Tool and Assessment Method for Determining Flood Risk Evolution or Reduction

- Technical Report -

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Contents

List of figures

List of tables

List of annexes

Document status

*The **ICPR** has developed a **method** to provide evidence of the effects of measures upon the risk of flooding, integrated into a **Geo-Information System (GIS)**.*

*This **Technical Report** (ICPR Technical Report no. 237, 2016) describes the methods and calculation processes of the ICPR tool for demonstrating the change or reduction in flood risk due to measures undertaken. It introduces the tool and the underlying methods, data, indicators and assumptions for future users e.g. other river basin organisations, thereby documenting the procedure.*

*The **Synthesis Report** (ICPR Technical Report no. 236, 2016) contains a summary of the method and the results of calculations undertaken using the GIS tool to demonstrate the change or reduction in the flood risk along the main stream of the Rhine, due to measures undertaken. It also contains an evaluation of the effect of measures and indicators, as well as recommendations for the further use of the tool by the ICPR and by third parties, and stipulations for the wider use of the tool.*

The development of the methodology, the GIS tool and the calculations performed by the tool was undertaken between 2013 and 2016 by the ICPR in collaboration with the consortium HKV Hydrokontor and HKV Lijn in Water. The ICPR Expert Group "Flood risk analysis" of the Working Group "Floods" managed the commissioning.

Note regarding transfer of the tool to a third party:

It is possible for the tool (entitled “ICPR FloRiAn [Flood Risk Analysis])” and its User Guide to be transferred to a third party. This is undertaken in principle free of cost, but with compensation for expenses where applicable.

Future users may work with the tool autonomously. In return, users will be asked to notify the ICPR of how the tool is used (and potentially the results), as well as of any further developments relating to the tool.

If further developments are made to the tool, the ICPR shall receive a free copy.

The transfer of the data used for the calculations and the baseline data (calculation results) shall take place where the owner of the data has provided consent.

Introduction

In 1998, one of the four targets set by the states bordering the Rhine in the Action Plan on Floods (APF, 1998) was to reduce the risk of flood damage by 10% by 2005, and by 25% by 2020, in comparison to the 1995 figures. The ICPR has conducted regular evaluations for the APF. In order to provide evidence of the reduction in the risk of flood damage, a more qualitative method has been used for the years 2000 and 2005 (see ICPR Report no. 157).

The most important objective of the Flood Risk Management Directive (FD; directive 2007/60/EC), valid since 2007, is the reduction of the adverse consequences for human life and health, the environment, cultural heritage and economic activity, associated with floods. An evaluation is also planned within the framework of the regular review of the Flood Risk Management Plan for the International River Basin District of the Rhine (FRMP Rhine Part A) and the implementation of the FD in 6-year cycles. Similarly to the APF, in the future, flood risk evolution should be assessed within the ICPR for the entire main stream of the Rhine, taking into account flood risk management measures that have been implemented.

The ICPR has developed an evaluation tool for reviewing both the APF and the FRMP Rhine Part A. Using the tool developed, calculations relating to the main stream of the Rhine could be carried out by the ICPR for the first time. The results are presented in the Synthesis Report.

The flood risk is the product of the damage potential and flood probability. In accordance with the FD, a distinction is made between human health, the environment, cultural heritage and economic activity.

In order to determine the flood risk for the four receptors, the national details taken from the flood risk maps (FRM) for the Rhine in accordance with the FD (see Rhine Atlas 2015) are used in the calculations. In addition, theoretical, planned or implemented measures according to the categorisation of the FD (see "Guidance for Reporting under the Floods Directive (2007/60/EC)") are reviewed, and their effect on the evolution of the risk is assessed.

In terms of human health, the number of people affected in the event of a flood is used as the indicative parameter.

In terms of the environment and cultural heritage, a different approach is taken, whereby a classification based on the combination of water depth categories and categories relating to the vulnerability of potentially affected protection areas as well as the significance of cultural heritage, is used. This provides a matrix, through which the potential damage can be assessed. In terms of all four receptors, the focus lies upon the direct consequences of, or damage resulting from, flooding[1].

In determining the risk with regard to economic activity, CORINE Land Cover (CLC) land use maps are used together with flood hazard maps (FHM) in accordance with the FD (see Rhine Atlas 2015), which are available for the entire main stream of the Rhine, although the individual states usually use detailed, domestically available land use data. As regards economic activity, a monetary risk is determined based on the flood level with regard to a certain flood probability/return period and existing economical value.

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[1] Estimations of consequential losses e.g. due to interruptions to production are thus not undertaken.

Measures that have an impact on flood risk can be divided into measures with an impact on flood probability and those that have an impact on the potential adverse consequences/damage.

Within the framework of the FD, categories of measures have been established at EU level. For the categories of measures utilised here, the following main classifications apply: "prevention", "protection" and "preparedness". Both categories "prevention" and "preparedness" comprise measures that above all limit the potential impact. For example these involve non-structural measures, establishing/raising awareness, the preparation of forecasts, communication and crisis management. The measures under "protection" primarily have an effect on flood probability change, by lowering the water level, for example, through measures such as retention areas, dike relocations, etc.

In order to monitor the status of the implementation of planned measures, so-called 'indicators' have been defined. These should

1. be representative of larger groups of measures, and should
2. also be measurable using the existing data.

The relationship between the degree of implementation of the measure and the consequences has been defined for each indicator. Where possible, this is undertaken on the basis of quantified data, but also based on expert judgement. The effectiveness of a measure is the result of the combination of its maximum possible effect and the degree of its implementation per time horizon and area.

Geographic Information Systems (GIS) offer excellent opportunities to combine different types of information and data in order to conduct a risk analysis. The ICPR therefore commissioned the consortium HKV Hydrokontor and HKV Lijn in Water to develop such a tool as a GIS application.

Note on the aim and structure of the document

This technical report comprises replicable documentation relating to calculations and procedure, both for the ICPR and for other users of the tool.

It describes the method of calculation – which differs for each receptor (human health, environment, cultural heritage, economic activity), the necessary data, the combination of measures with established indicators, and how the effects of measures are calculated.

Note on the method and data sources: The specific methodology for estimating the flood risks and the impact of measures on the evolution of these risks, and the large-scale communally available data bases used for the Rhine catchment may deviate from the national calculation methods and results (e.g. within the context of flood risk management planning) which are based on a more accurate basis of data.

In addition, there is a **technical handbook** for the **practical use of the tool** (User Guide - see reference at the end of the report), which will be made available to future users.

Further detailed information can be found in the **internal final report** of the consortium[2].

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[2] This is available upon request from the ICPR.

Structure of the document

Sections 1 and 2 describe the general means of calculating flood risk, the specific methods for evaluating the receptors human health, environment, cultural heritage and economic activity, and the assumptions made as regards the methods.

Chapter 3 outlines the range of data required for the use of the tool and contains some recommendations for the collection, formatting and usage of this data.

Chapter 4 contains further details of the flood risk management measures used within the context of the tool, as well as details regarding the use of indicators for the rendering and evaluation of the effect of measures on risk mitigation, the collected information, the established calculation methods and underlying assumptions.

Section 5 describes the tool in detail, and describes the way in which data can be integrated into the tool, the different calculation modules, and some of the ways in which results can be represented (tables, maps). The entire sequence of a standard calculation is also shown. This section is complemented by a specific handbook (User Guide), which is available from the ICPR.

Chapter 6 provides conclusions regarding the use of the tool, the associated calculation procedure and the method. It should be noted that a separate ICPR Synthesis Report (cf. ICPR Technical Report no. 236, 2016) contains the calculation results and specific recommendations.

1. Method of calculating the flood risk

This chapter describes the general method for calculating flood risks, which underpins the use of the tool[3]. The main objective of the calculation is to quantify the change in flood risk as a result of measures undertaken. The APF deals with the evaluation of the measures implemented. A review of planned/future measures to be undertaken is also possible, and has been carried out by the ICPR in conjunction with the FD.

The calculations of the flood risk are carried out using a Geo-Information System (GIS). In the GIS tool[4], the calculations take place at the level of raster cells. During the evaluation, the results of individual raster cells are aggregated at the desired level in a table: e.g. stretches of the Rhine (cf. Annexe 1), municipality, district, region/federal state, or the Rhine as a whole. In the following, the calculations are described at raster cell level in terms of individual events/time horizons. A calculation can subsequently be undertaken comparing different years, in order to evaluate the change or reduction in the risk due to theoretical or actual measures implemented. In the case of the ICPR calculations, the following time horizons were used, in line with the APF: 1995, 2005, 2015, 2020 and 2020+ (~2030).

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[3] The poster in Annexe 2 provides an overview of the structure of the tool, with 4 modules (Model Builders) "Damage assessment", "Risk assessment", "Measure impact" and lastly "Flood risk reduction".

[4] The calculation process was undertaken via toolboxes and ModelBuilders in the GIS-Software ARC-GIS Desktop 10 (= HIRI tool/instrument).

In general, the flood risk is defined as the product of the potential damage and the probability of occurrence (Figure 1 provides an overview of the approach used in the risk analysis).

General formula for flood risk:

Flood risk (€/year or amount/year)

= potential damage to be expected (€ or amount) x flood probability (1/year)

Abbreviated formula: $R = D \times P$

With:

R = Flood risk (€/yr or amount/yr)

D = Damage potentially expected in the event of a flood (€ or amount)

P = Flood probability (1/yr)

The APF mainly addresses the economic damage/risk. However, according to the FD, human health, the environment and cultural heritage should also be evaluated. Human health is expressed in the number of people affected. The environment and cultural heritage are evaluated using a sensitivity matrix in the form of categories (cf. Section 2). The statements in this section refer to the evaluation of economic activity.

In the event of a flood, the level of damage is determined by the flood depth and the land use/properties/receptors/value of goods at the location of the flood.

The flow velocity was not taken into account here in the context of the large-scale approach described. More detailed explanations are provided in the descriptions relating to individual receptors.

In this approach, the FD forms a fundamental basis. The flood hazard maps (FHM), which were prepared under the framework of the FD for the three flood probabilities (HQ10, HQ100 and HQextreme; *hereinafter referred to as "HQhigh", "HQmedium/med" and "HQextreme/ext*"), provide the basis for the water depth. For the calculation of risk reduction, measures from various aspects of flood risk management (prevention, protection and preparedness) are taken into account. These cover the aspects as per the FD (EU Common Implementation Strategy CIS[5]). In order to identify land use and for the calculation of economic damage (or land use development) various CORINE Land Cover data sets (CLC 1990 and/or 2000 for the time horizons 1995 and 2005 and CLC 2006 for the time horizons 2015, 2020 and 2020+) were used, as this database is widely available for Europe, with the exception of Switzerland and Liechtenstein (in the case of individual data sets). For determining the risk to human health as well as for the receptors environment and cultural heritage, the data which the countries had recorded as part of the implementation of the FD for their national flood risk maps (FRM) was used i.e. the data which was aggregated into the Rhine Atlas 2015.

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[5] Cf. "Guidance for Reporting under the Floods Directive (2007/60/EC)- Guidance Document no. 29: A compilation of reporting sheets adopted by Water Directors", Table 10.3-2 (Link: http://icm.eionet.europa.eu/schemas/dir200760ec/resources) and amended list of the LAWA, Older English version: http://www.lawa.de/documents/LAWA_HWRM-Plaene26032010_Text_Germany_ENG_337.pdf)

Flood risk can be affected/influenced in two ways: by changing the flood probability (cf. Annexe 3) and by influencing the potential damage. The modification of flood probability due to water level reduction measures such as retention measures and riverbed enlargement is described in the ICPR Technical Report no. 229 (cf. summary in Annexe 3).

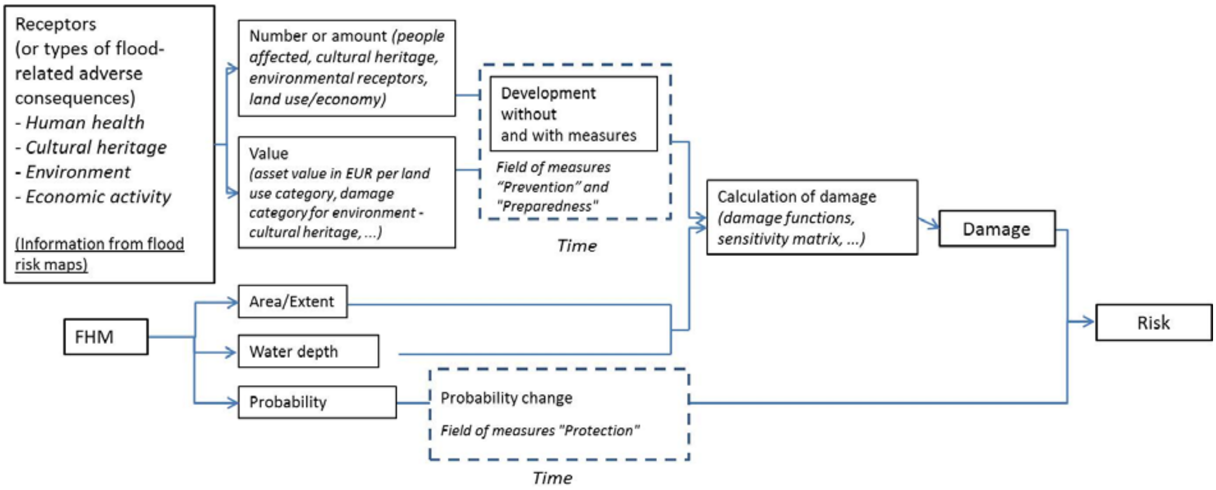

Figure 1: Procedure used for risk analysis

The change in flood risk is related to a reference year. In the case of the APF, this is 1995.

As an example, a calculation for the period between two time horizons (here 2005 in comparison to the reference year 1995) was used. The modification in risk is then calculated for the period between 2005 and 1995 as follows:

$\Delta R_{2005/1995} = (R_{2005} - R_{1995})/R_{1995}$

Damage in this context is understood in the broadest sense as economic damage; as "damage" to human health, to cultural heritage and to the environment. Economic damages are calculated based on the damage functions and the asset values, according to the method from the Rhine Atlas 2001 (Annexes 4 and 5). To meet the requirements of the FD, a different type of evaluation to that of the method used for economic activity is needed for human health, the environment and cultural heritage. Please refer to Section 2 in this regard.

In addition, indicators were determined for each of the categories of measures as per the FD (cf. Section 4). An indicator is a measurable factor; a benchmark that provides a simplification of the actual conditions. An indicator has a reference function – it provides an insight into a particular development. The indicators should be measurable and representative of the different types of measures. They provide the most objective and quantifiable information possible regarding the implementation of measures. For each indicator there is an expected effect that has been estimated and determined on the basis of literature and expert knowledge. The national data collected regarding the implementation of measures (expressed in indicators) provides the degree of realisation of a measure.

$S_{\text{with measure}} = S_{\text{without measure}} \times (1 - \text{effect} \times \text{realisation})$

Example: If the damage without measures is €1,000 and the product of effect and realisation is 20%, then the damage is reduced by €200. So there remains damage of 80%, i.e. 1000 x (1-0.2) = €800.

2. Methods for assessing the risk to human health and the receptors environment, cultural heritage, economic activity; as well as other general capacities of the tool

This chapter explains the methods for assessing the risk to human health, the environment, cultural heritage and the economy as well as the assumptions made as regards the methods.

The methods presented here, which underpin the tool, are based on the implementation of a macroscopic/large-scale analysis of flood risk at the level of the Rhine basin (for four specific receptors), and also on the potential adverse consequences associated with different flood scenarios, their temporal and spatial evolution but also their possible reduction due to the implementation of various measures.

The method presented here can also be applied on a smaller scale, or locally. For this purpose, however, the necessary databases are also to be adapted to suit the desired small-scale level.

The three receptors human health, cultural heritage and the environment are not monetarily evaluated; they are calculated on the basis of expert estimates and specific assumptions in a different way to that used for the receptor economic activity. To this end, the **methods/calculation procedures** of the ICPR were **re-defined**, i.e. the number of potentially **affected people**, **the protected areas or the cultural assets** were calculated based on the water level classes from the Rhine Atlas 2015 [6] (Table 1). These methods are presented in Sections 2.2 – 2.4.

Table 1: Water level classes from the Rhine Atlas 2015

Water level classes	
1	h < 0.5 m
2	0.5 m < h < 2 m
3	2 m < h < 3 m
4	3 m < h < 4 m
5	> 4 m

The receptor economic activity, on the other hand, can be and is evaluated monetarily; on the basis of the combination of various economic information/details with data relating to the water depths (cf. Section 2.1).

2.1. Human health

Human health is quantified using the number of those affected and/or people at risk.

Within the framework of this project, a two-stage approach is developed:

1. Representation of all people affected regardless of the water depth or other parameters. In addition, the number of people affected can be established for the water level classes defined within the context of the ICPR project.

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[6] http://www.iksr.org/en/documentsarchive/rhine-atlas/index.html

2. Establishing the number of people who cannot get to safety or be evacuated (cannot or do not want to do so), using the approach of a state or area-specific safeguarding rate.

The risk is calculated as follows:

Risk for human health = number of people affected x (1 - safeguarding rate) x probability [number/year]

The proposed procedure is illustrated in Figure 2.

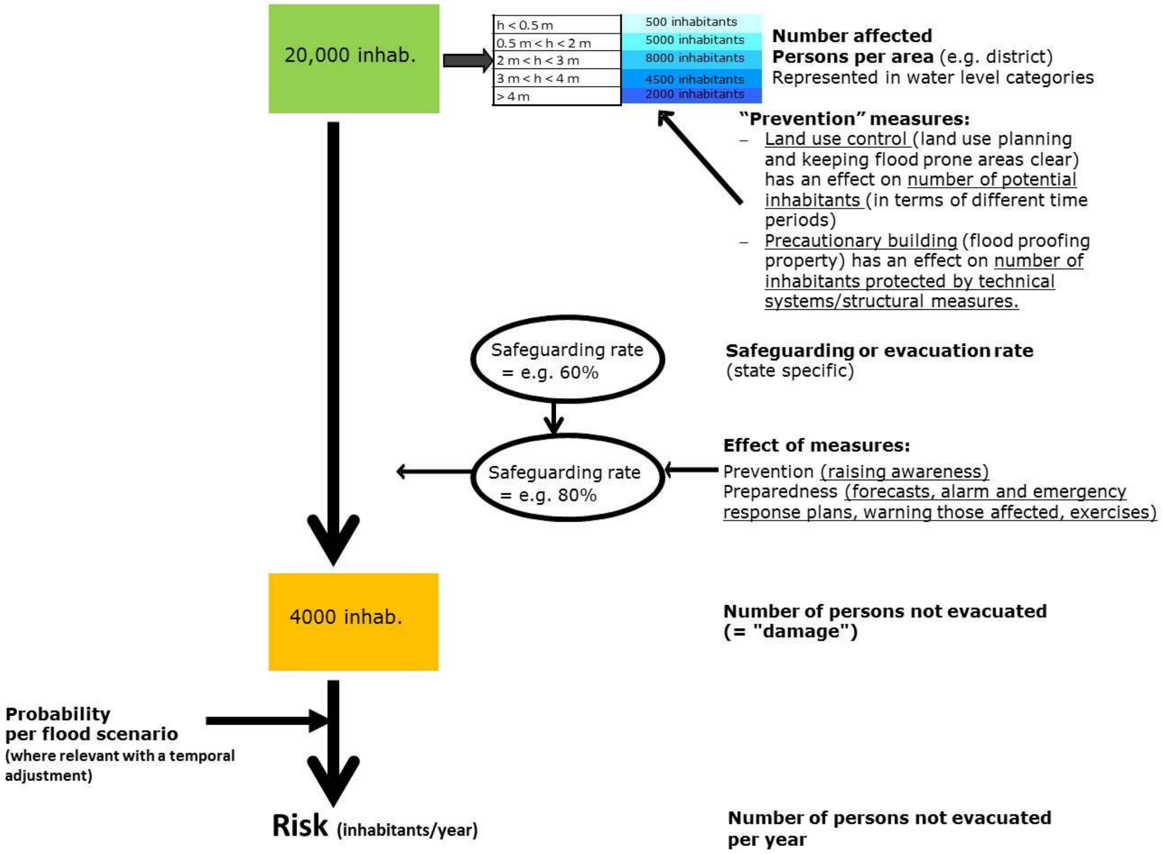

Figure 2: Procedure for the assessment of human health

The population data collected for the 2015 time horizon was taken as a basis (updating of the Rhine Atlas), and calculated for other periods under consideration (scenarios) in alignment with the regionally specific relative changes determined in the table in Annexe 7, meaning that the population evolution in the period 1995 to 2020+ is encompassed (cf. Annexe 8).

The sum of the inhabitants affected in 2015 per flooding scenario is derived from the calculations of the states/regions or federal states, and was supplied during the creation of the Rhine Atlas 2015.

The data relating to the people affected by flooding (Rhine Atlas) is unfortunately not sufficiently detailed in spatial terms that it can be used directly. A realistic spatial distribution was therefore selected, which matched the degree of detail of the CORINE Land Cover data, where the only localisation of people affected was carried out for those situated in built-up areas/urban areas (settlements).

In using this procedure, there may be significant deviation from the numbers of people affected as established in national flood risk management planning documents. For a small-scale, regional analysis, it is technically recommended that recourse is made to the more detailed information from the regional/national flood risk management planning documents.

2.2. Environment

This new method for assessing flood-related risks to the environment[7] assumes that it is not the flood event itself, but rather the negative consequences triggered by the event that cause damage to surface water bodies that have a good or very good ecological status and to receptors/protected areas, in accordance with Annexe IV Number 1 Items i and v of the Directive 2000/60/EC[8]. Negative consequences are understood to be the contamination of bodies of water via IPPC plants, SEVESO operation areas and waste water treatment plants, due to flooding. Possible damages caused by the direct effect of flooding on the environment are not included in the study.

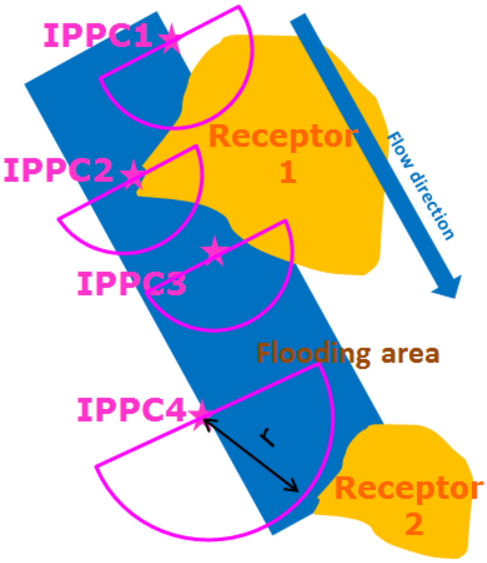

Figure 3: *Representation of the impact of IPPC plants on ecological receptors*

Based on the assumptions made for this large-scale assessment – that damage can only result for a receptor if it is located downstream of a flooded hazardous installation, the hazardous plants IPPC 1 and IPPC 2 are a hazard to receptor 1; whereas plant IPPC 4 is situated – in terms of flow direction – below receptor 1, and therefore poses no threat to receptor 1. Plant IPPC 4 also has no impact on receptor 2, as the impact range (represented by the pink circle) does not reach receptor 2.

With regard to the environment as well, this simplistic approach to the large-scale assessment of flood risks differs significantly in places from the analyses of flood risk for such installations undertaken within the context of national/regional flood risk management planning.

Similarly to the procedure under "Evaluation of the receptor cultural heritage" (see below), a matrix was created for assessing the receptor environment. As explained previously, the impact parameter is described not only in relation to the flood event itself, i.e. the water depth, but also in relation to the resultant hazard/threat from the classified installations and municipal waste water treatment plants (cf. Table 3).

The information on waste water treatment plants (shapefile) is also used by the ICPR in addition to the information regarding nature and drinking water protected areas.

