contents in the natural atmosphere probably exist, but they have not yet been found. It will be more difficult to obtain an estimate of the natural loading in groundwater and river flow under the present Dutch flow regime.

Before trying to estimate the natural compound, we should consider the importance of these data. One of the targets of differentiating between the background concentration and loadings of agricultural origin may be to point out where and whether measures aimed at reducing the nutrient loadings may be taken. However, measures targeted at reducing the nutrient loadings of agricultural origin will often influence the flow regime and thus also alter the background concentration of natural components.

Conclusions

For the Dutch catchment, the definition given in the progress report 1992 cannot be applied to the background concentration of natural components.

It is time-consuming to estimate the natural loadings under the present flow regime and these data are of little importance. Therefore, the data presented differ from the original definition.

Annex 5

Indications concerning the data on the structure of the Rhine catchment

Swiss data

The data on the structure of the Swiss Rhine catchment area downstream the lakes (**R**h**e**inein**z**ugs**g**ebeit **u**nterhalb der **S**een – REZGUS) used for the present caculations are taken from the Swiss area statistics 92/97 (Bundesamt für Statistik, 1999). This area statistics is based on the interpretation of an aerial photo analysis with a sample network of 100 x 100 m screen aperture and an assignment of 74 categories of uses for the years 1994 to 1996. This method is not directly comparable to the Swiss method of area statistics of 1972 used for calculating the diffuse P and N inputs in 1986. The latter had been carried out by interpreting maps at a scale 1/25,000 and 1/50,000 dating back to the 1960s visually assigning 12 categories of dominant uses in a 100 x 100 m screen aperture. Changes in land use in the REZGUS between 1986 and 1996 do thus not or only partly correspond to actual changes in land use. The 1996 model for substance flow takes into account a total soil surface which is 5802 ha bigger than that of 1986. Only farmland surfaces are taken from the 1986 and 1996 census of agricultural enterprises. Since there were no modifications in the method of statistic survey, these data are comparable. Thus, between 1986 and 1996, farmland increased by 6419 ha (4.6 %).

German data

The German data on soil use are based on the CORINE Land Cover (CLC) survey. In the GIS, these data were blended with the boundaries of the German Rhine catchment downstream Lake Constance.
The regulations on surveying CLC agreed upon throughout Europe take into account 44 classes of soil use, 36 of which can be found in Germany. These classes have been integrated into the classes listed in Table 1. The CLC survey carried out at a scale 1/100.000 with the help of satellite images dating back to the period 1989-1992 was compared to topographic maps, aerial photographs and site visits. Individual objects were only recorded if they are at least 25 ha big and 100 m broad. Thus, rare soil uses or those only extending to small surfaces (e.g. traffic ways outside built-up areas, rivers, small villages and scattered settlements) are partially not recorded, so that their share in the surface is slightly underestimated. Agricultural surfaces and forests are overestimated correspondingly. Compared to the survey of the main uses of soil this may result in an error rate of about 9 %.

French data

Available sources of information
In the last decade, information systems developed considerably, so that today we dispose of 3 main data sources:

The general maps of the „INSTITUT GEOGRAPHIQUE NATIONAL (IGN)“ (scale 1:50.000) completed by data of the Agence de l'Eau and the French ministry of environment

Construction of data bases (BD CARTO; BD CARTHAGE) ready for use for the Rhine-Meuse catchment since 1994.

General agricultural surveys (RGA)

Every 10 to 15 years (last in 1988), the use of agricultural surfaces is surveyed in detail (field scale). The statistical data are updated annually and for each Departement. It is difficult to attribute data to the catchments, as some Departements cover two or three catchments (Rhine, Rhône, Meuse) and the distribution of population density is rather heterogeneous.
The Departements with the main surface in the Rhine catchment (the two Departements in Alsace, the Departements in Lorraine, apart from the Departement Meuse) represent the soil use in this catchment.

Since the surface of the 5 Departements concerned is slightly above the size of the surface of the French Rhine catchment, a 0.916 coefficient was applied to the results obtained.

CORINE LAND COVER

For the northern parts of France, the IFEN (Institut français de l'environnement) has interpreted the SPOT image based data material covering 1989 to 1994. Different exogenous data were used, particularly the BD Carto of the IGN and the national survey of forestry.
The general precision seems to be obtained with maps at a scale 1/100,000 to 1/200,000. The area is entirely covered, but small elements are even less inventoried than is the case with the BD Carthage, and structures such as water surfaces may be considerably underestimated.
Also, the category "heterogeneous agricultural surfaces" (codes 24 …) covers agricultural surfaces and nature areas with a complex division of land.

Conclusions

With a view to obtaining sufficiently representative results, one must fall back on all three information systems. As far as large surfaces are concerned (catchment area, farmland and forests), the data material may be directly used. The data on small scattered areas are systematically below the given facts and need to be corrected.

The table below illustrates the origin of the data for the years 1992 and 1996 and, as far as scattered surfaces are concerned, the gross data and the corrected data:

	1992	**1996**
1. Catchment surface		SIG BD Carthage 23.614 km²
2. Farmland	RGA 10.900	RGA 10.798 km²
3. Forests	SIG BD Carto temporary 8.822	Corine Land Cover 8.829
4. Fallow land	RGA 628 → 1.073	RGA 659 → 1.011
5. Water surfaces	SIG BD Carthage temporary 363 → 518	(SIG BD Carthage) 377 → 578
6. Urban and industrial areas	SIG BD Carto temporary 1.347 → 2.301	(Corine Land Cover) 1.564 → 2.398
Not declared	1.614 (7 %)	1.387 (6 %)

Dutch data

The "Structure of the Rhine catchment" is based on the Dutch LGN-maps (Landelijk Gebruik bestand Nederland). The 40 categories of this map illustrate land use in the Netherlands fragmented to 25 x 25 m. The maps were drafted on the basis of satellite images taken in 1995 and 1997.