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[7] This simplistic approach to the large-scale assessment of flood risks differs significantly in places from the analyses of flood risk for such installations undertaken within the context of national/regional flood risk management.

[8] Areas identified for the extraction of water for human consumption; areas which are identified for the protection of habitats or species, (...) including the Natura 2000 sites (...). Annexe IV, Number 1 iii) was not taken into consideration here.

The following tables are exemplary in describing the procedure developed by the ICPR.

Table 2 indicates the scale and criteria of ecological sensitivity and the regenerative capacity of an environment-related receptor.

In agreement with the ICPR Working Group Ecology, the following relative weightings for sensitivity for the three receptors were formulated (1 = lowest and 3 = greatest sensitivity) (cf. Table 2):

- Drinking water and water source protection areas: greatest sensitivity (= 3). Reason: these areas are of primary importance for the supply of drinking water, i.e. relevant to human health.
- Water-dependent flora & fauna habitat protected (Natura 2000) areas: medium sensitivity (= 2); reason: these areas form important habitats for water-dependent flora and fauna. Water pollution would affect more species than in a bird protected area.
- Water-dependent bird protected areas: low sensitivity (= 1). Reason: here, the negative consequences of water pollution are mainly limited to bird species (in contrast to Natura 2000 sites).
- WFD surface water bodies (and ecological status of water bodies): medium sensitivity (= 2); according to the WFD, 5 status classes are defined. However, only surface water bodies with a good or very good ecological status are considered here, because for these water bodies, flooding from IPPC plants would mean that the required WFD 'good' status would not be attained.
- Other: various other undefined receptors. Here, the lowest sensitivity category is allocated (=1).

Table 2: Criteria for assessing the ecological sensitivity of water-related receptors

Scale		**Sensitivity criterion**	**Environmental receptors**
Quantitative	**Qualitative**		**Description**
1	low	low ecological sensitivity	Water-dependent bird protected areas, other (various other undefined environmental receptors)
2	intermediate	intermediate ecol. sensitivity	Water-dependent flora & fauna habitat protected areas, surface water bodies (WFD)
3	high	high ecol. sensitivity	Drinking water and water source protected areas

At this point reference is again made to the fact that the method developed here and the associated assumptions are based on expert estimates. This simplistic approach to the large-scale evaluation partially differs from the approaches in the national/regional flood risk management planning documents (cf. box below). For a regional analysis, it is useful, where applicable, to take into consideration the relevant information and approaches from the regional or small-scale flood risk management planning documents.

Example in Baden-Württemberg:

In Baden-Württemberg, during the analysis of the effects of flooding in IPPC plants, no differentiation was made for the sensitivities of the potentially affected protected areas, as it can be assumed that in agricultural areas in particular, soil decontamination will be necessary. Independently of the impact of the flooded IPPC plants, for the Natura 2000 sites, the specific sensitivity with regard to flooding was analysed by specialists. In doing this, it became clear that even without particular pollution from IPPC plants there was an increased risk in one section of the area, as habitats were considerably disturbed (for example the large blue). This risk can be reduced as part of the Natura 2000 planning measures.

Four classes are shown in Table 3 (below) as regards the impact which, in addition to the water depth, can be described using the risk categories of the IPPC directive and the contamination potential (toxicity) of the substances and materials present in the plant. For IPPC plants, only one of the six major categories of plant as per the IPPC Directive is used. A further two categories are used for operational areas in accordance with the Seveso Directive (quantity threshold high SEVESO 2 and low SEVESO 1 - cf. Annexe I of this directive), and another for municipal waste water treatment plants (water treatment plants of all capacities, i.e. for all population equivalents), meaning that a total of four plant types occur (cf. Table 3).

The hazard is described using a scale, and in terms of the practical application of the tool, the "negative consequences" of the plants are intersected with the receptors. The negative consequences are defined using the flow direction, in line with pollutant dispersal and transport models, via an impact range (distance of a hazardous source to the receptor). The dispersal of pollutants in the event of flooding is particularly dependent on material properties, on packaging, storage conditions and the failure of safeguards. For simplicity, it is generally assumed that independently of hydraulic properties, an increasing concentration gradient and pollution also entail the increase of the impact range. The impact range was established on the basis of a theoretical assessment of the potential overall ecological risk by the ICPR. Here, a SEVESO plant was generally perceived to be more hazardous than an IPPC plant. The materials present in each individual case and their quantities were not taken into consideration here. This is an estimate, which is nevertheless classified by the ICPR as realistic, but has not (yet) been proven through scientific studies.

Table 3: Scale and criteria for describing the impact on the receptor "environment"

Scale (pollution potential)		**Criterion**	
Quantitative	**Qualitative**	**Type of installation**	**Impact range, km**
2	intermediate	IPPC	10
3	high	SEVESO1	20
4	very high	SEVESO2	50
2	intermediate	Waste water treatment plant	10

As both the water depth and the pollution potential[9] existing in the substances present in the hazardous/exposed installation determine the impact on the receptors, a threat/exposure matrix (Table 4) is formed from Table 3 (pollution potential) and Table 1 (water level classes: physical impact).

Table 4: Threat matrix

Contamination potential	**Physical impact (water depths)**				
	1 h < 0.5 m	2 0.5 m < h < 2 m	3 2 m < h < 3 m	4 3 m < h < 4 m	5 > 4 m
1	1	1.5	2	2.5	3
2	1.5	2	2.5	3	3.5
3	2	2.5	3	3.5	4
4	2.5	3	3.5	4	4.5
5	3	3.5	4	4.5	5

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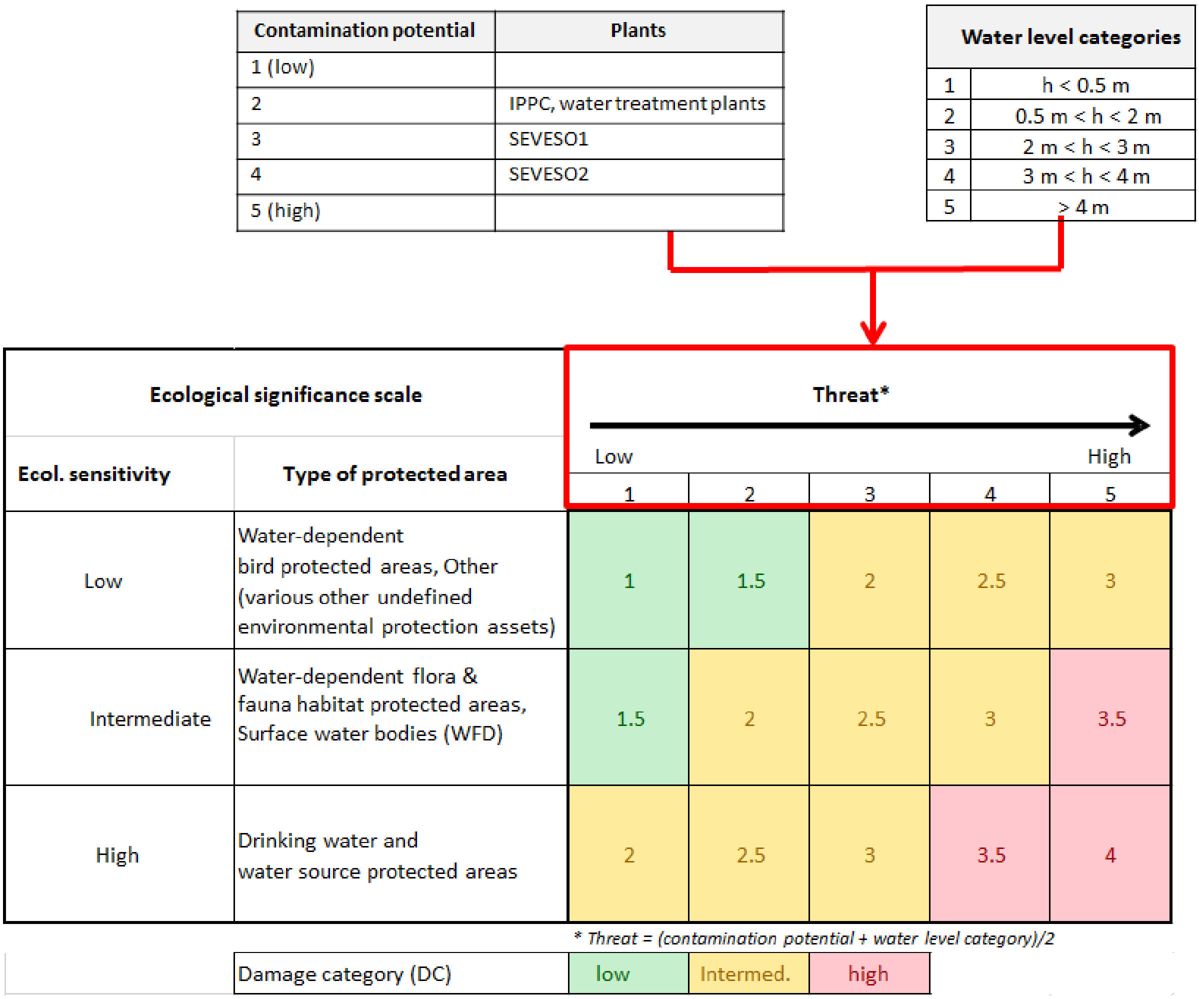
[9] NB: The "pollution potential" corresponds to the quantitative scale in Table 3.

The assessment of the ecological damage (cf. Table 5) is derived from the threat matrix (cf. Table 4) and the ecological sensitivity (cf. Table 2), with the direction of flow taken into account[10].

Table 5: Method of assessing the damage to the environment



Contamination potential	Plants
1 (low)	
2	IPPC, water treatment plants
3	SEVESO1
4	SEVESO2
5 (high)	

Water level categories	
1	h < 0.5 m
2	0.5 m < h < 2 m
3	2 m < h < 3 m
4	3 m < h < 4 m
5	> 4 m

Ecological significance scale		Threat*				
		Low				High
Ecol. sensitivity	Type of protected area	1	2	3	4	5
Low	Water-dependent bird protected areas, Other (various other undefined environmental protection assets)	1	1.5	2	2.5	3
Intermediate	Water-dependent flora & fauna habitat protected areas, Surface water bodies (WFD)	1.5	2	2.5	3	3.5
High	Drinking water and water source protected areas	2	2.5	3	3.5	4

* *Threat = (contamination potential + water level category)/2*

Damage category (DC)	low	Intermed.	high

2.3. Cultural heritage

In accordance with the Rhine Atlas 2015, data for the **four different material cultural heritage types**: UNESCO World Heritage Site, monuments, protected urban areas/sites and others, was provided (see further explanations in the background document on the 2015 Atlas). The ICPR developed a methodology for evaluating the receptor cultural heritage, which is based on the importance and vulnerability of the different types of cultural heritage. The methodology is based on the procedure developed within the framework of the Federal Ministry of Education and Research [BMBF]-funded research project XtremRisk (Dassayanake, 2012). A simplified method was developed based on the aggregated database in this project for the large-scale assessment of flood risks.

The selection of cultural assets and their classification in terms of "significance" may therefore deviate from the approach within the framework of national/regional flood risk

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[10] NB: The pollution potential was established for the plants specified in Table 3, and the sensitivity of the protected areas is shown in in Table 2. Dividing by 2 the sum of the pollution potential and physical impact produces the threat/exposure value, e.g. if the pollution potential = 3 and water depth = 2, the sum = 5 divided by 2 = 2.5.

management planning – in places considerably[11]. For a regional analysis, it is technically recommended that recourse is made to the more detailed information in the relevant flood risk management planning documents.

Table 6 provides an overview of the qualitative and quantitative significance of the different cultural heritage types in terms of the evaluation criterion of spatial significance.

Table 6: Cultural significance of historical cultural assets

Description	Significance		Criteria
	Quantitative	Qualitative	
UNESCO world heritage site	3	high	international significance
Protected urban areas/regions	2	intermediate	national significance
Monuments	1	low	local significance
Other			

The classification and the criteria for physical impact caused by hydrostatic impounding (water depth) and/or low flow rates (< 2 m/s) were adopted by Dassayanake (2012) in a slightly modified form.

By combining the significance of cultural heritage (Table 6) with water depth (Table 1), the matrix for assessing the damage to cultural heritage is produced (Table 7). Cultural assets with low significance in water levels of less than 2 m can expect a low level of damage, whereas water levels of 2 m or more lead to medium or high levels of damage.

Table 7: Method for evaluating cultural damage

Cultural significance scale	Physical impact scale (water level)				
	1 h < 0.5 m	2 0.5 m < h < 2 m	3 2 m < h < 3 m	4 3 m < h < 4 m	*5 > 4 m*
1 local significance (monuments, other)	🟩 1	🟩 1.5	🟨 2	🟨 2.5	🟨 *3*
2 national significance (protected urban areas/regions)	🟩 1.5	🟨 2	🟨 2.5	🟨 3	🟥 *3.5*
3 international significance (UNESCO world heritage site)	🟨 2	🟨 2.5	🟨 3	🟥 3.5	🟥 *4*

Damage category (DC)	🟩 low	🟨 intermediate	🟥 high

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[11] For example, in the German federal state of Baden-Württemberg, archives are understood to be cultural assets. These are very sensitive to flooding in general, and cannot be recovered – or only at considerable expense. For the destroyed Cologne city archive alone, it is estimated that it would take 6000-6,500 person-years to restore the partially destroyed archival material (for details see http://www.stadt-koeln.de/leben-in-koeln/kultur/historisches-archiv/der-wiederaufbau-der-bestaende).

2.4. Calculation formula with regard to environment and cultural heritage

In terms of the environment and cultural assets, the evaluation of damage is undertaken per damage category. As an example, the formula for calculating the sum of the cultural damage for the damage category (DC) is shown. The calculation of the ecological damage is undertaken in a similar way:

$$S_{sum_{cult}} = \sum_{i=1}^{k} AZ_i \times S_{cult(i)}$$

whereby:

S_{sum_cult}= sum of cultural damage

i= number of the cell associated with a a municipality/a study area

AC_i = Amount of cells (i) with cultural damage, situated within a municipality

$S_{cult(i)}$ = cultural damage per cell (i), situated within a municipality. The calculation of the sum of the cultural damage across all damage categories is undertaken in the same way. The calculation of the cultural damage with measures and of the cultural risk is undertaken in accordance with the definitions above.

2.5. Economic activity

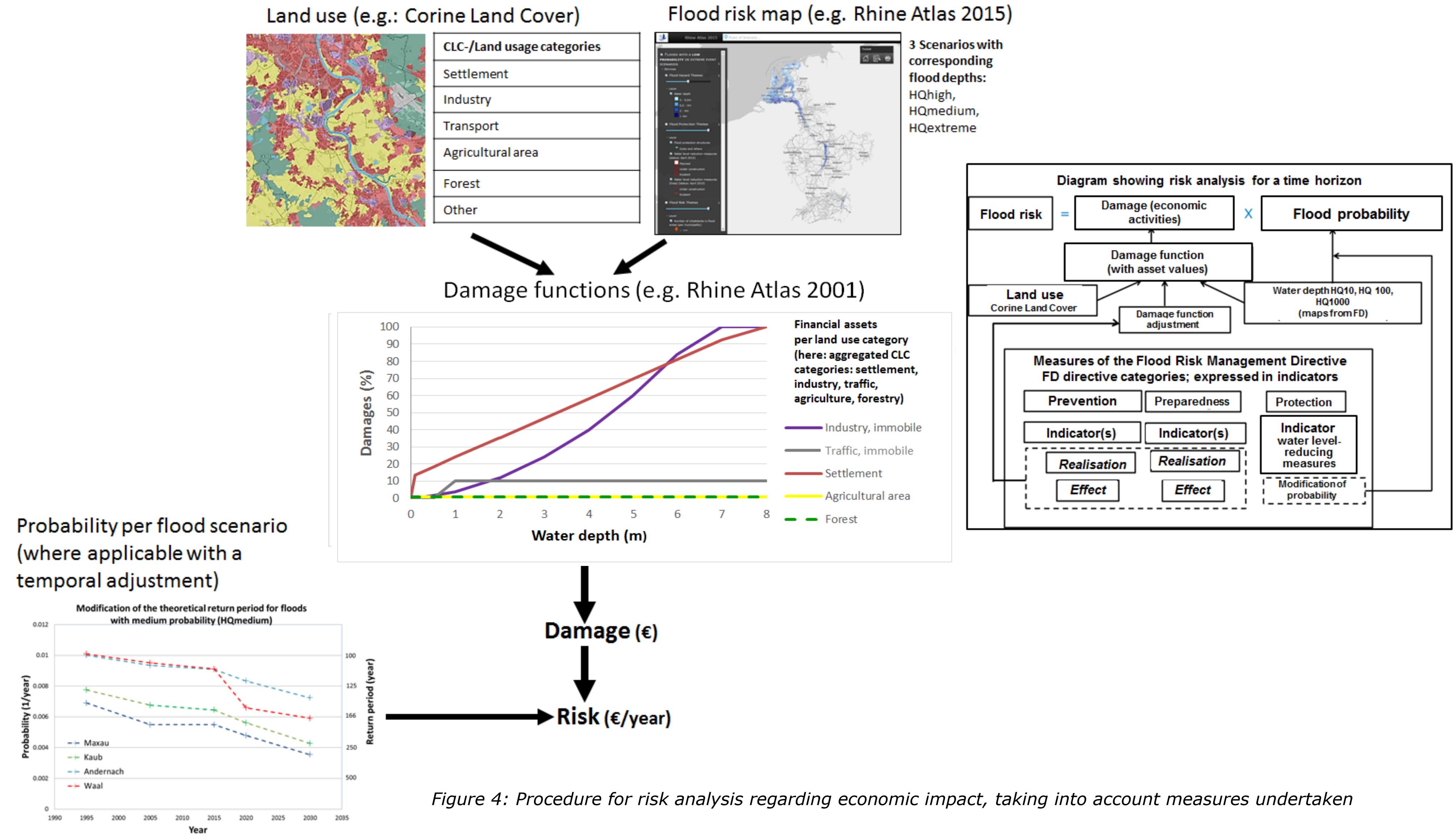

Figure 4: Procedure for risk analysis regarding economic impact, taking into account measures undertaken

The determination of the **potential economic damage** is based on knowledge of the relationship between water depth and the resulting damage; the so-called damage functions. Within the framework of the ICPR, the direct economic damage potential is calculated similarly to the Rhine Atlas 2001, in order to achieve comparability with the previous calculation results. Economic damage due to production stoppages in the affected businesses or due to the interruption of supply chains is therefore not taken into account. This damage may sometimes, for example in the automotive sector, exceed the direct potential damage many times over. Within the context of the large-scale analysis of flood risk proposed in this project, the data necessary for such considerations is not available. Where the approach is used on a small-scale level, the technical recommendation is that this aspect is taken into account.

In terms of regional analyses, as a rule, the databases available – which are usually considerably more detailed – should be used. In this way, the potential damage in different countries/federal states, for example, can be calculated on the basis of specific/detailed land use data or usage information for individual buildings. This method enables statements that are considerably more detailed.

The flood depths are the input variables for application in the damage functions pertaining to the usage. The damage functions from the Rhine Atlas 2001, which are presented as a formula in Annexe 4, or graphically depicted below, are adopted in an unchanged form for the land-use categories.

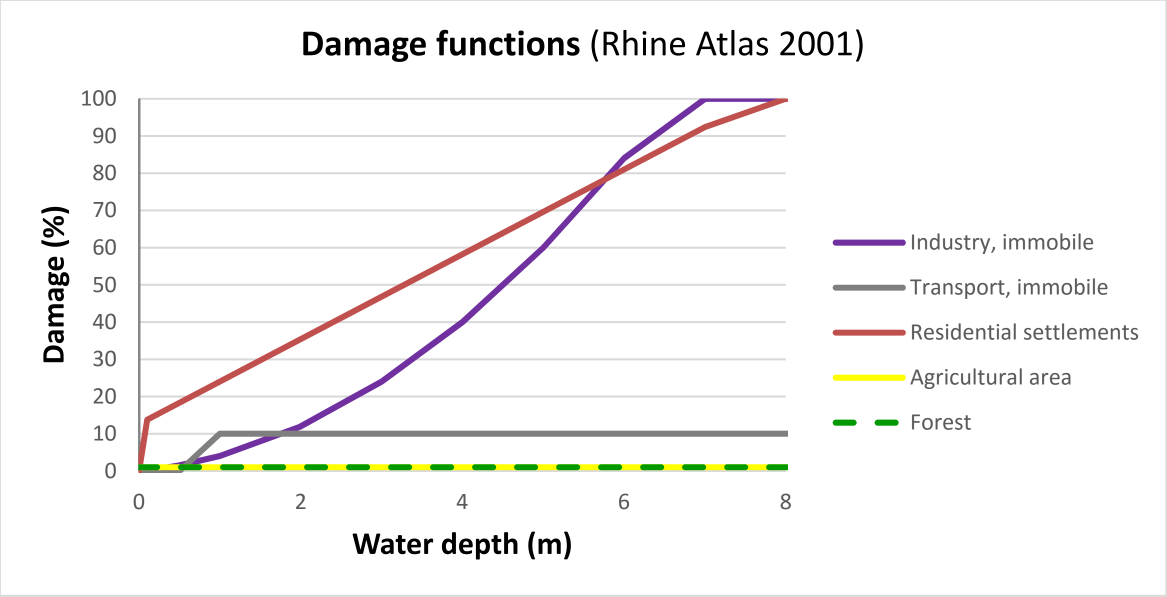

Figure 5: Damage functions Rhine Atlas 2001

The specific asset values from the Rhine Atlas 2001 (cf. Annexe 4) are adjusted for each evaluation horizon, on the basis of economic growth and/or the consumer price index at a regional level (states or federal states) (cf. Section 3.2.4).

The **economic damages** are calculated per raster cell using the following formula:

Potential damage = asset value (for each land use category; €/m^2*) x damage function "water depth - damage" (for each land use category) x raster cell (flood area or flood extent) for 3 flood scenarios and corresponding water depth data)*

Abbreviated formula: D_{Cell}=Asp(LU) x Y(WD,LU) x RC

With:

D_{Cell} = Potential damage in event of flood per raster cell (€ or amount)

Asp(LU) = Specific asset value per land use (LU) (€/m^2) (Annexe 5)

Y(WD,LU) = relative damage function (%), function from (WD) water depth and (LU) land use (Annexe 4)

RC = Area of raster cells, in present case 100m x 100m

The designation of specific asset values and the damage functions is based on the CORINE land cover data. The individual land uses are allocated in accordance with the categories of the Rhine Atlas 2001 (cf. Annexe 4). Through the intersection of hydraulic, economic and macroeconomic information in a geographic information system (GIS) and the application of damage functions, the potential damage in €/m^2 can be shown and the sum total can be calculated.

The **effect of the measure** is integrated into the calculation through a modification of the damage function. Depending on the measure, the modification of the function can be water depth-dependent, or incorporated by a set factor, independently of water depth. In section 4 an explanation is provided for each individual measure as to how a damage function changes as a result of a measure.

The **risk** is then calculated separately for all three scenarios (frequent, medium and low probability) for all time horizons (1995, 2005, 2015, 2020 and 2020+).

The formula for the flood risk is described in Section 1: *Flood risk (€/yr) = potential damages (€) x flood probability (1/yr)*

Moreover, the so-called **integral risk or the yearly expected value** is calculated. For this calculation, the damages calculated for the three probabilities of occurrence are combined into one yearly expected damage value (i.e. the average annual risk over a longer period). Here, there is no addition of the individually calculated risks for the three scenarios, but a separate (extra) calculation according to the mathematical formula provided below.

$$YDE = \frac{1}{T_{HQext}} * \mathrm{DHQext} + \left(\frac{1}{T_{HQmed}} - \frac{1}{T_{HQext}}\right) * \frac{\mathrm{DHQmed} + \mathrm{DHQext}}{2} + \left(\frac{1}{T_{HQhigh}} - \frac{1}{T_{HQmed}}\right) * \frac{\mathrm{DHQhigh} + \mathrm{DHQmed}}{2}$$

(Source: HKV, 2006)

whereby:
YDE = Yearly damage expectation
T^x = Probability of occurrence for HQ_x discharge
HQhigh = Discharge for frequent event

HQhigh = Discharge for medium event
HQext = Discharge for extreme event
DHQext, med, high = Damages for all 3 flood scenarios.

In a similar way, for the separate risk calculation, the **change in risk** can be calculated on the basis of the differences in the ADE for the reference year (1995) and the further periods under review.

2.6. General possibilities, assumptions and limitations of the tool and the methods

Note regarding general possibilities, assumptions and limitations of the tool and the underlying methods (details can be found in the corresponding sections):

- The tool was developed for large-scale flood-related analyses at river basin/river district level, and for the four receptors calculates the potential damage and the risk per flood scenario as well as the integral/total risk. It enables these calculations to be carried out with or without the effect(s) of one or more measures. If these calculations are carried out for different time horizons, the evolution or modification of the potential damage or risk can be calculated using the output data of the tool. The output data of the tool comprises maps or tables.
- The tool and the methods are closely aligned with the requirements of the FD: human health, the environment, cultural heritage and economic activity, the three defined flood scenarios, types of measures such as prevention, protection and preparedness; this means that to a certain extent corresponding data is required.
- A limited number of flood risk management measures were implemented in the tool. These are fed in via indicators, meaning that not all individual measures can be considered. Specific methods and data for the indicators with many assumptions based on expert knowledge (cf. Section 4).
- The monetary risk for the economic activities is based on land use, damage functions "water depth - damages", asset values and the consumer price index. If other parameters are to be calculated, the user should adjust the information in the input data (e.g. for land use). Specifically developed methods for human health, the environment and cultural heritage are in part strongly based on expert knowledge and cannot be assessed in monetary terms. It is not possible to use other calculation methods in the tool, but it is anticipated that other/different input data such as other land use data and damage functions could be used. Specific data is required such as cultural assets, IPPC plants, nature conservation areas, ...
- This tool does not conduct cost-benefit analyses, but it is possible to use the output data produced by the tool for cost-benefit analyses.
- The processing of input data and the post-processing of the output data are undertaken outside of the tool, and require specific GIS knowledge.
- For the application of the tool, ArcGIS with Spatial Analyst and GIS knowledge are required, as well as an understanding of the methods developed by the ICPR.

3. (Input) data for use of the tool

The subject of this section is a summary of the necessary data, its format and preliminary instructions regarding the pre-processing of the data for the tool. For third party users, this ICPR data processing is an example of the processing of the input data. Within the framework of the ICPR project, data was collected for the three flood scenarios HQ10, HQ100 and HQextreme, as well as for the time horizons 1995, 2005, 2014/2015, 2020, 2020+ (~2030). Annexe 10 contains a summary table with details of the data supplied, important notes and information on limitations.

The necessary data regarding the measures/indicators is outlined here, but explained in detail in the next section. The indicators are also defined in Section 4.

3.1 General

Table 8 contains the list of digital data to be used in the tool. With regard to the data formats, within the framework of updating the Rhine Atlas (Rhine Atlas 2015) data templates were created by the BfG (German Federal Institute of Hydrology) (cf. ICPR document GIS(3)13-04-02d as well as the Wasserblick system), which dictate the structure and/or designation of the data. These predefined templates and shapefiles/data formats can also be used by third parties, thereby facilitating the use of the tool (no new data formatting). An example of such shapefiles can be found in Annexe 9.

Much of the data in the ICPR project is derived from the Atlas 2015 data. The rest was taken either from the ICPR's own databases (damage functions or asset values; see Annexes 4 and 5), European databases (e.g. CLC land use, waste water treatment plants) or national databases (e.g. population statistics, the consumer price index). The areas deemed to be risk areas are those officially identified as per the FD (cf. ICPR FD reports here http://www.iksr.org/en/floods-directive).

All of the geo-data was then represented in the coordinate system GCS_WGS_1984, meaning that where necessary, the data supplied had to be projected and/or transformed.

Table 8: Necessary and supplied data

Necessary and supplied data		
Data	**Relevant for...**	**Who/where?**
General	Overview	
Topographical data		ICPR
Administrative/political boundaries		ICPR
Rhine kilometre marking		ICPR
Flooding depth and probability		
Flooding rasters 3 scenarios, 2015 period	Damage potential	WasserBlick/Rhine Atlas 2015
Flooding polygons 3 scenarios, 2015 period	Damage potential	WasserBlick/Rhine Atlas 2015
Flood probabilities - Alpine Rhine to Iffezheim	Damage risk	ICPR
Flood probabilities - Iffezheim to Lobith	Damage risk	IKSR-HVAL
Flood probabilities - Lobith to Delta Rhine	Damage risk	IKSR-HVAL
Receptor "human health"	Damage potential, psychosocial	
Inhabitants 3 scenarios, 2013/2014 period		WasserBlick/Rhine Atlas 2015
Population change/prognosis		Statistical offices of the federal states/countries
Evacuation rates		Federal states/countries
Damage function population (not used)		*HKV*
Receptor "environment"	Damage potential, ecological	
Drinking water protection and abstraction areas (shp files)		ICPR (WFD)/WasserBlick/Rhine Atlas 2015
Bird protection areas		ICPR (WFD)/WasserBlick/Rhine Atlas 2015
Natura 2000 sites		ICPR (WFD)/WasserBlick/Rhine Atlas 2015
IPPC plants (shp files) and/or SEVESO operations (shp files)		ICPR (WFD)/WasserBlick/Rhine Atlas 2015
Waste water treatment plants (shp files)		ICPR/EEA (or national databases)
Receptor "cultural heritage"	Damage potential, cultural	
Cultural assets (shp files)		WasserBlick/Rhine Atlas 2015
Land use		
CORINE Land Cover 1990, 2000, 2006	Damage potential	ICPR/EEA, CH + LI or in the future, directly from WasserBlick/Rhine Atlas 2015
Receptor "economic activity"	Damage potential, economic	
Economic growth scenario 2020/2020+		Federal states/countries
Damage functions Rhine Atlas 2001		ICPR
Specific asset values Rhine Atlas 2001		ICPR
Measures/indicators		
Effects of measures		Literature/ICPR/HKV
Measures that are non-water level-reducing with realisation factors, georeferenced	Damage potential/damage risk	Federal states/countries
Flood protection infrastructure	Damage risk	WasserBlick/Rhine Atlas 2015

For measures and indicator data: Table 9 indicates the units, level, time periods and formats that should be supplied in terms of the information on the measures (indicators). The accompanying survey is provided in Annexe 6. The data on the measures is delivered as xls spreadsheets or directly as shapefiles for the individual time horizons. Examples of xls tables or indicator shapefiles are available on request from the ICPR (cf. Annexe 9).

Table 9: Unit, scale and format of the indicators

No.	Type of measure	Indicator	Unit of indicator	Unit	Preferred format	Scale / magnitude
I Prevention						
I.1.1	Spatial planning, regional planning and land use planning	Building regulations/building development plans, in which requirements for flood protection are contained (flood-adapted construction)	Expanse of area in which flood-adapted construction is regulated by building development plans [m²] and percentage of the municipality area for which development plans with these types of regulations exist.	m²	Polygon shapefile (alternatively data in % in the form of a table)	Municipality or higher level
I.1.2	Keeping flood prone areas open/clear and adapted usage of areas	Modification of land use data (CLC data) within and outside of the flooding areas of the FHM under analysis.	Modification of land use [m²]	m²	CORINE Land Cover data or detailed land use data CLC: Scale /magnitude 100 *100 m raster	
I.3.1	Flood-adapted design, construction, renovation	Measures implemented regarding flood-adapted development/building	Unit of indicator: Measures implemented in %.	% (realisation)	Polygon shapefile or table	Municipality or higher level
I.3.2 - Receptor "economic activity/cultural heritage"	Precautionary building/flood-proofing property for households/municipalities	Protected areas due to precautionary building/flood-proofing property and/or mobile systems	Unit of indicator: Polygon with the area protected by the flood-proofing of property or mobile systems [m²]	m²	Polygon shapefile (alternatively data in % in the form of a table)	Municipality or higher level
I.3.2 - Receptor "environment"	Precautionary building/flood-proofing for installations at risk	Protected installations due to technical protection, precautionary building/flood-proofing property and/or mobile systems	Unit of indicator: List of installations that are protected/not protected.	Per installation: protected/not protected	Point shapefile (alternative data in the form of a table with geo-localised information regarding the installations)	IPPC, SEVESO installations (information from the Atlas 2015) and waste water treatment plant data
I.3.3 - Receptor "economic activity/cultural heritage"	Flood-proof storage of water-polluting/hazardous substances for households/municipalities	Securing of oil tanks and/or safe storage of water polluting substances in upper storeys	Unit of indicator: Number of households (as proportion of affected households in %), that have secured oil tanks or stored water polluting substances in upper storeys (per municipality) (survey results Bubeck)	% (realisation)	Polygon shapefile or table	Municipality or higher level
I.3.3 - Receptor "environment"	Flood-proof storage of water-polluting/hazardous substances in hazardous installations	Safeguarding of oil tanks and/or safe storage in upper storeys	Unit of indicator: List of installations in which secured oil tanks are safeguarded or pollutants are stored in upper storeys.	Per installation: Securing of oil tanks and/or safe storage of water polluting substances in upper storeys YES /NO	Point shapefile (alternative data in the form of a table with geo-localised information regarding the installations)	IPPC, SEVESO installations (information from the Atlas 2015) and waste water treatment plant data
I.4.1	Provision of flood hazard and risk maps / establish awareness for precautionary behaviour, education and preparation/preparedness for flood events	Frequency/update intervals with regard to information campaigns	Unit of indicator: Update frequency of information campaigns (years)	various	Polygon shapefile or table	Municipality or higher level
II Flood protection						
II.2	Retention measures	Modification of probability (data ICPR Expert Group HVAL)		Modification of probability and localisation	Polyline, point, polygon SHP	Stretch of river/gauge
II.3	Dykes, dams, flood walls, mobile flood protection, ...	For these measures, a probability is also indicated: Percentage evolution/modification of flood probability between 1995 and present day due to improvements in protection		Localisation, renewals, modification of probability due to improvements in protection (%)		Stretch of river
II.5	Maintenance/renewal of technical flood protection systems			Localisation, renewals, modification of probability due to improvements in protection (%)		Stretch of river
III Preparedness						
III.1.1	Flood information and forecasts	Improvement in flood forecasting within defined time period	Unit of indicator: Forecast period in hours/days as well as further aspects	various	Polygon shapefile or table	Federal state/state
III.2.1	Alarm and emergency response planning (incl. recovery/aftercare) /warnings for those affected/exercises/training	Presence and update frequency of alarm and emergency response plans number of warning systems (warning methods/ways and communication means) details of civil protection/crisis management exercises including frequency	Unit of indicator: number of systems and update frequencies	various	Polygon shapefile or table	Municipality or higher level

3.2. Clarifications regarding the data supplied and data processing

Here, further details are provided regarding the data processing used within the framework of the ICPR project for the calculations for the time horizons 1995, 2005, 2014/2015, 2020 and 2020+. These may also be exemplary, and as such, relevant to external users of the tool. Annexes 10 and 12 provide an evaluation of the data, and reference is made to the corresponding/specific assumptions and limitations.

3.2.1. Land use data - CORINE

The CORINE data was downloaded from the website of the European Environment Agency (http://www.eea.europa.eu/). There are three sets of data available in different formats (GeoTIFF or shapefile) for the time horizons 1990, 2000 and 2006[12]. The data records cover the entire Rhine catchment area up to Switzerland and Liechtenstein (only the record from 1990 is missing).

For Switzerland and Liechtenstein, land use data was submitted which was aligned with the methodology and nomenclature of the area determination of the CORINE data.

Data preparation

The land use data supplied was reviewed and standardised with respect to its projection and nomenclature, meaning that it could be aggregated into one complete data set for each of the time horizons 1990, 2000 and 2006.

The data from Liechtenstein was not used for generating the record for 1990, because it was supplied too late. Instead, the raster cells from the 2000 record were integrated into the record from 1990, and adjusted at a later date with the newly supplied data. As hardly any changes have taken place in the part of the Rhine basin located in Liechtenstein, no further changes were made.

As a result of the processing of the CORINE data, three raster data sets (1990, 2000 and 2006) are available; these are projected in a uniform manner with a raster width of 100 m for the Rhine basin.

Note: When evaluating the results it became clear that a comparison of the time horizons 1995, 2005 and 2015 was difficult due to the use of different CORINE records (the quality of the 1990 CLC data seems to be lower than that of the 2000 CLC; the same applies to the data of the 2000 CLC, which is of a lower quality than that of the 2006 CLC.) After the conclusion of the contract with HKV, the ICPR therefore carried out a supplementary comparison of the damage and risk evolution using the CORINE records (2006 CLC) for all time horizons. In this way, it was possible to avoid calculation artefacts due to a changed quality in the survey methods. This enabled an evaluation in terms of the achievement of the objectives of the APF (action target 1).

3.2.2. Water depths

The water depth raster for the three scenarios was prepared for the current conditions (2014/2015) under the framework of the Rhine Atlas 2015, on the basis of data supplied by the states and federal states, prepared by the BfG and made available by the ICPR.

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[12] Note: it was not the aggregated CLC 2006 data sets - as represented in the Rhine Atlas 2015, that were used, but rather the raw CLC2006 data sets from the EEA (see Annexe 4).

This data was used for the calculations in the sensitivity analysis (cf. Section 4.7). When analysing the results, it was apparent that the data was inconsistent in terms of the raster width, the affected area (e.g. Area HQ100 < Area HQ20) and the water depth (e.g. WD HQ20 > WD HQ100). This is partly due to errors in the individual national data sets of the relevant countries, and partly to the merging of the individual rasters to form an overall raster for the Rhine catchment area. New water depth rasters were created by HKV on behalf of Rijkswaterstaat, on the basis of the national data sets (HKV, 2015).

Data preparation

The national records of the different countries and federal states were firstly analysed – taking into account the units of water depth, the spatial resolution, the data format, the projection used and the data type.

In a second stage, the country-specific data sets were standardised with the aid of ArcMap, by implementing a common format according to the specifications, within the context of a subsequent processing level.

This firstly involved the conversion of the vector data provided by France (FR), Liechtenstein (FL) and Switzerland (CH) into raster data with a preliminary spatial resolution of 20x20 m, which corresponds to the resolution supplied in the raster data of the other countries.

The water depth rasters for all countries were subsequently standardised using a uniform unit (cm), with the exception of the Netherlands (NL) and Hesse (DE-HE), which did not require conversion.

The water depth raster supplied from Austria (AT) for the scenario HQext had to be adjusted for the *NoData* values integrated in the raster (value = 999), by declaring as *NoData* all pixels with the value 999, and thus reducing the range of the data set to the values 0-100 as a result.

The data set provided by North Rhine-Westphalia (DE-NW) was also re-projected from ETRS 89 / UTM 32N (EPSG: 25832) into ETRS 89 / ETRS LAEE (EPSG: 3035) and along with the Baden-Württemberg (DE -BW) data set, was converted from the data type *floatingpoint* into the data type *integer*, in order to eliminate unwanted artefacts of the now unnecessary decimal places – due to the conversion of the units.

After this necessary pre-processing, the data sets for each country were combined to create a comprehensive raster for the entire Rhine catchment area, corresponding to the three scenarios HQhigh, HQmedium and HQextreme.

Water depths of 0 cm were then excluded, and the values of the corresponding pixels set to *NoData*.

Any deviation in the consistency of water depth and flood areas was eliminated by comparing the water depth rasters with one another via a differential calculation, and in the case of a negative deviation (i.e. water depth of HQhigh > water depth of HQmedium), the water depth of HQhigh was integrated into the raster of the HQmedium using the function "Mosaic to New Raster". In a similar manner, this step was carried out for the water depth rasters of the scenarios HQmedium and HQextreme. In this way, it could be ensured both that the water depths of the rare events were always higher or at least the same as the less rare (or more frequent) events, and that the flood areas of the more frequent events were not larger than the rare ones.

In the third step, the three scenarios were re-sampled at a resolution of 100x100 m using the spatial extent of the CORINE land cover data for the Rhine catchment[13].

Finally, the water depths partially influenced by the sea outside of the selected dyke rings in the Netherlands were excluded.

As a result, in terms of the units of water depth, spatial resolution, the charting used and the data types, unified raster data sets of water depths for the Rhine catchment area are available, with a spatial resolution of 100x100 m, taking into account the consistency of the water depth and flood areas between the different scenarios, for the three scenarios HQhigh, HQmedium and HQextreme.

3.2.3. Flood probabilities and flood protection (cf. Section 4)

The measures in the APF and the FRMP for lowering the water levels (ICPR report nos. 199 and 200) contribute to the reduction of the probability of occurrence (ICPR report no. 229), thus producing a reduction in the flood risk. In dyked areas, the probability can also be reduced by adjusting the level of protection.

The flood probabilities in relation to retention measures were determined by the ICPR for the three scenarios HQ10, HQ100, HQextreme for the development conditions/stages in 1995, 2005, 2010, 2020 and 2020+ for the section of the Rhine from Maxau to the river mouth. For the section of the Rhine from Maxau to Lobith, the evaluation was based on gauges. For the section below the river mouth of the Sieg (gauges at Cologne, Lobith and three Delta Rhine branches) it was based on a route-by-route basis (cf. ICPR report no. 229 on www.iksr.org). Further subdivision of the sections of the Rhine can be seen in Annexe 1. Above Maxau, no change in the flood probability has been demonstrated. The flood probabilities for the three scenarios and the different time horizons were included in the calculations (cf. Annexe 3).

(Dyke) protected areas: The areas protected by technical flood protection measures are required to calculate the effects of the measures. The data provided in the form of line shapefiles from the Rhine Atlas 2015 were converted to polygon shapefiles, which the exception of those relating to the Netherlands. For the Netherlands, the polygon shape files for the dyke rings could be used immediately. This shapefile for the Rhine basin which is generated is used for all time horizons.

Data preparation

As the first step, the sections of the Rhine (cf. Annexe 1) were defined based on the approach of ICPR report 157. The stretches relating to the Rhine kilometre marking [Rhein-Kilometrierung] were then integrated into a polygon shapefile, as – similarly to the dyke rings of the Netherlands – self-contained area units were required for the calculation of the flood risk, i.e. an area which indicates a defined probability. The demarcation of the area was defined on the basis of existing topographical conditions (breaklines) with the aid of detailed maps.

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[13] During re-sampling, the pixel values were interpolated during the transformation of the raster data sets. This procedure is used when the input and output are not a one hundred percent match – when the pixel size changes, for example.

In the Netherlands, there was a revision of the boundaries of the dyke rings, meaning that the areas situated outside the dykes were also recorded in the polygons (displacement of the dyke ring borders from the dyke crest to the river bank).

Finally, for each of the time horizons 2005, 2010, 2020 and 2020+, a shapefile was created, to which the flood probabilities of the three scenarios HQ10, HQ100, and HQextreme (see detailed attribute table in Annexe 3) were added.

In the Netherlands, the only dyke rings taken into account were those in which the flood probabilities are influenced by the Rhine. Dyke rings that are influenced by the sea were not included in the calculations. The border of influence from the Rhine or the North Sea is situated at about Rhine km 938. Accordingly, all dyke rings west of dyke rings 44, 43 and 41 were excluded from the calculation.

3.2.4. Data for the calculation of damage to human health and to the receptors environment, cultural heritage and economic activity

In order to calculate the damage to human health and to the receptors environment, cultural heritage and economic activity, the following data was supplied, which was collected and processed by the BfG within the context of the creation of the Rhine Atlas 2015:

- Persons affected for the three scenarios HQ10, HQ100, HQextreme for the time horizons 2014 (point shapefile and polygon shapefile)
- Cultural assets (point shape file)
- IPPC/SEVESO plants (point shape file) The waste water treatment plant information and data not derived from the Rhine Atlas 2015 was supplied by the ICPR Secretariat and converted into a shapefile.
- Water-related protection areas (polygon shapefiles)
- (Dyke) protected areas (line shapefiles)

In addition, the baseline data:

- Rhine kilometre marking (point shapefile)
- Administrative boundaries (polygon shapefile)

as well as the information from the 1st Management Plan of the IRBD Rhine for good and very good ecological statuses of the water bodies according to the WFD, were made available. The damage functions and specific asset values were adopted (in a modified form) from the Rhine Atlas 2001 (ICPR, 2001).

Data preparation - human health

The point shapefile, which includes the persons affected for the three scenarios for the 2015 period, was converted to a polygon shapefile on the basis of the administrative boundaries via the JOIN function in the GIS. Furthermore, two attribute fields were added for the 1995 and 2020+ safeguarding rates.

In allocating the affected persons to the relevant municipality areas, an issue arose, which was that the areas of the municipalities were not always clearly designated. Given the scale of the Rhine basin, however, this error was deemed negligible.

The absolute population figures were taken from the official national statistics. The values for 2015, 2020 and 2020+ represent projection values. In Switzerland and Germany, the results of different scenarios are published. Those shown here in the table in Annexe 7, relate to an average population evolution scenario.

As detailed in Section 2, the population evolution is considered at a regional level (federal state, region, canton, province). The breakdown of the regional levels is based on the shapefile of the administrative borders of the Rhine basin, which was provided by the BfG. The individual federal states and countries have different administrative levels (for example in Germany: federal state, district government, county), which do not all go into the same level of detail. The tables in Annexes 7 and 8 show the absolute and relative changes in population for the periods relevant to the ICPR project. Whilst in Germany the projections show both rising and declining trends; population growth is assumed in all other districts (with the exceptions of Bludenz (A) and Limburg (NL)). The source of the data is contained in the xls table.

The shapefiles for the time horizons 1995, 2005, 2020 and 2020+ were created on the basis of the 2014 shapefiles and the population evolution.

For the calculation of persons affected per water depth category, a dbf table was created.

Side note: Population evolution on the basis of the change in the CORINE data (Annexes 7 and 8)

To supplement the statistical data regarding population evolution, an analysis of built-up areas in the CORINE data was performed ("areas with consistent urban characteristics" and "areas with inconsistent urban characteristics") similarly to that of the regional context for population evolution. CORINE data is available for the periods 1990, 2000 and 2006 for the Rhine catchment area (with the exceptions of Switzerland and Lichtenstein; these were added later).

With the exception of Vorarlberg and the county of Speyer, from 1990 to 2000 and 2006, the built-up areas increase across all regions.

A direct comparison of the results of the analysis of the CORINE data and the statistical population evolution is not possible due to the different time periods in the baseline data. For this reason, the relative evolution of the built-up areas between 1990 and 2006 and the population evolution from 1995 to 2005 were compared (last column of the table in Annexe 8). With two exceptions, the quotient of relative population evolution and relative area evolution is always less than 100%, meaning that the relative increase in area is greater than the relative increase in population. This could on the one hand be due to the larger period under review for area evolution (15 years) in comparison to that of population evolution (10 years) and on the other hand, due to the fact that the size of households (number of people living in a household) is continuously decreasing.

As a basis for the calculation of the number of persons affected as a result of flooding, the statistical population data is considered a better information base, as this stems from the figures of the Federal Statistical Offices, the "factor of uncertainty" for which is deemed very low. Furthermore, the population figures are available for all time horizons studied within the context of the project.

Data preparation - receptor "environment"

The polygon shapefile for water-related receptors was initially created from the individual records from the Rhine Atlas 2015 (drinking water protected areas, birdprotected areas and flora & fauna habitat protected areas - also called "water-dependent Natura 2000 sites"). Since the ecological status under the WFD had to be added, firstly, all water bodies with a good or very good ecological status were selected and added to the shapefile. The only bodies that lie in the Rhine catchment and meet the criteria are Lake Constance and the Sauer, a tributary of the Mosel on the German-Luxembourg border (in French: Sûre), which lies outside the flooding area, however. The width of the Sauer was estimated to be 9 m (measured using aerial images near the town of Rombach-Martelange, Luxembourg). The WFD surface water bodies were assigned sensitivity levels in accordance with Table 2.

Furthermore, the shapefiles for flood probability were altered, in that the areas according to the kilometre marking of the Rhine were divided into sub-areas (at intervals of 5 km), as the possible negative effects of hazardous installations only have an impact on those receptors that lie downstream (Figure 3).

For the shapefile for hazardous installations, the waste water treatment plants were added. The information in the xls spreadsheet was firstly geo-referenced, and then pollution potential (toxicity) attributes were allocated as well as the impact range – as per Table 3.

The tables shown in Section 2 were converted into dbf tables.

Data preparation - receptor "cultural heritage"

It was possible to adopt the shapefiles that were supplied for cultural objects, in an unaltered form. The dbf tables were produced according to Section 2.

Data preparation - receptor "economic activity"

The damage functions and specific asset values are processed based on the Rhine Atlas 2001, meaning that these are available as dbf-tables for the calculations. The damage functions are given in parts per thousand dependant on the water depth (cm). The specific asset values are processed as polygon shapefiles (subdivided according to country or federal state) for the time horizons 2005, 2010, 2020 and 2020+. Here, the consumer price indices are used.

Research regarding the consumer price index or gross domestic product (GDP) in the Netherlands made it apparent that this data is available in Germany at federal state-level and in the other countries at national level. The average annual change is highest in the Netherlands and lowest in Switzerland. Within the framework of the ICPR project, the decision was taken to use the consumer price index as indicative of economic growth at national level (and where the data is available, also at regional level).

Based on this data, a projection (extrapolation) can be made for the average annual change for future time horizons.

Table 10: Consumer price index/GDP and average annual change

SHN0NAMN1	SHN1NAMN1	Consumer price index				Average annual modification		
		1995	2001	2005	2010	1995-2001	2001-2005	2005-2010
Germany	Baden-Württemberg	100	107.00	112.40	119.90	1.17	1.35	1.50
Germany	Bavaria	100	106.80	112.70	120.70	1.13	1.48	1.60
Germany	Hessen	100	106.80	111.20	117.90	1.13	1.10	1.34
Germany	North Rhine-Westphalia	100	107.20	112.30	119.20	1.20	1.28	1.38
Germany	Rhineland-Palatinate	100	106.80	111.80	118.30	1.13	1.25	1.30
France	-	100	106.80	114.30	122.10	1.13	1.88	1.56
The Netherlands	-	100	112.50	120.40	128.40	2.08	1.98	1.60
Austria	-	100	108.50	115.70	125.20	1.42	1.80	1.90
Switzerland	-	100	107.70	110.30	115.70	1.28	0.65	1.08

In addition, the decision was undertaken to consider the various national/regional indices in terms of economic growth and not EUROSTAT data (not 100% suitable for the ICPR calculations).

No specific asset values were contained in the Rhine Atlas 2001 for the German federal state of Bavaria, for Austria or Liechtenstein, which is why the values of Baden-Württemberg were adopted for Bavaria. For Liechtenstein and Austria, the values were determined based on a comparison of the purchasing power parities of the countries. A comparison of the purchasing power parities for Germany, Liechtenstein and Austria is shown in the table below. However, at the end of the project it became apparent that the consumer price index (and the specific asset values) for Liechtenstein, which were calculated on the basis of purchasing power parities, were set very high in comparison to those for Switzerland (common economic space) and Austria, and are flawed. For this reason, the results for Liechtenstein for economic activity were removed from the calculations. The data must be re-calculated at a later date with the correct parameters.

Table 11: Purchasing power parities of Germany and Austria (DE = Germany; the purchasing power (PP) in 2013 in Germany shall be taken to equal 100% (DE = 100%))

Country	**Purchasing power parities**	
	PP 2013 [€/yr]	**PPP (DE = 100%)**
Germany	20621	1.000
Austria	21295	1.033

The specific asset values for all states and German federal states (Länder) can be found in this report (Annexe 5).

4. Measures and indicators

Section 4 illustrates the flood risk management measures used within the tool and the hypotheses and calculation methods which were established for the indicators associated with the measures. This section also provides clarification on a sensitivity analysis undertaken, relating to the impact of measures.

To simplify the work and for integration into the tool, a code/particular number was determined, containing the major categories of measures of the FD (I. Prevention, II. Protection, III. Preparedness) as well as the specific measure/indicators (in Arabic numerals). E.g. "spatial planning, regional planning and land use planning" = Measure I.1.1.

The indicators vary depending on four potential adverse consequences of flooding per receptor of the FD: human health, the environment, cultural heritage and economic activity. After a general section on indicators (4.1), Sections 4.2 and 4.3 introduce the indicators for the three categories prevention, protection and preparedness, which are linked to "human health" and "the environment" while Section 4.4 is dedicated to the measures/indicators defined for the receptors "economic activity" and "cultural assets". Annexes 11 and 12 contain further details regarding the availability of the indicators. Annexe 13 illustrates a matrix containing the combinations of the impacts of the measures/indicators (see explanations in Section 4.5). Certain measures in combination can strengthen one another, or cancel one another out. Furthermore, in Section 4.6 general information on the use of indicators is provided, explaining key assumptions and restrictions of use. Finally, Section 4.7 introduces the sensitivity analysis regarding the theoretical effect/impact of the measures on the reduction of flood risk, and the findings.

4.1 General

Indicators are used to quantify the information relating to the implementation of measures. Indicators can be of a monetary, quantitative or qualitative sort.

Explanation For the calculation of risk reduction, measures from various aspects of flood risk management (prevention, protection and preparedness) are taken into account. These cover the aspects listed in the FD (EU Common Implementation Strategy – CIS). Indicators were defined for each category of measures, in accordance with the FD. An indicator is a measurable factor; a benchmark that provides a simplification of the actual conditions. An indicator has a reference function – it provides an insight into a particular development. The indicators are measurable and representative of the different categories of measures. They provide the most objective and quantifiable information regarding the implementation of measures. For each indicator there is an expected effect that has been estimated and determined on the basis of literature and expert knowledge. The national data collected with regard to the implementation of measures (expressed in indicators) provides the degree of realisation of a measure.

The indicator is therefore the combination of the effect and the degree of realisation. The various indicators are linked to a number of characteristics.

Effect:	rate per raster cell and scenario, at which the potential damage can be reduced if the measures are implemented. The effect is input/integrated into the tool.

Realisation parameter/degree: The realisation parameter or degree indicates whether a measure – measured by an indicator – has been implemented. An inventory is taken of the realisation externally, (for example, within the ICPR) and this serves as an input factor for the tool.

In the tool, the effect is a parameter which is estimated on the basis of literature or expert statements. The degree of realisation for indicators must be identified based on an inventory, and used as an input factor for the calculations. The degree of realisation in itself provides – as a function of time – the qualitative details of improvement.

Table 12 provides an overview of the measures and indicators integrated into the instrument and the calculations. Some measures were excluded or summarised due to their minor significance for the Rhine catchment area.

Table 12: List of measures and indicators

No.	Types of measures	Indicator
I	**Prevention**	
I.1.1	**Spatial planning, regional planning and land use planning** *(in User guide = regional planning, preventive planning and design of buildings)* Approximate correspondence to EU types of measures: "Avoidance": "Measure to prevent the location of new or additional receptors in flood prone areas, such as land use planning policies or regulation"	Building regulations and codes/building development plans, in which requirements for flood protection are contained (flood-adapted construction)
I.1.2	**Keeping flood prone areas open / clear (preventing the location of new or additional receptors) and adapted usage of areas** *(in User guide = preservation of flood areas and adapted land use)*	Modification of land use data (CLC data) within and outside of the flooding areas of the FHM under analysis.
I.3.1	**Flood-adapted design, construction, renovation** *(in User guide = flood adapted constructions, adaptive construction of buildings)* Approximate correspondence to EU Types of measures: "Avoidance": "Measure to prevent the location of new or additional receptors in flood prone areas, such as land use planning policies or regulation"	Measures implemented regarding flood-adapted development/building
I.3.2 - Receptor "economic activity/cultural heritage" *(in User guide = technical object protection within the flood area (for example with a mobile wall, mobile constructions or small local dams))*	**Precautionary building / flood-proofing property for households / municipalities** Approximate correspondence to EU Types of measures: "Reduction": "Measure to adapt receptors to reduce the adverse consequences in the event of a flood actions on buildings, public networks, etc..." Also "Protection"(e.g. for (mobile) walls or dykes): "Channel, Coastal and Floodplain Works"; "Surface Water Management"	Protected areas due to precautionary building/flood-proofing property and/or mobile systems
I.3.2 - Receptor "environment"	**Precautionary building / flood-proofing property in hazardous installations (IPPC plants, SEVESO operation areas and waste water treatment plants)** *(in User guide = technical object protection within the flood area (for example with a mobile wall, mobile constructions or small local dams))* Approximate correspondence to EU Types of measures: "Reduction": "Measure to adapt receptors to reduce the adverse consequences in the event of a flood actions on buildings, public	Protected installations due to technical protection, precautionary building/flood-proofing property and/or mobile systems

	networks, etc...” Also “Protection‟ (e.g. for (mobile) walls or dykes): “Channel, Coastal and Floodplain Works”; “Surface Water Management‟ Also “Recovery and Review (Planning for the recovery and review phase is in principle part of preparedness)”: “Environmental recovery Clean-up and restoration activities (with several sub-topics such as mould protection, well-water safety and securing hazardous materials containers)”	
I.3.3 - Receptor "economic activity/cultural heritage"	**Flood-proof storage of water-polluting / hazardous substances for households / municipalities** *(in <u>User guide</u> = storage of polluting substances, (for example oil tanks from households))* <u>Approximate correspondence to EU Types of measures:</u> Reduction: Measure to adapt receptors to reduce the adverse consequences in the event of a flood actions on buildings, public networks, etc... Also “Recovery and Review (Planning for the recovery and review phase is in principle part of preparedness)”: “Environmental recovery Clean-up and restoration activities (with several sub-topics such as mould protection, well-water safety and securing hazardous materials containers)”	Securing oil tanks and/or safe storage in upper storeys
I.3.3 - Receptor "environment"	**Flood-proof storage of water-polluting / hazardous substances for installations at risk (IPPC plants, SEVESO operation areas and waste water treatment plants)** *(in <u>User guide</u> = storage of polluting substances, (for example oil tanks from installations/industries))* <u>Approximate correspondence to EU Types of measures:</u> Reduction: Measure to adapt receptors to reduce the adverse consequences in the event of a flood actions on buildings, public networks, etc... Also “Recovery and Review (Planning for the recovery and review phase is in principle part of preparedness)”: “Environmental recovery Clean-up and restoration activities (with several sub-topics such as mould protection, well-water safety and securing hazardous materials containers)”	Securing oil tanks and/or safe storage in upper storeys
I.4.1	**Provision of flood hazard and risk maps / establishing awareness in relation to precautionary behaviour, education and preparation / preparedness for flood events** *(in <u>User guide</u> = hazard and risk map and information (sensitisation of the public/information campaigns))* <u>Approximate correspondence to EU Types of measures:</u> “Other prevention”; Under “Preparedness”: “Public Awareness and Preparedness: Measure to establish or enhance the public awareness or preparedness for flood events to reduce adverse consequences”	Frequency/update intervals with regard to information campaigns (incl. provision/presence of FHM and FRM)
II	**Flood protection** <u>Approximate correspondence to EU Types of measures:</u> “Natural flood management / runoff and catchment management”; “Water flow regulation”; “Channel, Coastal and Floodplain Works”; “Other Protection”	
II.2	**Retention measures**	Modification of probability (ICPR Report No. 229)
II.3	**Dykes, dams, flood walls, mobile flood protection, ...**	For these measures, a probability is also indicated: Percentage evolution/modification of flood probability between 1995 and present day due to improvements in protection (In the User guide there is the additional,
II.5	**Maintenance / renewal of technical flood protection structures**	

		more precise clarification that the information of the river stretches/sections which are protected and non-protected by structural flood protection systems should be determined for/used in the calculation)
III	**Preparedness**	
III.1.1	**Flood information and forecast** *(in <u>User guide</u> = flood forecast system)* <u>Approximate correspondence to EU Types of measures:</u> "Flood Forecasting and Warning": "Measure to establish or enhance a flood forecasting or warning system"	Improvement in flood forecasting within defined time period
III.2.1	**Alarm and emergency response planning (incl. recovery/aftercare) /warnings for those affected/exercises/training** *(in <u>User guide</u> = alarm and emergency plans, warning systems, crisis management exercises)* <u>Approximate correspondence to EU Types of measures:</u> "Flood Forecasting and Warning" - in terms of warning: "Measure to establish or enhance a flood forecasting or warning system"; "Emergency Event Response Planning / Contingency planning": "Measure to establish or enhance flood event institutional emergency response planning" Also "Recovery and Review (Planning for the recovery and review phase is in principle part of preparedness)"	Presence and update frequency of alarm and emergency response plans; number of warning systems (warning methods/ways and communication means), details of civil protection/crisis management exercises including frequency
Receptor "human health"	**Safety/safeguarding/evacuation of (potentially) affected persons**	Details of minimum and maximum safeguarding rate for those affected in a particular area

In Section 4 (Table 12) and in the overarching Table 9, for each indicator the following is described:

- Explanation of the indicator
- Which receptor the indicator represents (firstly the indicators for human health and the environment are introduced, then those for the receptors economic activity and cultural heritage).
- Application of the indicator in the calculation and calculation procedure, i.e. implementation in the tool.
- For the realisation: the unit or order of magnitude of the indicator[14]
- In which form and for which time horizons the data must be supplied.
- How great the maximally anticipated effect is, and under which assumptions this was calculated.
- Details of the degree of realisation of the indicator.

In addition, details of combinations of individual indicators are also part of this section (see also Annexe 13).

Further details of the measures and indicators supplied for the ICPR project as well as the necessary data processing tasks can be found in the Synthesis Report of the ICPR (ICPR Technical Report no. 236, 2016).

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[14] The effect of the indicator is not mentioned in the aforementioned table. This can be found within this section in the sub-chapter relating to the various indicators.

4.2. Indicators for human health

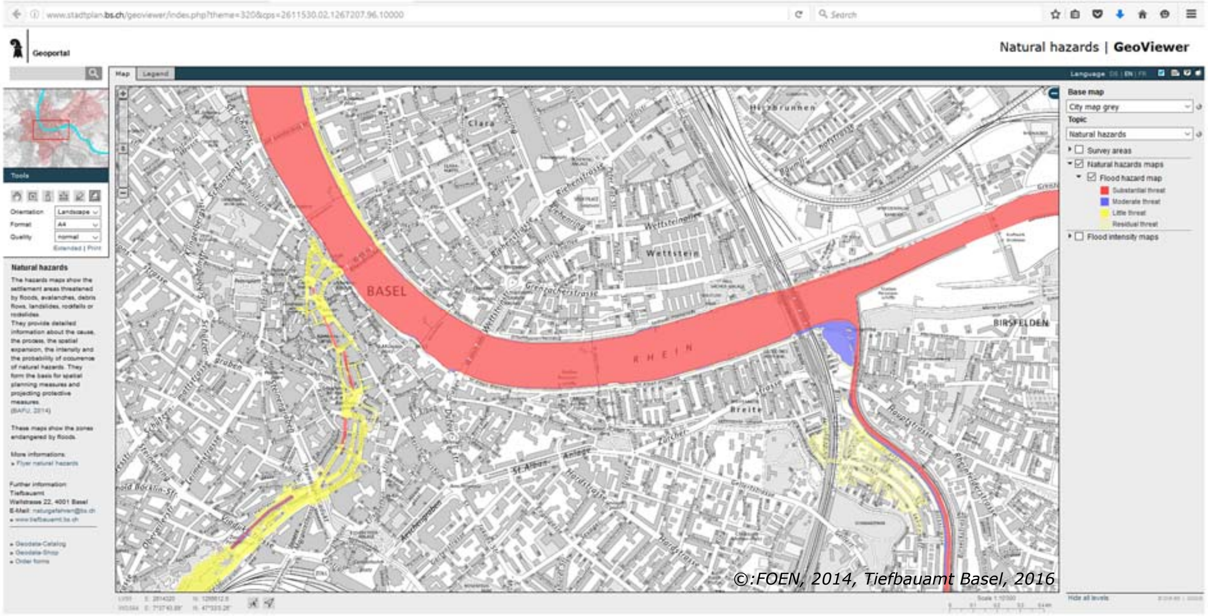
(cf. details on indicators in Section 4.4)

Spatial planning, regional planning and land use planning (I.1.1) and keeping clear/open flood prone areas, as well as the adapted usage of areas (I.1.2)

Both measures relating to precautionary land use (land use planning I.1.1 and keeping clear/open flood prone areas I.1.2) have an effect on the number of potential residents, with I.1.1 affecting only the growth of totals of people at risk. Here, a max. effect of below 100% should be selected. The indicator is the number of inhabitants in the flooding area (3 scenarios and integral risk) with the relevant time horizon applied (taking into account the population growth using data from the statistical offices). For human health, the maximum effect of the indicator precautionary land use should be dynamically structured in accordance with the evaluation of the receptor economic activity (cf. Section 4.4).

Precautionary building (I.3) and flood-proofing property (I.3.2)

In terms of precautionary building measures (I.3), it is only flood-proofing property measures (I.3.2) that have an impact on the receptor human health. Where the flood protection system is not inundated by water entering above or below it, this is 100% effective (h < 2m). The indicator is the number of inhabitants protected due to the flood-protection system.



©:FOEN, 2014, Tiefbauamt Basel, 2016

Basel City risk map (cf. http://www.stadtplan.bs.ch/geoviewer/index.php?theme=320)

Provision of FHM/FRM and establishing awareness (I.4.1) as well as preparedness for flood events (III)

The provision of FHM/FRM (I.4.1) and preparedness measures for flood events (III) have an effect on safeguarding rates. It is assumed that the safeguarding rate (effect) can be increased through the implementation of these measures. The procedure for calculating the effect is explained below. The indicators are the same as those used for the receptor economic activity.

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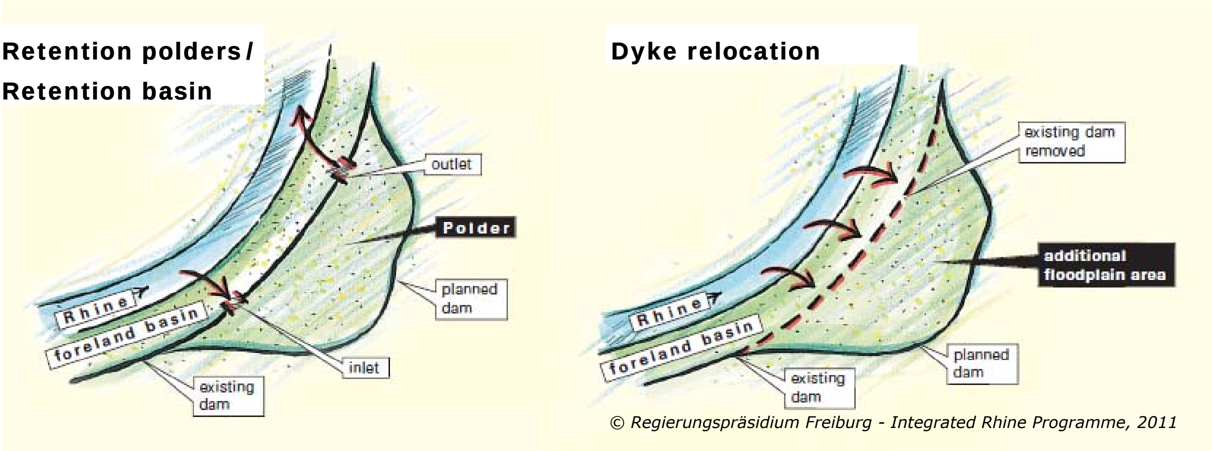
Diverse info materials

Extract: Rhine Atlas 2015 for flood hazard maps and flood risk maps (based on national maps)

Flood protection measures: Modification of flood probability (II)

The flood protection measures are taken into account by calculating the modification of the probability (established within the framework of the ICPR by the EG HVAL). The indicator is thus the modification of flood probability.



Retention polders / Retention basin

Dyke relocation

© Regierungspräsidium Freiburg - Integrated Rhine Programme, 2011

Examples of water level-reducing measures for the Rhine

The following flowchart shows the implementation within the tool of the indicators "provision of FHM/FRM and establishing awareness (I.4.1), as well as preparedness for food events (III)". This flow chart and the associated point system are based on ICPR assumptions and expert estimations, which assume that an increase in the sensitisation and knowledge of the potentially affected people increases their awareness/perception of risk. An example of the allocation of points can be found in the information below under "Required data and calculation" and details are also provided in Annexe 14.

In order to calculate the effect, first of all, the following information is necessary – which is provided by the ICPR.

Required data and calculation:

- Input of safeguarding rate in % through surveys in the relevant countries, i.e. the proportion of persons per region that could be evacuated in advance of a potential flood, and are therefore no longer in danger, for the reference time horizon 1995, and in relation to the area under consideration (e.g. at municipality level, dyke rings). This concerns the safeguarding rate without measures, in the sense of the FD. Other measures that have already been undertaken at this time can affect the safeguarding rate. The "safeguarding rate" can be improved through measures such as raising awareness, forecasts, warnings and crisis management.
- Input of maximally achievable safeguarding rate (2020+) in the area under consideration. This is largely dependent on the characteristics of the area. While in shallow areas with low water depths a high maximum safeguarding rate can be achieved, this is not the case in low-lying polders, due to the possible sudden failure of flood protection structures, high water depths and limited transport capacities.
- For the time horizons under consideration: 2005, 2015 and 2020, the safeguarding rate is calculated using the flow chart. To this end, a polygon shapefile is required for each area with the following attributes:
    - Presence of FHM/FRM with update frequency in years
    - Implementation of information campaigns with details of frequency in years
    - Information on flood forecast (III.1.1) in accordance with Section 4.2.3
    - Details of alarm and emergency response plans including update frequency
    - Details of warning systems including number of warning methods.
    - Details of civil protection/crisis management exercises including frequency

Using the above information and with the aid of the flowchart, firstly, for each scenario and time horizon, the point score can be calculated. The maximum point score is 48. Here, the factors shown in the orange box were taken into account. It is through these that the weighting of the individual measures is undertaken. Whilst the measures of forecasting and information are attributed a high weighting (factor 3), the significance of FHM/FRM is estimated to be rather low (factor 1). (The reason for these different factors is the assumption that the flood forecast is the most important measure. The presence of maps without the corresponding forecast information demonstrate no real use in the event of evacuation.) All other measures are allocated the factor 2.

Firstly, the maximum improvement potential (I_{max}) can be calculated from the difference between the safeguarding rate at a reference point (S_{ref}) and the maximum safeguarding rate (S_{max}).

$$I_{max} = S_{max} - S_{ref}$$

After calculating the point score, using the following formula, the relative proportion of the effect can be calculated.

$$\text{Effect}_{rel} = \text{point score achieved} / \text{maximum point score}$$

Multiplying the relative effect of the measure with the maximum improvement potential produces the improvement achieved (I_{achv}) in the period under consideration, in comparison to the reference time period.

$$I_{achv,\ year\ i} = \text{Effect}_{rel,\ i} * I_{max}$$

The safeguarding rate for the year under consideration (S_i) is then calculated by adding the safeguarding rate to the reference time period and the improvement.

$$S_i = S_{ref} + I_{achv}$$

By specifying the safeguarding rate for the reference time period and the maximum safeguarding rate, the question as to whether it is a dyked or non-dyked area can also be indirectly taken into account.

In the flow chart, as an example, a safeguarding rate for a reference time period of 50% and a maximally achievable safeguarding rate of 95% are given. The data supplied by the ICPR for a time period (for the example, it is assumed that these are for the year 2015) are represented by the green border of the box. First of all, from this information the point score achieved and the relative effect can be calculated.

Improvement potential = 95 % - 50 % = 45 %

point score achieved $_{2014}$ = 1*1+1*3+(2+1+3)*3+2*2+2*2+0*2=30

Impact $_{rel,\ 2014}$ = 30/48=0.625

I_{2014} =0.625*45 % = 28.125 %

S_{2014} = 50 + 28.125 = 78.125 %

The implementation within the tool is explained using an example in Annexe 14.

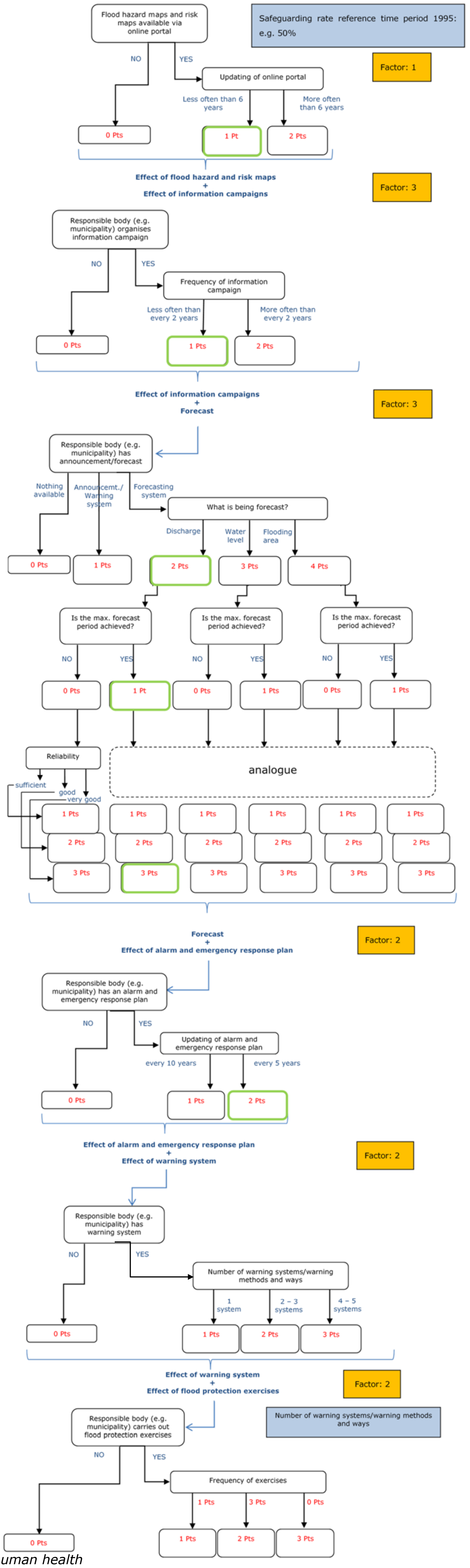


Figure 6: Flow chart of the indicators for human health

4.3. Indicators for the receptor "environment"

For the measures "flood-proofing property (I.3.2)" and "flood-adapted storage of water-polluting substances (I.3.3)", indicators were defined for the receptor environment, which are aligned with the indicators for the receptors economic activity and culture (cf. Section 4.4) and modified, taking into account the methodology for calculating the potential damage for the receptor environment (cf. Section 2). In this methodology, the water-related receptors are specified as drinking water and Natura 2000 areas.

Flood-proofing property (within the flooding area) (I.3.2)

Indicator:

Installations protected through technical flood protection measures, flood-proofing of property (technical object protection) and/or mobile systems (IPPC, SEVESO, waste water treatment plants).


© ICPR, 2002

Mobile wall: Bayer AG, Leverkusen

Explanation:

Through mobile systems, the relevant installations and their storage areas are protected so that they do not become flooded. In this way, the contamination of flood water, and the associated adverse effects on the receptor environment are reduced or avoided. These measures are only effective in water depths of max. 2 m, where the systems do not overflow with water.

Effect of measure:

Flood-proofing property (technical object protection) has an impact on HQ10 and HQ100 areas, as well as on the further-reaching HQextreme areas.

Max. 90 % per scenario per raster cell, if the measure prevents inundation.

Source for effects of measures:

- Expert estimation

By protecting hazardous installations (IPPC, SEVESO operating areas and waste water treatment plants) through the use of mobile systems, it is assumed that no water or significantly less water penetrates the operational premises/sites of these installations, and the negative consequences (the contamination caused by the installations) impacting on water-related receptors can be avoided.

The water-proofing of buildings using different systems, as long as they can withstand the water pressure, is deemed one of the most efficient measures of preventing damage. Depending on the system, different degrees of water may seep through the system or through e.g. sewer backwater into the building, which is why a maximum rate of 90% is assumed. In contrast to the evaluation of the receptors economy and cultural heritage, for the evaluation of the receptor environment, a simplified approach is taken, which is established using the calculation method for the receptors, on the basis of the impact range. The impact range is reduced by 90 % for all hazardous installations which, without this measure, are filled with a water depth of max. 2 m. This alters the affected areas of the individual water-related environmental receptors.

Calculation:

The effect of the measure entails the reduction of the impact range (yellow dotted line, in comparison to blue dashed line) (cf. Figure 7). While, for the scenario without measures, both of the water-related environmental receptors are almost entirely affected, in the case of a reduction by 90 % of the impact range, only a minor proportion in terms of area of the smaller receptor is affected.

With regard to flood-proofing property (technical object protection), it is assumed that this reduces the damages, regardless of whether an area is dyked or non-dyked. The indication of the degree of protection, i.e. for which scenario the measure is effective, represents significant information. The effect is calculated for each raster cell and for each scenario.

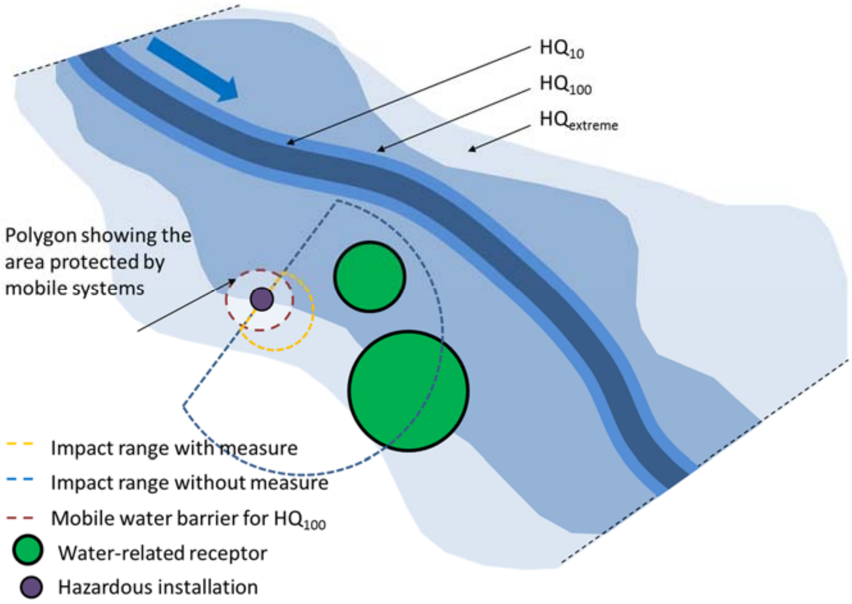


Figure 7: Illustration of the measure "flood-proofing of property (I.3.2)" with respect to the receptor environment

Flood-adapted storage of water-polluting substances (I.3.3)

Indicator:

Securing oil tanks and/or safe storage in upper storeys in installations at risk

Storage of fixed tanks

Explanation:

By securing tanks or the storage of water-polluting substances in upper storeys, the damages to water-related protected areas can be significantly reduced.

Effect of measure:

The flood-adapted storage of water-polluting substances has an impact on HQ10 and HQ100 areas, as well as on the further-reaching HQextreme areas.

Max. 50 % per scenario per raster cell.

Source for effects of measures:

- ICPR (2006): immobile potential damage for Germany and Switzerland (only non-dyked) 90 % (h <0.5 m), 90 % (h <2 m), 50 % or 0 % for Switzerland (h >2 m)
- ICPR (2002): 30 - 40% due to adapted use; extent of damage increases due to heating oil (200 to 300%); in commercial establishments, the storage of hazardous substances in upper storeys leads to a reduction of 50-75%, and in the case of storage outside of the flooding area, to 100%.
- Kreibich et al. (2005): 53 % due to adapted use
- Expert estimation

Calculation:

The calculation of the effect of the measure "flood-adapted storage of water-polluting substances" is carried out for all three scenarios, similarly to the measure "flood-proofing property (I.3.2)", according to Figure 7. The impact range for this measure is reduced by 50%.

4.4. Indicator for the receptors economic activity and cultural heritage

4.4.1. Prevention (I)

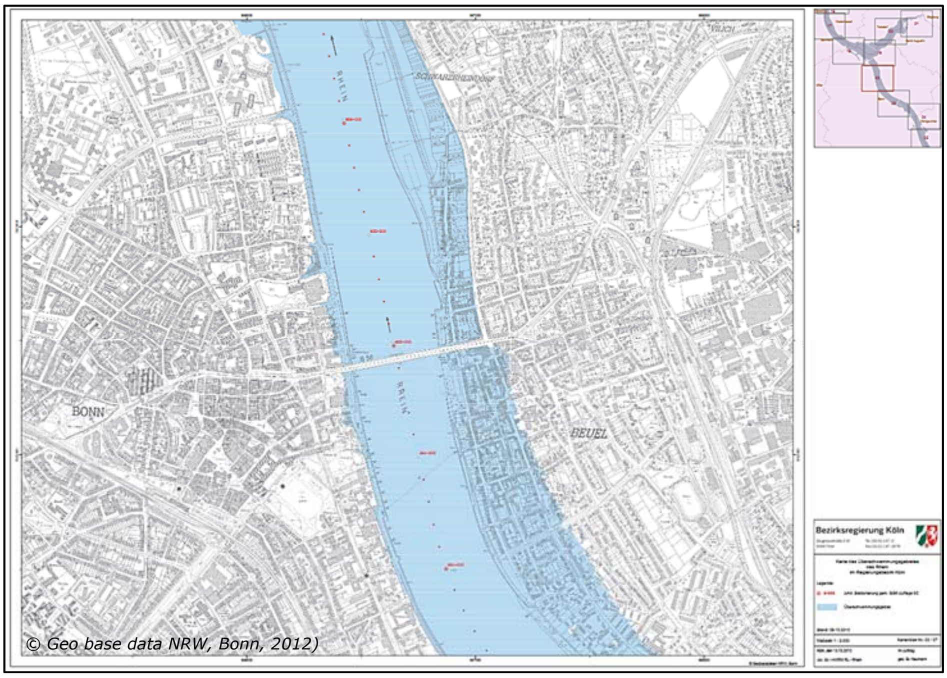
Precautionary land use (I.1)

For the precautionary land use measures, the evaluation is based on the issuance of statutory provisions[15]. This does not change the existing land use, but rather the future use. It is important here that the reference condition relates to 1995, i.e. that from a current perspective, a change in risk in the past (e.g. 2005 as the year under review) is possible.

Spatial planning, regional planning and land use planning (I.1.1)

Indicator:

Building regulations and codes/building development plans, in which requirements for flood protection are contained (for example flood-adapted construction)



© Geo base data NRW, Bonn, 2012)

Established/legally binding flooding areas, Bonn (cf. http://www.bezreg-koeln.nrw.de)

Explanation:

The requirements of spatial planning are further specified and supplemented in building development plans.

Specialist information relating to water management is taken into account e.g. through the identification/labelling and safeguarding of areas for planned flood-protection measures.

Through the preparation of building development plans, the development of settlements is restricted (adapted) or prevented, meaning that potential damage (in the future) does not increase, or only to a minor extent. The effect of the measure is the difference in damage between the conditions after the plans regarding space allocation and building

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[15] Building development plans and/or keeping flood prone areas clear, legally identified flood areas in Germany, PPRI in France.

development have come into force (damage avoidance), and the current conditions of land use. This means that in the future, damage may occur even with adapted usage, but this will be to a significantly lesser extent.

The measure "spatial planning, regional planning and land use planning (I.1.1)" with the proposed indicator, refers to building development which is adapted via statutory regulations (building regulations), and which can take place in compliance with the regulations. An example might be a building without a basement, or the design of the ground floor as a raised/mezzanine floor. The measure primarily relates to newly designated construction areas, and thus to potential, future damages. The building regulations are also essentially valid in existing settlement areas, in conversion work or in gap closures in existing built up areas. However, it is assumed that this relates to a smaller proportion, which can be dismissed in this large-scale evaluation.

The measure does not distinguish between different jurisdictions and the type of measure; i.e. at present, the integration of flood areas in the land use plan will be evaluated in exactly the same way as a building development plan, which entails that the entry threshold must be 1 m above ground level. The real impact of the examples specified is certainly different, but in the context of the macro-scale approach and from the perspective of data collection, it was only possible to make a rough estimation.

Effect of measure:

The ICPR (2002) assumes an annual growth rate of the potential damage of 1 to 2 %. This order of magnitude can also be derived for the baseline evaluation of settlements in Germany using experiences in the field of renovation for energy-efficiency purposes (cf. inter alia German Federal Ministry of Transport, Building and Urban Development [BMVBS] 2013)[16]). By implementing the measure "spatial planning, regional planning and land use planning (I.1.1)" this growth in the potential damage can be reduced. Given the limitations upon settlements in areas at risk of flooding (predominantly in Germany due to the determination of flooding areas), a growth rate of 1 % was estimated to be too high. For the calculations of the time horizons, **a dynamic maximum effect** of 0.5 % with regard to the reference year is therefore set for the entire Rhine catchment area.

This highly simplified approach can only be applied where the indicator I.1.2 "keeping flood-prone areas free and flood-adapted land use" is not used, otherwise the concept of keeping the HQ100 area free would be considered multiple times.

In addition, in applying the realisation parameters, the following aspects must be considered:

- the pinpointing of flooding areas takes generally place in stages
- the pinpointing of flooding areas and/or of land use planning regulations is almost exclusively in the area of the HQ100. Here, inter alia due to building regulations, the effects of the information regarding the HQ100 and generally higher insurance premiums, a reduction in the increase of potential damage can be expected. For the area in between HQ100 and HQextreme, a reduction in the increase seems unrealistic. Thus, for example, in the German federal state of Baden-Württemberg, generally no regulations are made outside of the HQ100 area. The

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[16] http://www.bbsr.bund.de/BBSR/DE/Veroeffentlichungen/BMVBS/Online/2013/DL_ON032013.pdf?__blob=publicationFile&v=5

impact of establishing/raising awareness is deemed rather low in this area. This also applies to protected areas/zones. In practice, a particularly large increase in the potential damage is actually often observed here. For these reasons, in these areas a largely unaffected level of potential damage growth should be expected.

It would be more realistic – especially for future updates – to make the distinction between the growth of potential damage in existing buildings because of renovation works in the area of HQ100 and a growth rate of potential damage which corresponds to the regional growth rate as a minimum. It is not possible to depict this in the current large-scale model.

Table 13: Maximum effect of the indicator "spatial planning, regional planning and land use planning (I.1.1)"

	1995	2005	2014	2020	2020+
Growth of potential damage where measure is realised completely [%][17]	0	5	9.5	12.5	17.5

The table therefore contains the linear decrease in potential damage and increasing reduction in the growth of the potential damage, as compared to a situation in which there are no building regulations.

From the table it is also clear that after 200 years, in theory all of the buildings would be renewed once (or would no longer be built) and thus no damage potentiality would be present, as future buildings would all be flood-adapted.

Source for effects of measures:

- Own assessment (HKV and ICPR)
- ICPR (2002)
- Data from BW (see HKV Final Report)

Calculation:

The description of the calculation procedure is illustrated by the figure below. The three flood scenarios are represented in blue, the existing settlement areas in red, and the new building development lying outside of the HQ100 area, which should comprise flood-adapted construction, in light yellow. In considering the HQextreme flooding area, a proportion of approximately 80 % of the affected built-up area (red area) is not flood-adapted in terms of construction, and approx. 20 % (yellow area) is flood-adapted.

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[17] More information about the assumptions regarding maximum effects and sources regarding the effects of these and other indicator(s)/measure(s) can be found in the internal final report of the project (HKV final report). It is important in general to stress that the assumptions regarding the indicators are in part strongly based on (ICPR) expertise.

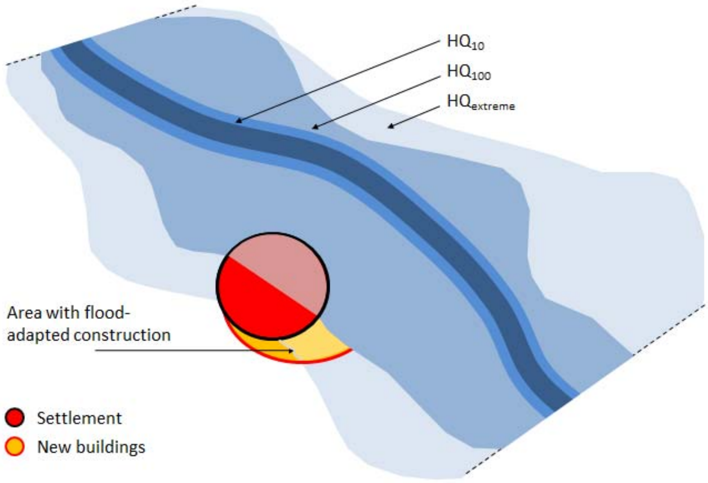

Figure 8: Illustration of measures spatial planning, regional planning and land use planning (I.1.1)

Keeping flood prone areas open/clear (preventing the location of new or additional receptors) and adapted usage of areas (I.1.2)

Indicator:

<u>Modification of land use data</u> (CLC data) within and outside of the flooding areas of the three scenarios represented in the FHM under analysis.

© ICPR

Example of land use modification over time

Explanation:

Through the designation of flooding areas (in Germany on the basis of the Federal Water Act [Wasserhaushaltsgesetz - WHG] and the German water act of the federal states [Landeswasserhaushaltsgesetz - LWG] for a 100-year event; in France: 100-yearly or the highest known flood), construction-related use (constructability) of these areas is restricted and/or <u>prohibited</u>. Building permits are issued (only in exceptional cases) taking into consideration the flood risk (flood-adapted construction and/or technical flood protection measures). The effect of the measures is the difference between the damage level where measures are implemented (damage avoidance) and the current land use. A comparison of the development of settlements within and outside of the flooding areas demonstrates how the settlement development progresses with and without implementing measures.

In terms of the measure "keeping flood prone areas clear/open and flood-adapted land use (I.1.2)," the focus is on the construction ban in flooding areas, whereby the increase of built-up areas will be prevented in the future (no growth in potential damage due to new-builds). Here, it is assumed that the exceptional rulings (e.g. the establishment of a business with the appropriate conditions, from the perspective of safeguarding the location of an economic activity zone) are negligible. In the existing built-up areas, the potential damage will increase as a result of economic growth and through renovations/upgrades of usage in existing buildings (see I.1.1).

Effect of measures:

Keeping flood prone areas clear/open has an effect on HQ10 areas and HQ100 areas. For the wider HQextreme areas, no effect is expected because by definition, there is no legally stipulated flooding area here.

Effect: 100% per scenario per raster cell

Source for effects of measures:

- Own assessment (HKV, ICPR)
- ICPR (2006)

Calculation:

The calculation of the measure is described using a diagram (Figure 9) – similarly to that of the previous measure.

Due to the measure "keeping flood prone areas clear/open", there is only an increase in the settlement area outside established flooding area (HQ100) (yellow areas). In the areas shown here in pink, construction is prohibited, meaning that no growth in potential damage will take place in these areas.

Due to the availability of the CORINE data, the effect of the measure can only be calculated for the years 2005 and 2014. If in the future, further up-to-date CORINE data sets or other land use data is available, a calculation of the effect of the measure will also be possible for the years 2020 and 2020+. In this case, a comparison/adjustment with the indicator I.1.1 must, however, take place (see above).

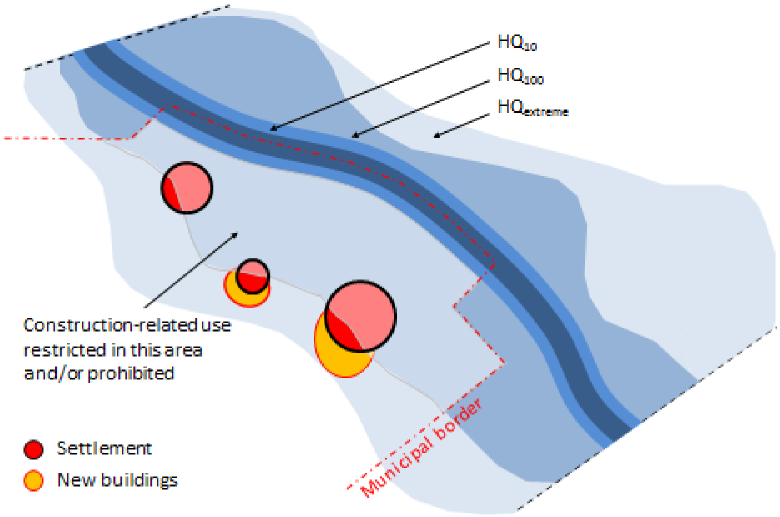

Figure 9: Illustration of measures "Keeping flood prone areas open/clear (prevention of the location of new or additional receptors) and adapted usage of areas (I.1.2)"

Precautionary building (I.3)

For the definitions of measures regarding flood-adapted construction (I.3.1) and flood-proofing property in the flooding area (I.3.2), the following assumptions are made:

Flood-proofing property within the flooding area (shielding) is not a permanent measure in comparison to flood-adapted construction (precautionary building), but rather an active response is required in the event of a flood. In a flood, the flooding of a building is prevented e.g. through sealing the inlet openings (doors, windows, shafts) – see images below.

In flood-adapted construction processes, the water is not kept away from the building, but rather the buildings are designed and built so that damage is minimised (for example, pressure-sealed doors and tiles).


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Examples of "flood-adapted construction (I.3.1)" (left) and "flood-proofing property (I.3.2)" (right) (cf. http://www.bmub.bund.de, Hochwasserschutzfibel (= Flood Protection Handbook))

Flood-adapted design, construction, renovation (I.3.1)

Indicator:

Number of measures implemented in terms of flood-adapted development/building

Explanation:

In the case of flood-adapted construction, damages can be reduced in water depths of up to 2 m. A differentiation between the reduction of damage in buildings and the damage to household items is made by using damage functions for the settlement area. A further subdivision occurs in terms of the type of measure; between so-called wet (adapted building usage and fittings) and dry flood proofing (shielding, sealing, reinforcement). This subdivision is not applied within the tool however, i.e. the estimation of the realisation refers to all precautionary building measures.

The measure "flood-adapted design, construction, renovation (I.3.1)" – in comparison to the measure "spatial planning, regional planning and land use planning (I.1.1)" – refers to a voluntary measure carried out by the owner (or it can also be by the municipality, for example) to reduce or prevent damage in the event of a flood. Furthermore, this measure is aimed primarily at existing buildings, i.e. the construction/design of property/objects affected by flooding (example: adapted cellar use, keeping no high value items in the basement); the implementation of this measure can also be found, however, in new planning.

Effect of measures:

Flood-adapted design and building (I.3.1) has an impact on HQ10 and HQ100 areas, as well as on the further-reaching HQextreme areas. In addition, a distinction is made here between dyked and non-dyked areas, both indicated through polygons/polylines and not per municipality. In specifying the realisation factor, consideration must particularly be given to the fact that the effectiveness can be very different depending on the flood depths in the different flood scenarios. In non-dyked areas, the buildings and household items may be frequently adversely affected by floods (HQhigh and HQmedium). It is not expected that the measures are also effective in an HQextreme event.

Household items: Where the measure is fully implemented, the damage can be reduced by max. 40% of the value before implementation (dyked); 55% (non-dyked) in the event of h <2 m per scenario, per grid cell. In the event of h > 2 m, there is no effect.

Buildings: Max 30% (dyked); 60% (non-dyked) with h <2 m (in the cellar 80%) per scenario, per grid cell. In the event of h >2 m, there is no effect.

For the calculations, an average is selected from the ICPR (2002) and Kreibich et al (2005) indicating figures for household items and buildings of 35% for dyked areas, and 55% for non-dyked areas for h <2 m (no difference in the event of < or >1 m) (see details below).

Source for effects of measures:

- ICPR (2002): Household items up to 40 % and buildings 60-100 % (h <1 m); *not used*: *15 – 35 % when using water-insensitive materials in buildings; 75 - 85 % when waterproofing cellars*

- Kreibich et al. (2005): 24 % in buildings without a cellar (h <1 m); for flood-adapted construction techniques 36 – 53 % for buildings and 48 – 53 % for household items (h <2 m)

For the effect on household items, a low value was applied for dyked areas, and a higher value for non-dyked areas, to reflect the assumption that in non-dyked areas people have more experience of flooding (see explanation below).

In the case of reduction factors for damage to buildings (immobile damage), the range of effects is greater than that relating to household items. Due to the fact that the adapted fittings (i.e. permanent measures, in comparison to flood-proofing property, which still requires an active response in the event of a flood) play an essential role here, and that these are clearly influenced by flood awareness, the difference between dyked and non-dyked areas is more significant here than when considering household items. As, within the context of the ICPR, this is a question of a large-scale evaluation, and a distinction is not made between the various precautionary building measures (e.g. sealing openings can lead to complete avoidance of damage), a percentage of 60 % is selected for the maximum effect in non-dyked areas, and 30 % for dyked areas.

The effect of the measure is an average of the references specified in the literature, differentiated in dyked and non-dyked areas. In non-dyked areas, it is assumed that because the people affected have more experience of flooding (flooding occurs here more frequently than in dyked areas) the reduction effect in terms of potential mobile damage (household items) is higher.

The effectiveness of a measure is dependent on the water depth (max. 2 m). The lower the depth, the greater the effect.

Calculation:

The calculation procedure is explained using the figure below for the scenario HQextreme. By implementing the measure, the potential damage within the contours shown here is reduced in the event of a water level <2 m; proportionately to the water depth. The damage function is modified depending on water depth for dyked and non-dyked areas in accordance with the above assumptions for maximum impact. The effect of the measure is calculated for each raster cell and for each scenario.

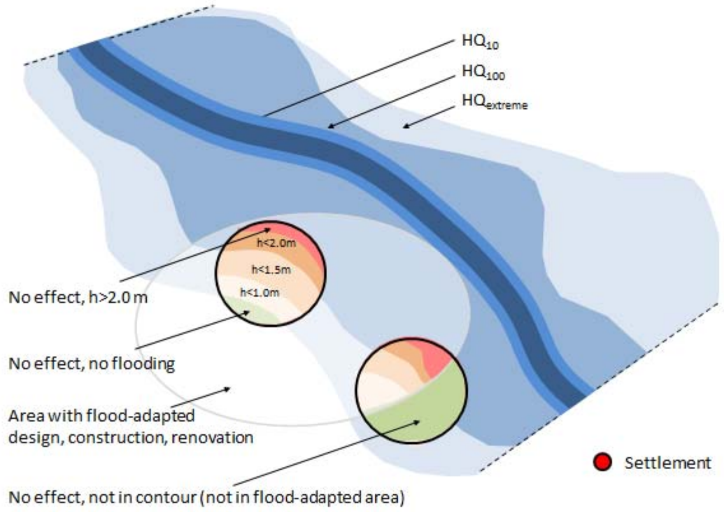

Figure 10: Illustration of the measure "flood-adapted design, construction, renovation (I.3.1)"

The green areas indicate that the measure is not applied in this area and/or that no flooding takes place in this area. The red areas indicate the areas in which the measure is implemented, however due to the water depth (h> 2 m), no reduction is achieved. In the areas with the red/orange gradient, the measure is effective in accordance with the modification of the function.

In more concrete terms, the damage functions for the categories "settlement" and "industry" (mobile and immobile) are modified, as shown below, due to the measure "precautionary building":

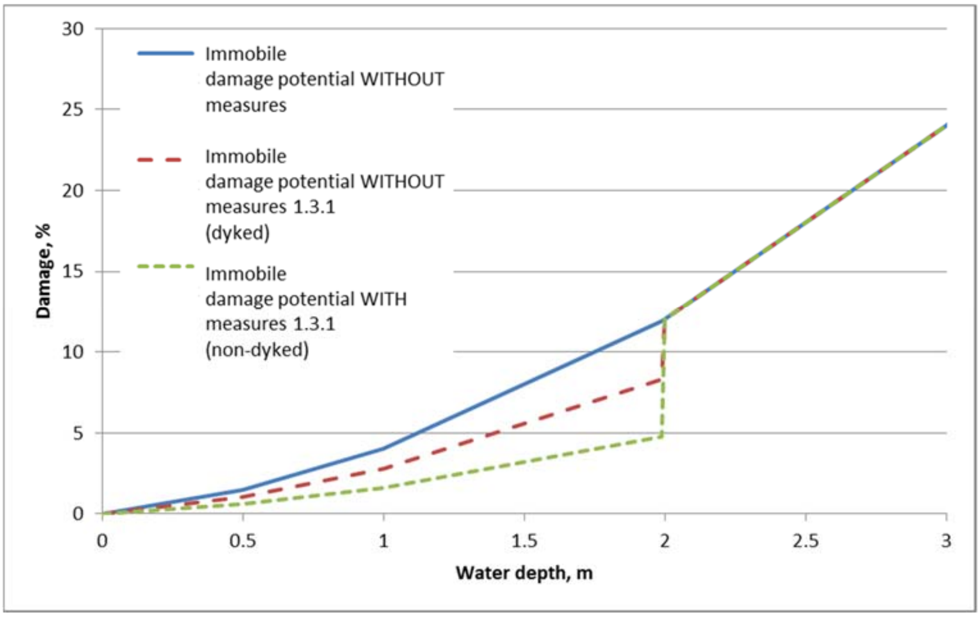

Figure 11: Modification of the damage function for immobile damage (industry) due to the measure "precautionary building (I.3)" for dyked and non-dyked areas (function applied (example without measures): " industry immobile" $y=2*x^2+2x$)

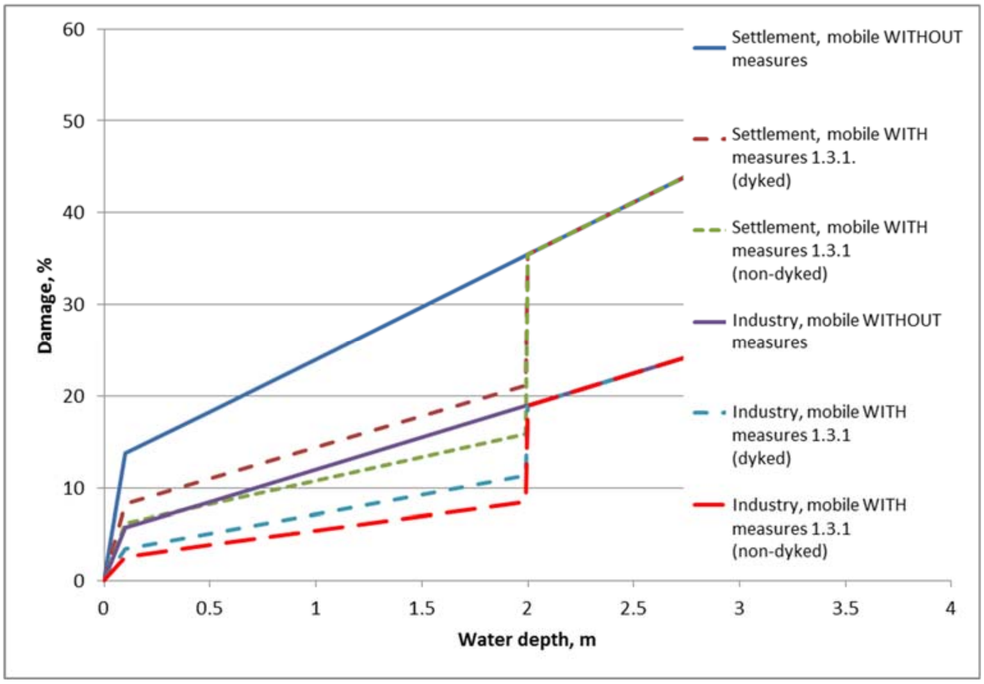

*Figure 12: Modification of the damage function for mobile damage (settlement and industry) due to the measure "precautionary building (I.3)" for dyked and non-dyked areas (function applied (example without measures): "Settlement, mobile (35% economy, 60% residential, 5% state)": y=11.4*x+12.625 as well as 'industry, mobile": y=7*x+5)*

Based on the information in the ICPR (2002) and Kreibich et al. (2005) a limitation of the effect of measures at water depths h <2 m is also directly apparent in the damage functions. At greater water depths, the potential damage level remains unchanged.

The calculation of the damage reduction is dependent on the effectiveness of the measure and the realisation. As an example, a municipality with 1000 houses in the flooding area (dyked and non-dyked) is analysed. In a survey, 100 home-owners claim to have implemented flood-adapted construction measures, i.e. the realisation factor is 10%. The effect of the measure in dyked areas therefore equals 3.5 % (effect = max. effect * realisation = 35 % * 10 %).

Within the framework of the large-scale assessment of flood risk, no detailed surveys could be carried out to identify (amongst other things) not only the presence of such building measures but also their effectiveness in the different flood scenarios. The realisation factors applied therefore only represent a rough estimation. As a rule, it is assumed that a strong relationship exists between the flood probability and the realisation factor. Even in the case of a regional assessment of flood risk, only very rough estimates are possible here in general. The question as to whether this indicator can be dispensed with, prioritising instead indicator I.1., should therefore be examined.

Flood-proofing property (within the flooding area) (I.3.2)

Indicator:

<u>Protected areas due to precautionary building/flood-proofing property and/or mobile systems</u>

Flood protection walls in Cologne

Small protective dykes

Explanation:

Buildings are protected using mobile systems, so that they do not become flooded. In this way, both the mobile and the immobile potential damage is reduced. These measures are only effective in water depths of max. 2 m, where the systems are not inundated by the water *(see explanation below)*. *Effect of measures:*

In the case of the full implementation of the measure, the potential damage can be reduced by a maximum of 90% per scenario per raster cell, if the measure prevents flooding, i.e. at water levels below 2 m (or protection up to 2 m).
Flood-proofing property has an impact on HQ10 and HQ100 areas, as well as on the further-reaching HQextreme areas.

Source for effects of measures:

- ICPR (2006): Settlement and industry (immobile = mobile) for Germany and Switzerland (only non-dyked) 90% (h <0.5 m), 50% (h <2 m), 10% (h> 2 m) (see detailed explanation below regarding the selection of these reductions in the calculations and/or damage functions).
- ICPR (2002): 50 - 80 % damage reduction in private buildings, with basement sealing even 100%; in commercial and industrial use 25-100 %

- Kreibich et al. (2005): 30 % damage reduction in private buildings

In the two ICPR documents, the impact of flood-proofing buildings (shielding) is described in relatively great detail, but without giving precise indications about which flood events and data this is based on (except for the Lucerne office/commercial building in Switzerland). The water-proofing of buildings using different systems, as long as they can withstand the water pressure, is deemed one of the most efficient measures of avoiding damage. Therefore, from our point of view, the impact scale specified by the ICPR (2006) for different water depths represents a realistic approach (and for this reason was also integrated into the damage functions, cf. Figure 14). In water depths that are lower than 0.5 m, it can be assumed that damage (both mobile and immobile) can almost entirely be prevented. Depending on the system, different degrees of water may seep through the system or through e.g. sewer backwater into the building, which is why a maximum rate of 90% is assumed. The higher the water level rises, the less effective the measure is. In water depths greater than 2 m, a minor reduction in the potential damage is still assumed.

Calculation:

The measure has a local impact in the areas that are protected by flood protection measures within the flooding area (cf. Figure 13, pink areas have the degree of protection for a HQ100 here). The protection can be applied for individual buildings or, as shown in Figure 13, for a group of buildings or urban areas. Within the protected area the damage is reduced, depending on the water depth, in accordance with the modified damage function (Figure 14). In terms of flood-proofing property, it is assumed that this reduces the damages, regardless of whether an area is dyked or non-dyked. The indication of the degree of protection, i.e. for which scenario the measure is effective, represents significant information. The effect is calculated for each raster cell and for each scenario.

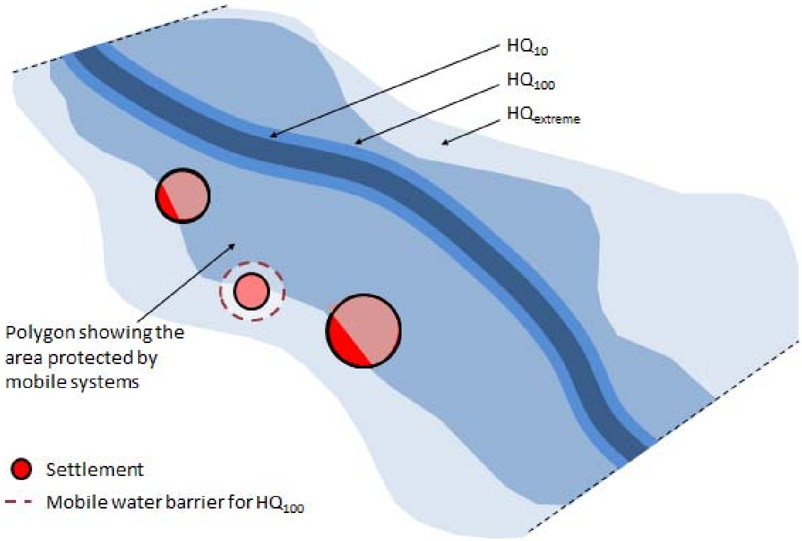

Figure 13: Illustration of the measure "flood-proofing property (I.3.2)"

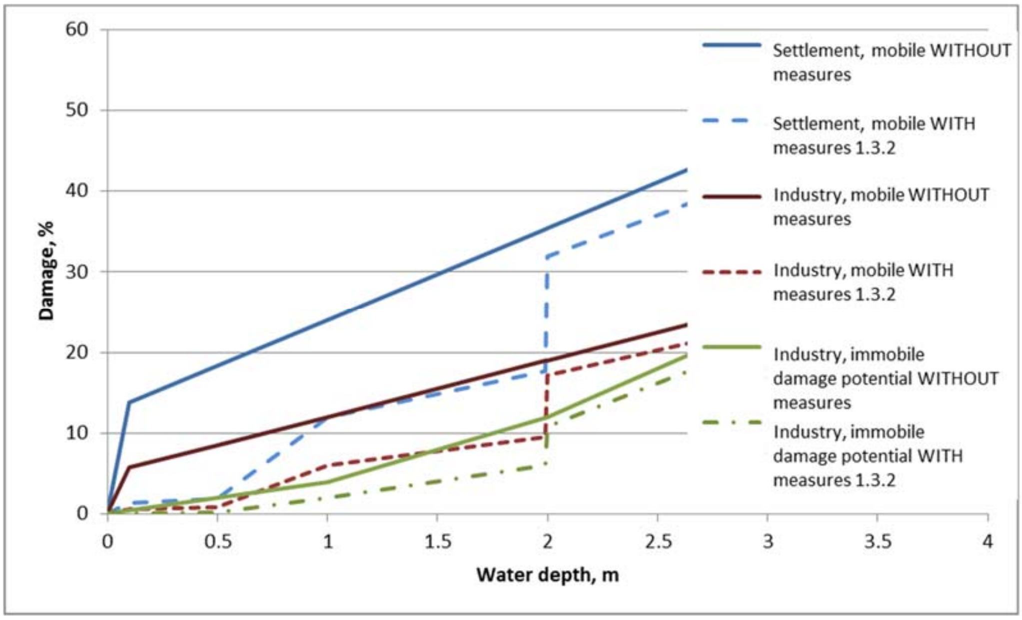

*Figure 14: Modification of the damage function for immobile and mobile damages (settlement and industry) due to the measure "flood-proofing property (I.3.2)" (applied function (example without measures): "settlement, mobile": y=11,4*x+12.625, "industry, mobile": y=7*x+5 as well as "industry, immobile": y=2*x²+2x) (here, the reduction percentage rates from the ICPR publication (2006) are implemented; cf. above details under "Source for effects of measures")*

As is the case for the indicator I 3.1, within the framework of the large-scale assessment of flood risk, no detailed surveys could be carried out to identify (amongst other things) not only the presence of such building measures but also their effectiveness in the different flood scenarios. The realisation factors applied therefore only represent a rough estimation. As a rule, it is assumed that a strong relationship exists between the flood probability and the realisation factor. Even in the case of a regional assessment of flood risk, only very rough estimates are possible here in general. The question as to whether this indicator can be dispensed with, prioritising instead indicator I.1., should therefore be examined.

Flood-adapted storage of water-polluting substances (I.3.3)

Indicator:

Securing oil tanks and/or safe storage in upper storeys

Example of anchoring an oil tank

Explanation:

By securing oil tanks or the storage of water-polluting substances in upper storeys, the damages can be significantly reduced.

The calculation of the damage reduction is thus dependent on the effectiveness of the measure and the realisation. As an example, a municipality with 1000 houses in the flooding area (dyked and non-dyked) is analysed. In a survey, 500 home-owners claim to have implemented safeguarding measures, i.e. the realisation factor is 50 %. The effect of the measure in dyked areas therefore equals 15 % (= 30 % x 50 %).

Effect of measures:

The flood-adapted storage of water-polluting substances has an impact on HQ10 and HQ100 areas, as well as on the further-reaching HQextreme areas.

Max. 30 % (dyked); 50 % (non-dyked, i.e. higher flood water depths and where application a larger proportion of people who are not prepared) per scenario, per raster cell.

For the calculations, an average from the ICPR and Kreibich et al, based on ICPR expert predictions, is calculated and selected for dyked and non-dyked areas (cf. details below).

Source for effects of measures:

- Expert estimates
- ICPR (2006): immobile potential damage for Germany and Switzerland (only non-dyked) 90 % (h <0.5 m), 90 % (h <2 m), 50 % or 0 % for Switzerland (h >2 m)
- ICPR (2002): 30 - 40% due to adapted use; extent of damage increases due to heating oil (200 to 300%); in commercial establishments, the storage of hazardous substances in upper storeys leads to a reduction of 50-75%, and in the case of storage outside of the flooding area, to 100%.
- Kreibich et al. (2005): 53 % due to adapted use

The details of the impact of the measure "flood-adapted storage of water-polluting substances" refers both to the securing of heating oil tanks in areas of private residential buildings as well as to safeguarding and precautionary/preparedness measures as regards commercial and industrial facilities. In ICPR (2002), the example of a petrol station in Vallendar is used. After the Rhine flood in 1993, this was protected by mobile elements, as it was filled with up to 1.3 m of flood water for 14 days during the flood.

This example leads to very high reduction factors, as does the storage of water-polluting substances outside the flooding area (impact = 100%). Due to the fact that within the context of the ICPR project, the survey results from Bubeck are used, which relate exclusively to private households, maximum reduction rates of 50 or 30% are applied, because in the private sector the effectiveness of this measure is estimated to be lower. This is also substantiated by the results in Kreibich et al. (2005). The distinction between dyked and non-dyked areas in terms of impact results from the familiarity/experience with flooding events, as explained in Section I.3.1. That means that in the case of non-dyked areas, it is assumed that because of the prior experience of flooding of the people affected (more frequent flooding than in dyked areas) the reduction effect is higher.

As is the case for the indicator I 3.1, within the framework of the large-scale assessment of flood risk, no detailed surveys could be carried out to identify (amongst other things) not only the presence of such building measures but also their effectiveness in the different flood scenarios. The realisation factors applied therefore only represent a rough estimation. As a rule, it is assumed that a strong relationship exists between the flood probability and the realisation factor. Even in the case of a regional assessment of flood risk, only very rough estimates are possible here in general.

Calculation:

The calculation of the impact of the measure "flood-adapted storage of water-polluting substances" is carried out for all three scenarios, as per the illustration below (Figure 15). At municipality level, the potential damage increases by the product of the maximum effect and the degree of realisation in the settlement areas. The calculation formula is:

Damage with measures implemented = 0.30 x realisation factor x damage without measures (for dyked areas)

or the damage potential can also be calculated using the water depth-dependent modification of damage function for settlement (immobile and mobile) and industry (immobile and mobile), Figure 16 and Figure 17, and multiplication with the realisation factor.

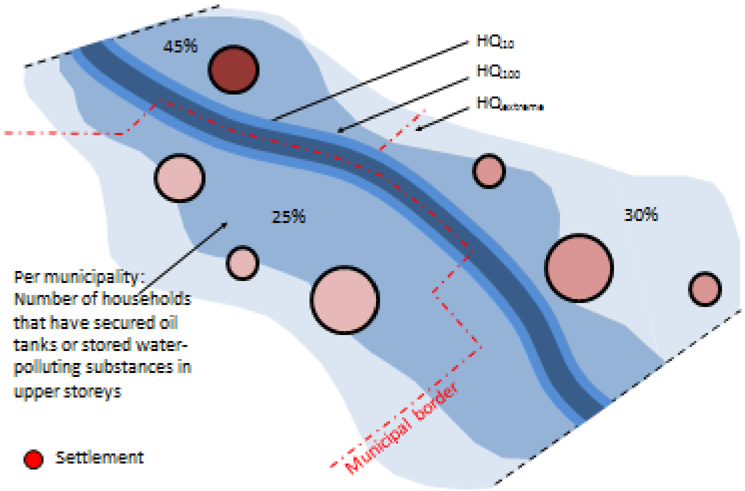

Figure 15: Representation of measure "flood-adapted storage of water-polluting substances (I.3.3)"

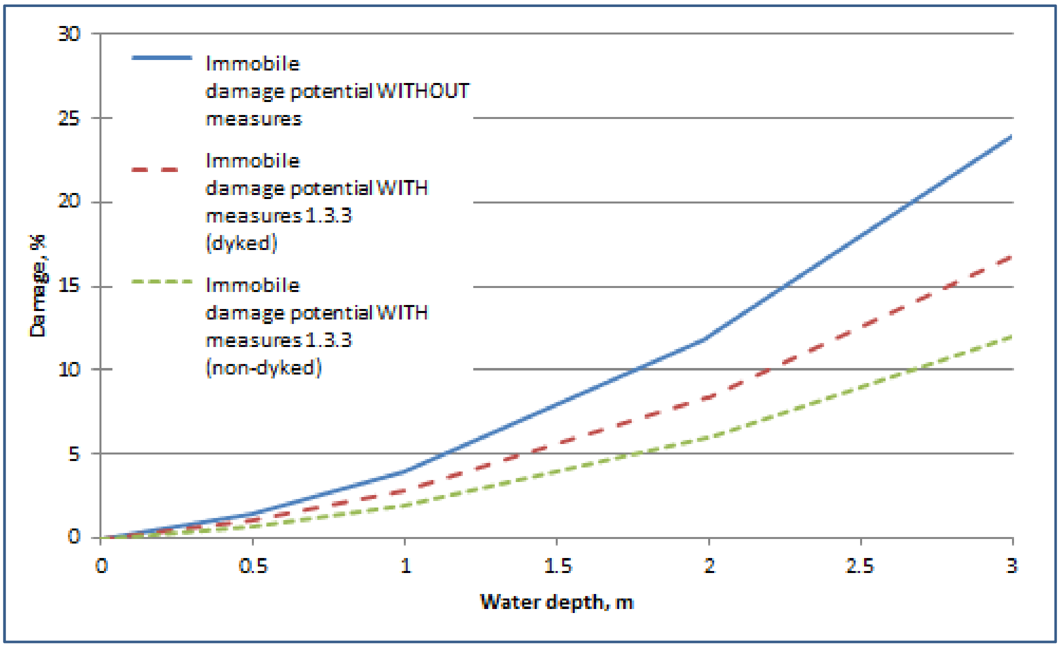

*Figure 16: Modification of damage function for immobile damage (industry) due to the measure "flood-adapted storage of water-polluting substances (I.3.3)" for dyked and non-dyked areas (function applied (example without measures): "Industry, immobile" y=2*x²+2x)*

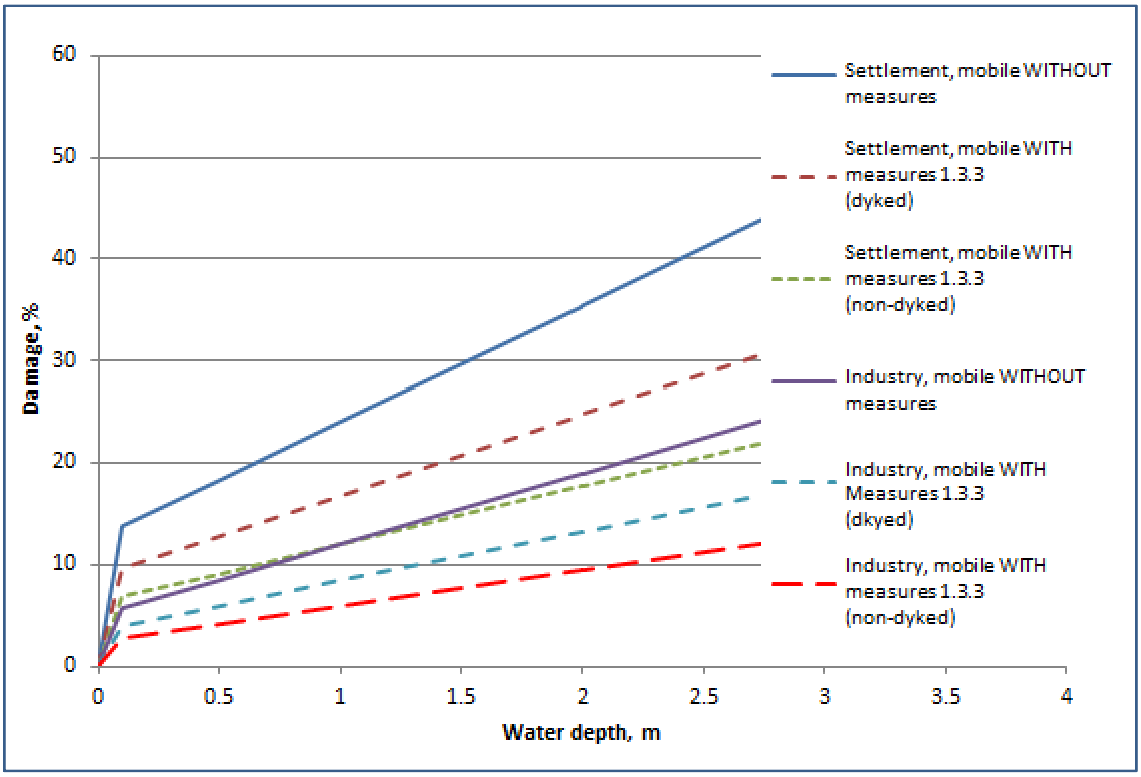

*Figure 17: Modification of damage function for mobile damage (settlement and industry) due to the measure "flood-adapted storage of water-polluting substances (I.3.3)" for dyked and non-dyked areas (function applied (example without measures): "Settlement, mobile": y=11,4*x+12,625 as well as "Industry, mobile": y=7*x+5)*

Other preparedness measures (I.4)

Provision of flood hazard and risk maps and establishing awareness for precautionary behaviour, education and preparation/preparedness for flood events (I.4.1)

Indicator:

Frequency of information campaigns (incl. provision/presence of FHM and FRM)

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Flood maps (cf. www.naturgefahren.at)

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HKC Info-mobile (HochwasserKompetenzCentrum; cf. http://www.hkc-online.de/en/projects/hkc-info-mobile/index.html): Mobile information unit for educational purposes

Explanation and calculation:

Raising awareness is an important prerequisite for a suitable response/actions from those affected by a flood. Only when the hazard and the possibilities regarding how to respond/act are known, can measures be taken effectively. The publication of FHM and FRM provides a good basis for this. Further materials also can be made available e.g. flyers or other information media (e.g. Flood Protection Handbook [Hochwasserschutzfibel] of the Ministry for Transport, Building and Urban Development [BMVBS]) In addition, information events, workshops, flood partnerships or similar can be organised.

Through the (vertical) evacuation of property – into upper storeys, or driving cars etc. out of the flooding area, mobile potential damage can be significantly reduced.

This reduction in potential damage can only be achieved if the danger and/or affected area is known (FHM and FRM).

The flowchart illustrates the implementation of the indicator in the tool. Where FHM and FRM exist, the effect is first of all dependent on keeping the maps up to date.

In a second step, an analysis is made as to whether information campaigns take place, and if so, how often. If FHM/FRM are updated more frequently than every six years and information campaigns are carried out more frequently than every two years, the maximum effect of the combination of these measures amounts to 5 or 10%.

In general, the assumption here is that the more improvements or updates to the maps and information campaigns there are, the more willing and prepared people are to safeguard their property, which leads to a reduction of the potential damage.

Effect of measures:

The combination of providing FHM and FRM and establishing awareness in terms of precautionary behaviour, education and preparation/preparedness for flood events has an impact on both HQ10 and HQ100 areas and surfaces as well as on the wider-reaching HQextreme areas. Max. 5 (dyked); 10% (non-dyked) per scenario per raster cell.

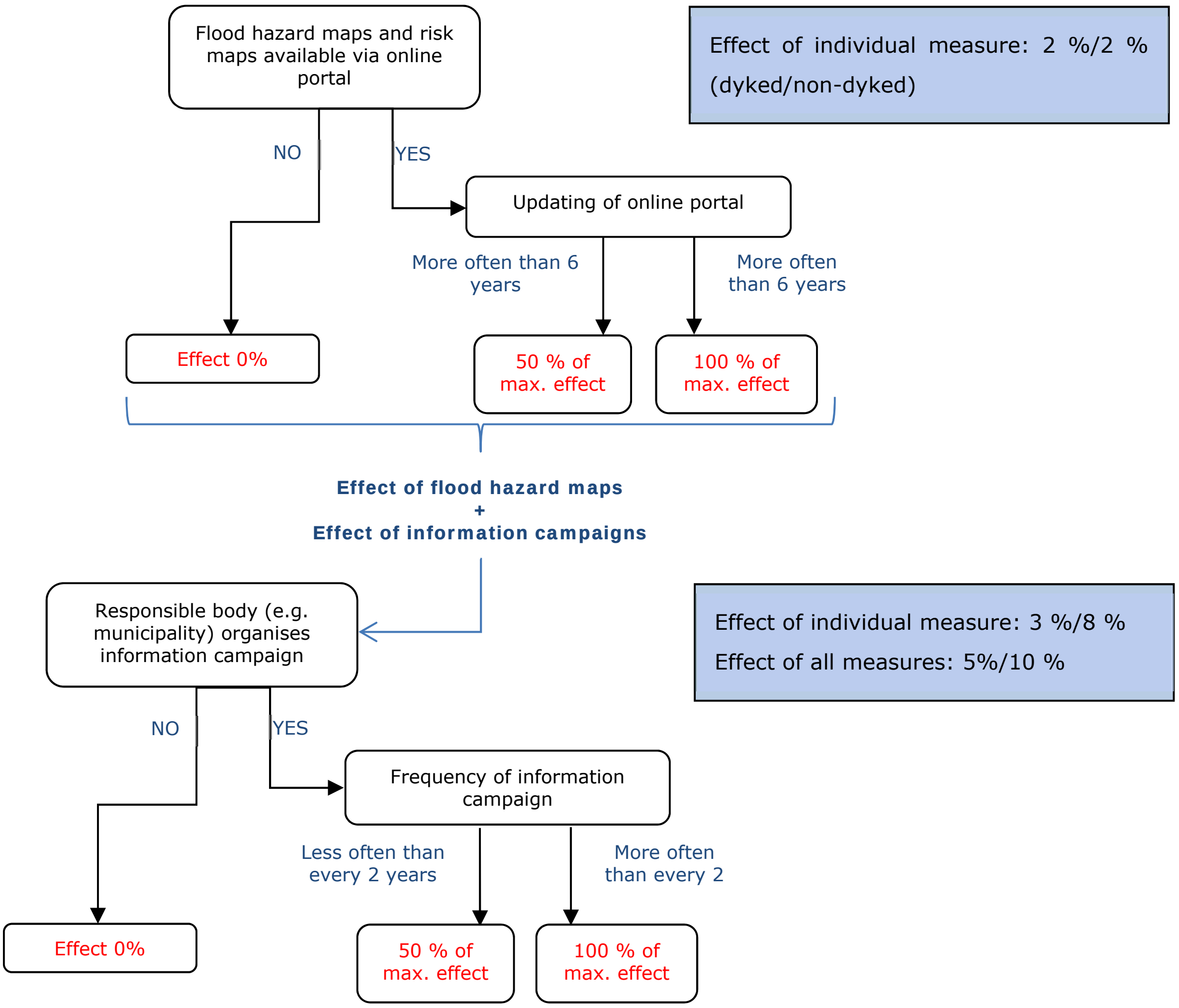

Figure 18: Flowchart for indicator "provision of flood hazard and risk maps and establishing awareness in terms of precautionary behaviour, education and preparedness for flood events (I.4.1)"

Source for effects of measures:

- Expert estimation

As yet, there is no prior experience with regard to the effect of the measure involving the provision of FHM and FRM and establishing awareness in terms of precautionary behaviour, education and preparedness for flood events. Thought the FD, which was adopted in 2007, the FHM/FRM were created for all areas with significant risk, and introduced to both the municipalities as well as the citizens, as well as being published in different ways (usually via online portals). Due to regular updating (6 year cycle), it is assumed that this measure has a lasting effect. The representation of the danger and establishing awareness amongst everyone affected form the basis of preparedness measures in the event of flooding. There are differing estimated effect levels of 5 or 10% for dyked and non-dyked areas, as it is assumed that the readiness to act upon and implement measures in non-dyked areas is greater, therefore the presence of FHM/FRM in these areas is more relevant.

The damage function is modified independently of the water level for settlement (immobile and mobile) and industry (immobile and mobile).

4.4.2. Flood protection (II)

Indicator:

The indicator is the modification of flood probability.

Explanation:

Flood protection measures are assessed by calculating the modification of the probabilities and the classification of risk analysis in protected/dyked and unprotected/non-dyked stretches of the Rhine (cf. Annexes 1 and 3).


© Klaus Wendling, MULEWF RLP

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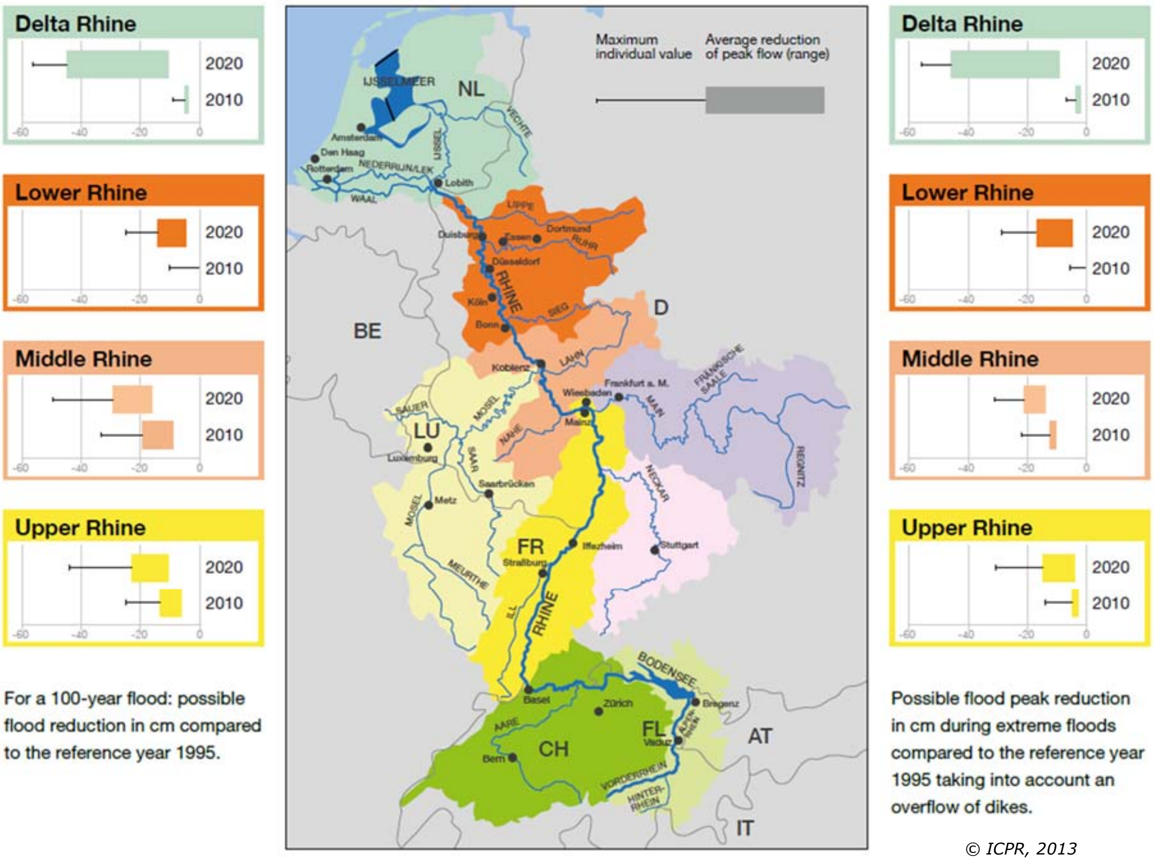
Left: Non-dyked stretch of the Rhine (Middle Rhine), right: dyked stretch of the Rhine (Upper Rhine)

In the calculations of the ICPR Expert Group Validation (EG HVAL), it was exclusively the retention measures that were taken into consideration (according to tables 9 and 12, the measures: restoration of natural water retention, regulation of water run-off and river training). Modifications of flood probabilities due to the improvement of protection through "technical flood protection measures" (e.g. mobile flood protection structures in Cologne) and "other technical measures" (e.g. raising the height of dykes) were provided by the ICPR (see Annexe 3). For both measures together, a probability is specified.

© Ruimte voor de Waal, 2015

Example of river widening measures at Lent/Nijmegen, Netherlands. Dyke relocations at Lent, right: current situation (after relocation) (programme "Room for the River", project "Room for the Waal" [http://www.ruimtevoordewaal.nl)](http://www.ruimtevoordewaal.nl)



For a 100-year flood: possible flood reduction in cm compared to the reference year 1995.

Possible flood peak reduction in cm during extreme floods compared to the reference year 1995 taking into account an overflow of dikes.

© ICPR, 2013

Possible peak reductions through water-lowering measures: Status in 2010 and 2010

4.4.3. Preparedness in case of flooding (III)

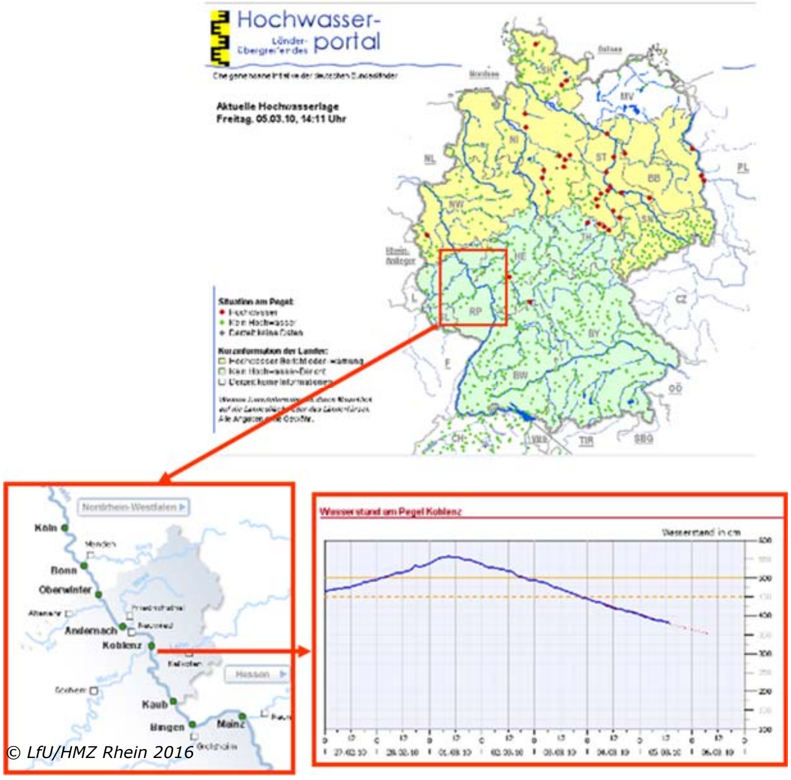
Precautionary/preparedness information, flood information and forecasting (III.1.1)

Indicator:

Improving flood forecasting within a defined period (inter alia by extending the forecast horizon)

© ICPR

Flood forecasting centres along the Rhine
(cf.http://www.iksr.org/en/topics/floods/flood-warning-and-forecasting-centres/interactive-map/index.html)



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Example of flood forecast information on the internet (Flooding early June 2016; cf. www.hochwasserzentralen.de)

Explanation and calculation:

Improved flood forecasting may lead to a longer prediction period and an associated longer warning and preparation time period, whereby damage reduction is increased and, where applicable, better evacuation results (a higher safeguarding rate) can be achieved.

Through the (vertical) evacuation of property into upper storeys, or driving cars etc. out of the flooding area, mobile potential damage can be significantly reduced. Raising awareness through information and forecasting forms the basis of precautionary building measures. The better and more long-term a forecast is, the greater the room for manoeuvre.

At the highest level of detail in the following flowchart, a distinction is made between announcement systems, forecasting systems and no system. In terms of the forecast systems, the parameter that is forecast is given a further degree of significance. Whilst, in terms of operational flood response, the forecast regarding run-off only provides an indication about possible floods and the resultant damages to those people who are have a good knowledge of flood development and discharge patterns, a forecast regarding probable flooding areas is also a useful and easily interpretable indication for those with less specialist knowledge, for predicting the consequences.

The maximum effect in terms of the forecast period in the case of the Rhine is reached by doubling the forecast period from 1995 to 2005. After 2005, as regards this criterion, no change is observed, as per the Rhine Action Plan on Floods. After 2005, a further improvement due to forecast accuracy (reliability) can be achieved, which must be assessed using the flood forecasting centres. If no statements can be made regarding reliability, the effect level shall be deemed to be "adequate".

The flowchart is explained using the following example (green box):
A forecast system that predicts the water level is operated. The maximum desired forecast period is reached and the reliability of the forecast is considered very good. As a result, 90% of the maximally achievable effect (15 % or 20 %) is reached, i.e. in dyked areas 13.5% (=0.9*15 %) and in non-dyked areas 18 % (= 0.9*20%).

Effect of measures:

Flooding information and forecasting has an impact on HQ10 and HQ100 areas, as well as on the further-reaching HQextreme areas.

Through these measures, a maximum of 15% (dyked) / 20% (non-dyked) of the mobile potential damage per scenario can be prevented per raster cell.

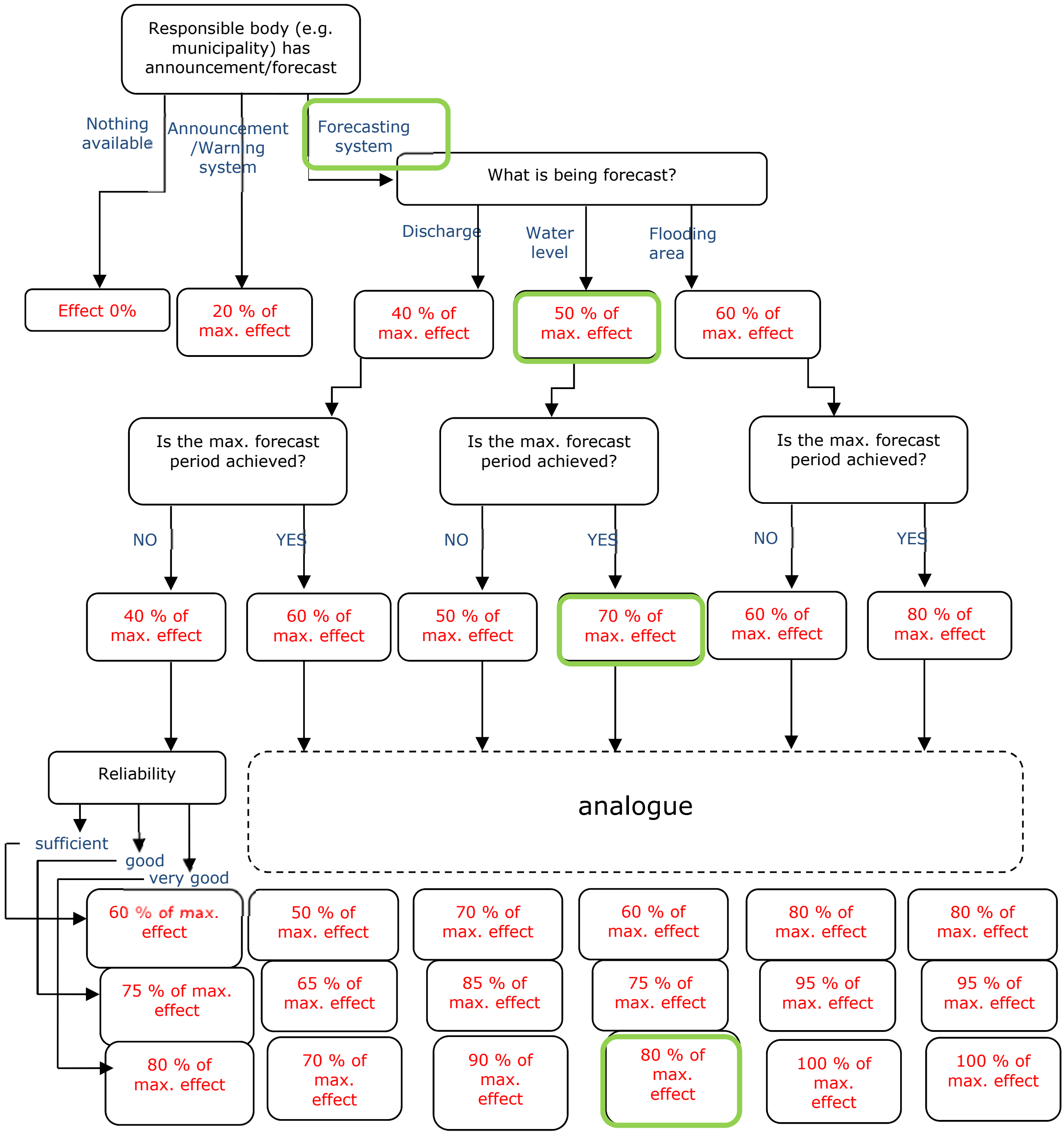

Figure 19: Flowchart for the indicator "Precautionary/preparedness information, flood information and forecasting (III.1.1)"

Source for effects of measures:

- Expert estimation
- ICPR (2006): mobile potential damages regarding settlement
- Messner et al. (2006): average of 21 % of direct, tangible economic potential damages; in the case of a pre-warning period of 8 hours max. 48 %
- Wind et al. (1999): 35 % reduction in potential damages in 1995 flooding in comparison to 1993 flooding; reduction is attributed to flooding familiarity/experience in private households and slightly longer pre-warning periods
- The effect of the measure "flood information and forecasting" has been examined both in the catchment of the Maas (1993 and 1995) as well as the Rhine (1993 and 1995). In all cases, significantly lower potential damages to the mobile value are recorded for the second event, which is due to improved flood forecasting, as

well as greater awareness, better preparation and the implementation of preventive measures. The mobile potential damages can be reduced by 80 %. These findings were also publicised for the catchment of the Elbe (Jüpner TU Kaiserslautern, Workshops, 2002 and 2013).

The difference between 15 % (dyked) and 20 % (non-dyked) is based accordingly on the explanation above as well as on the details in ICPR (2006). As this only refers to the measure "forecasting", the reduction factors specified in the literature for the combinations of measures have been reduced.

The damage function is modified independently of the water level for settlement (immobile and mobile) and industry (immobile and mobile).

4.4.4. Emergency response and civil protection / crisis management (incl. recovery / aftercare) (III.2)

Warning systems for those affected/alarm and emergency response plans/exercises and training (III.2.1)

Indicator:

Presence and update frequency of alarm and emergency response plans; number of warning systems (warning methods/ways and communication means), details of civil protection/crisis management exercises including frequency

Letzter Messwert: 10.04. 09:00 Uhr

< Mittelwasser

Wasserstand [cm]: 257

Vorhersage vom : 10.04. 07:00 Uhr der Bundesanstalt für Gewässerkunde

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Mobile app for visualisation and warning regarding flood levels

© STEB Cologne

© ICPR

Crisis discussion/meeting at the Flood Protection Center Cologne and exercises at DWA (German Association for Water, Wastewater and Waste) flood days

Explanation and calculation:

Through the (vertical) evacuation of property into upper storeys, or driving cars etc. out of the flooding area, mobile potential damage can be significantly reduced. The existence of an alarm and emergency response plan, and the warning system for those affected form the basis/prerequisite for (most) responses. The ICPR assumes the following: The better the flood forecast (inter alia longer forecasting periods), the earlier and more precise the warning. Emergency measures can form part of the emergency alarm and response planning.

Note: In reality, even with many new developments in recent years in terms of longer forecast periods, these still are not, however, expected to offer the same reliability as shorter-term forecasts. This means that a better/more accurate forecast is not always equated with a longer pre-warning period.

Furthermore, exercises and training form the basis of a secure flood protection system, preventing errors/ill-advised decisions in the event of a flood, and contribute to the sensitisation as well as the establishment and raising of awareness.

Through targeted preparation and briefing – both of emergency personnel and services and those people affected – the potential damage can be reduced.

The flowchart illustrates the implementation of the indicator in the tool. Initially, an inquiry is made as to whether an emergency response plan is in existence. If no plan is present, the effect of the combined measures is 0. If a plan is present, a check is made as to how up-to-date it is.

As an example, in a municipality in a dyked area, an alarm and emergency response plan is available, but it is updated less often than every 5 years. The effect is then 50 % of the maximal effect (0.5*10 %=5 %).

As the next step, the warning system and the number of warning methods and ways are considered. For the above-mentioned example, it is also assumed that a warning system is present, with 2-3 redundant warning methods/ways. The effect of this measure considered individually is 1.25 % (50 % of 2.5 %); the effect of the combination of measures of the alarm and emergency response plan and warning system is 6.25 %. As the last step, exercises and training sessions are considered, as well as their frequency. The evaluation of the effect of individual and combined measures is undertaken in a similar way to that of the evaluation of the measure "warning system".

In the example, it is now assumed that the municipality carries out flood protection exercises every two years. The individual effect is assessed at 100 % of the maximum effect (2.5%); the combination of all three steps leads to a total effect of 8.75% (6.25 % + 2.5 %).

To illustrate this example, in the following flowchart, the box for the individual results is outlined in green.

In the event that an alarm and emergency response plan exists, no warning system is present, and exercises are carried out, the left branch of the flowchart is followed (green arrow). The maximum achievable effect in this case is 12.5 or 25% respectively.

The sum of the effects depends on the dependency tables at the end of the document (cf. Annexe 13).

Effect of measures

The combination of the measures "warning those affected/alarm and emergency response plans/exercises and training" has an impact on both HQ10 and HQ100 areas and surfaces as well as on the wider-reaching HQextreme areas.

Through the measure, the potential damage can be lowered by a max. of 15 % (dyked) - 30 % (non-dyked) per scenario, per raster cell.

Source for effects of measures:

- Expert estimation
- ICPR (2006): mobile and immobile potential damage to the category settlement and industry. The effect is related to emergency measures, emergency response, civil protection/crisis management and emergency relief

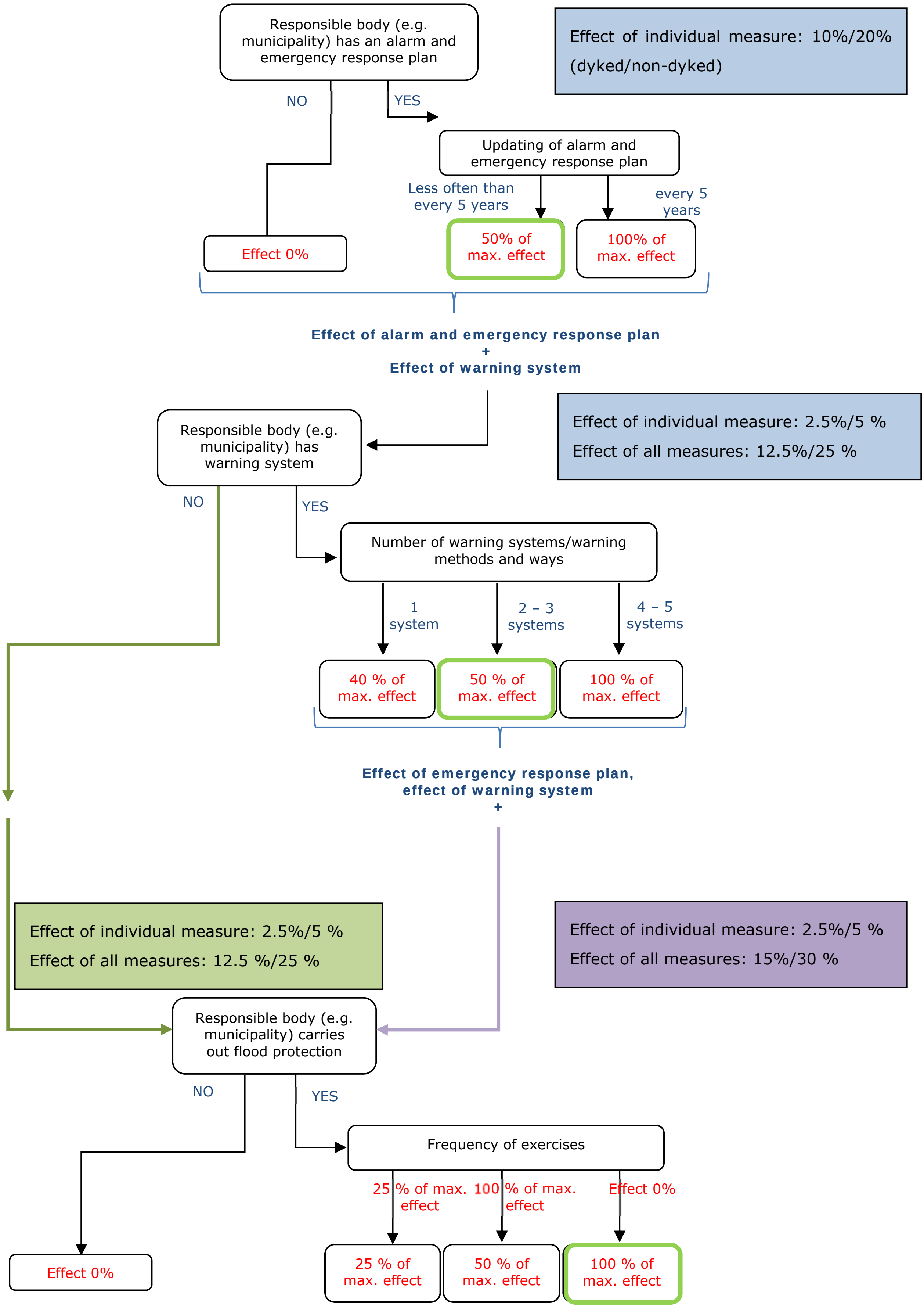


Figure 20: Flowchart for the indicator "warning systems for those affected/alarm and emergency response plans/exercises and training (III.2.1)"

4.5. Combinations of measures

In addition to the effect of individually effective measures, there are **correlations between measures** which are described in a dependency matrix, both for dyked and non-dyked areas (Annexe 13). Reminder: the use of the terms "dyked" and "non-dyked" in the context of the project means areas that are protected/not protected through technical flood protection systems.

If several measures for one area that have an impact on the receptors economic activity and cultural heritage are combined, as a rule, the effect of the measure cannot be summed up in a simple manner, as there is the possibility that the effect would exceed 100%. Secondly, it is assumed that individual measures only have an effect when supplemented or used in combination with other measures.

The following assumptions – which are based on ICPR expert estimations (more details in the HKV Final Report, 2016) – underpin the matrix:

- In the case of the **precautionary/preparedness measures for the event of a flood (III)** and /or **hazard and risk maps** (I.4.1), for two or more measures, the maximum effect is 1.5 times the effect of the more effective measure. This is equal to a max. of 22.5 % in dyked areas, and 45% in non-dyked areas.
- In the case of the **precautionary building measures (design, construction, renovation (I.3.1), flood proofing property (I.3.2) and flood-adapted storage of water-polluting substances (I.3.3))**, the more effective measure is selected where there is a combination of two measures in this sphere of action. When combining measures regarding **precautionary building** and **preparedness measures for the event of a flood**, the effect of the precautionary building measure is selected. When combining the measures **precautionary building** and the **"package" of measures FHM/FRM/information**, the effect is added up, to a maximum of 100%.
- When combining **flood protection measures (II)** and **other measures**, the effect of the measures (or combinations of measures) remains unchanged.
  Note: the specific adjustments of the effects of measures based on their location in protected or non-protected area is not mentioned here but is integrated in the other chapter about measures and indicators.

The combination of measures that have an impact on human health has already been described in Sections 2 and 4 ("Indicators regarding human health").

4.6. Notes on the use of indicators, important assumptions and restrictions of use

General limitations and restrictions:

- Much of the information on the effect and degree of implementation of measures remains strongly based on expert knowledge.
- The estimates and assumptions concerning the indicators/measures should in future be replaced by improved data. A continuous improvement of the input data is desirable; however data collection is associated with large expenditure/effort both in terms of time, and financially.

- On a large scale, for example, data cannot be calculated with acceptable expenditure for some indicators with a high level of detail such as the realisation of measures for flood-proofing property, and their effectiveness in the three flood scenarios; this is only possible locally/regionally.
- EU or state-level measures may deviate from those defined in the ICPR project categories, meaning that directly linking these with the monitoring of the FRMP may be difficult (this may particularly be the case with those non-EU countries that do not implement the FD). A reclassification of the national measures with the categories of measures implemented in the tool and a compatibility check between the definitions of national and ICPR measures should take place prior to the calculation.
- For the same indicators, partially very different/heterogeneous information and "interpretations" may be present.
- Logical issue: if a measure does not exist, or as not been realised or implemented/supplied, this does not necessarily mean that there is a negative impact on the reduction of risk.
- Culture: The lower the flood probability, the greater the number of affected cultural objects. Neither measures nor different time horizons have any impact on the number of objects.
- Environment: The lower the flood probability, the greater the area of affected receptors with regard to water. Neither measures nor different time horizons have any impact on the area.

Assumptions and decisions regarding the indicators:

With regard to the information and the use of indicators for the calculations, the following assumptions and decisions are relevant:

- Baden-Württemberg was the only federal state in the German Rhine catchment that was able to provide data at the present time. This data is transferred to all of the other German federal states.
- If no information is made available for an indicator, it is then not considered.
- For the safeguarding rate for the calculation of measures affecting human health, a theoretical value was selected (safeguarding rate 1995 20%, 2020+ 80%).
- The data used in the tool as regards the indicators is heterogeneous, due to different interpretations and possibilities for the input of the indicator.

Note on effort required:

- Some indicators require the input of many details.
- The integration/conversion of national data as input files (or templates) requires some effort and requires GIS knowledge. This is, for example, the case for the conversion of data as well as other information into shapefiles. The country in question should preferably take care of this data pre-processing.
- For all countries, it is difficult to obtain concrete information regarding the implementation of measures in the past and in the future (prognoses, estimates). Even determining the current degree of implementation in the required depth of detail is extremely time-intensive for some measures.

- It is very difficult/time-intensive to obtain detailed and evaluable data at the level of households, municipalities, IPPC plants, SEVESO installations and waste water treatment plants.

4.7. Sensitivity analysis of the theoretical effect of measures on the reduction of flood risk

Within the framework of the investigation of the impact of measures of the FRMP on the modification of risk and/or in connection with the implementation of the FD, the EG HIRI carried out a "sensitivity analysis", which is outlined in this chapter.

4.7.1. Foreword

As part of the analysis, an investigation was carried out concerning which measures are more effective than others and where "potential for improvement" lies. In the calculations with all indicators, both the parameter regarding the maximal effect and the realisation were varied. Overall, the variation of the maximum effect prompted a more sensitive reaction than the variation of realisation. Here, in the case of both parameters, improving the situation entailed a more minor effect on risk, than a deterioration of the situation would. This is due to the process of adding together individual measures to obtain a total reduction level of the damage.

In the sensitivity analysis, the behaviour of the relative modification of the damage and risk by changing the degree of realisation and the maximum effect of a measure was examined. This was carried out in the area of economic activity with hypothetical indicators (individually as well as the sum of all indicators).

The sensitivity analysis answered two questions:

1. In which range do the results lie if the assumption for the "effect" varies within realistic ranges?
2. Which indicators (representative of measures) have a **great influence** on the flood risk and its reduction?

In addition, **two types of calculations** were made:

1. Calculation with all indicators. Here, the conditions in 1995 and 2005 were taken as the basis. The realisation of measures is based on the condition in 2005, supported by an estimate derived from the 2005 HIRI Assessment (Report nos. 156 and 157).
2. Change/variation in individual indicators (also based on the prior estimated realisation from 2005)

4.7.2. Determining the ranges of results

Here, the potential ranges of results are analysed, by considering all indicators that affect the receptor economic activity.
The data from the assessment carried out in 2005 within the framework of the APF balance 1995-2005 (ICPR reports 156 and 157) was used as a starting point for determining the range. The conditions in 1995 were taken as a reference point. The CORINE Land Cover data set from 2000 was used.

The estimated realisation of measures at the time for 2005 was integrated into the realisation values of the current indicators. The newly calculated risk change is generally comparable to the risk change estimated in 2005, though (methodological) differences are nevertheless recorded. This is the case, for example, for the new data from the FD regarding the FHM, used in the new calculations, and for land use data other than that of the 2005 Assessment, meaning that an absolute comparison is not possible. In addition, in the APF, the focus was solely on HQextreme, whereas the present analysis considers three flood probabilities/scenarios. In the current analysis, provisional national data was used. Therefore, only aggregated results (risk change) will be presented/displayed here. In any case, the present analysis led to the calculation of risk reduction of about 20% for the period between 1995 and 2005, which on the whole aligns with the results from the 2005 assessment.

Based on this starting position, within the framework of the sensitivity analysis, two aspects/parameters were varied:

a) the realisation of all measures: in comparison to the reference condition in 2005, the realisation values were set at lower and higher values (see "realisation plus/minus" in Table 14).
b) the maximally achievable effect was varied in comparison to the reference condition (see "effect plus/minus" in Table 15). The condition in 2005 without measures was taken as the reference.

Table 14: Calculation variants

Description	Change effect	Realisation*
State 2005 without measures (reference)	None	*No measures (realisation = 0)*
State 2005 with measures	None	APH balance 2005 (cf. Annexe 1)
Effect plus	10%	APH balance 2005 (cf. Annexe 1)
Effect minus	-10%	APH balance 2005 (cf. Annexe 1)
Realisation plus	None	APH balance 2005 plus (cf. Annexe 1)
Realisation minus	None	APH balance 2005 minus (cf. Annexe 1)

**with realisation values from the APH balance 2005 (see detailed figures in Annexe 1)*

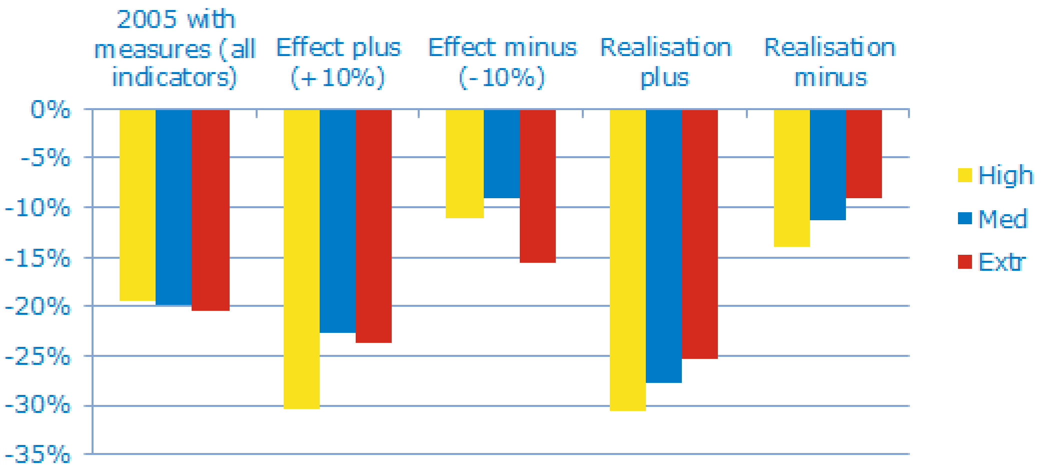


Figure 21: Change of (economic) flood risk (2005 condition) in application/calculation of different variants "2005 condition with measures", "effect plus/minus", "realisation plus/minus" (the reference here is to the condition in 2005 without measures; the "theoretical" measures for 2005 are taken from the 2005 APF assessment).

Although there are some differences, globally the influence of +10% or -10% realisation is identical to the change of the maximum effect. The range of results remains within ca. 10%.

Based on these results, an estimation can be made as to how accurate the statements regarding the change in risk can be. Due to the measurability of the indicators, it can be established that the accuracy of the calculated changes is to the order of around 20%.

4.7.3. Investigation of the effect of individual measures

In order to determine the relative contribution of the indicators to the change in flood risk, calculations were also carried out with individual indicators (see Figure 22 below), in accordance with the evaluation of the calculation with all indicators. Here, the "condition in 2005 without measures" was also used as a reference model for the change in risk. For each indicator the same realisation as that of 2005 was applied, and the realisation values of the remaining indicators were set to 0%.

Illustrative example" The relative change in risk relating to the measure "flood forecasting" relating to the variant "condition in 2005 without measures" amounts to approximately 15% for the scenario HQmed (blue column). This means that due to the measure "flood forecasting", the risk for the HQmed scenario is reduced by 15 %.

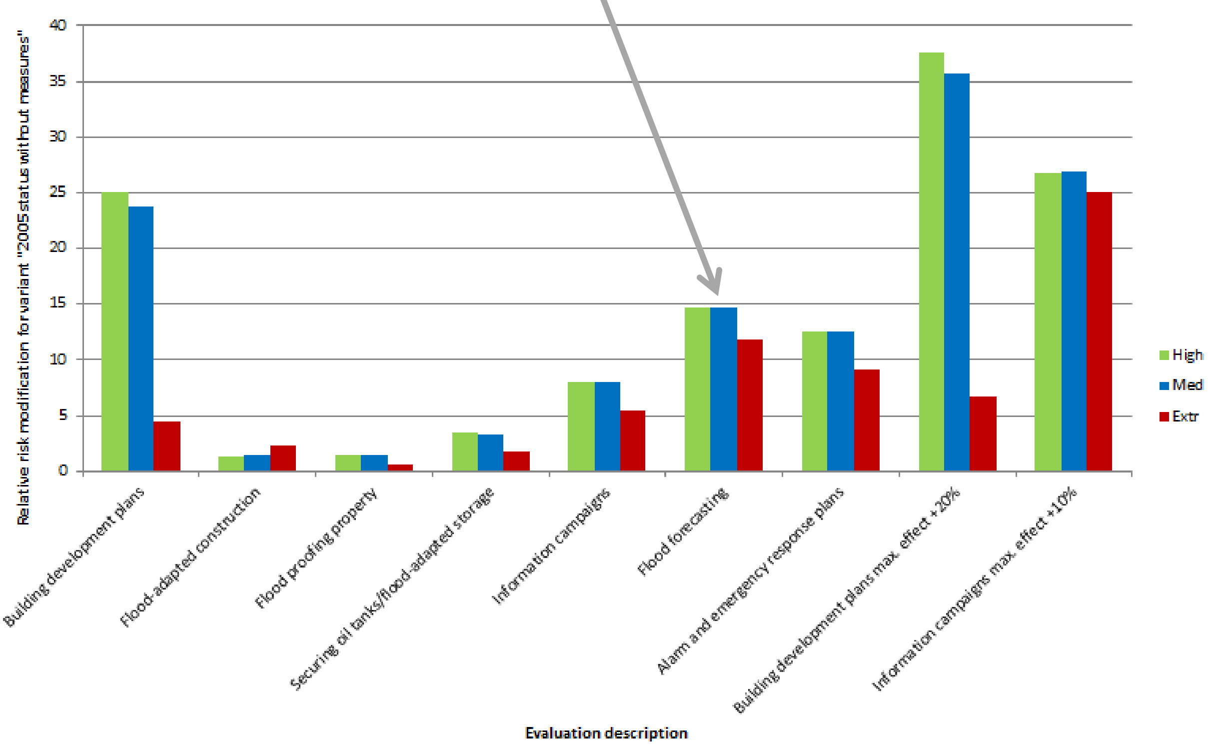


Figure 22: Risk change from calculations with individual indicators in comparison to the variant "condition in 2005 without measures, including growth of potential damage" in %

When comparing individual measures, a summary statement can be made that due to the large flooding areas in the German part of the Rhine basin in combination with the realisation of precautionary land use measures of 95%, a maximum risk reduction in the case of medium and frequent flooding events is achieved. Taking into account all scenarios, the risk mitigation related to measures in the area of "preparedness" (measures such as information campaigns, flood forecasting, alarm and emergency response planning) is the most promising. The other measures in the area "prevention" have a lower impact in terms of mitigation at Rhine basin level. In local terms, however, these may be deemed considerable.

In the case of measures relating to precautionary land use ("building development plans or spatial planning including keeping flood-prone areas free") and FHM/FRM ("information campaigns"), in this section of the analysis the maximum effect was also increased by 20% and 10% respectively (note: for the other measures, the effect was not changed). For both measures, a significant change in risk based on the increase in the maximum effect of the measure can be seen.

5. Tool for assessing the reduction in flood risk as well as calculation stages and examples

Here, the calculation stages, the structure of the tool "ICPR FloRiAn (Flood Risk Analysis)" with the various ModelBuilders (= calculation modules in ArcGIS) and the forms of presentation of the results are formulated and reproduced.

The User Guide as well as the help function (integrated into the tool) contain detailed descriptions of the installation of the tool, the individual toolboxes/ModelBuilders and types of calculation.

5.1. Calculation stages

Input: Outside of/separate from the tool (steps taken in advance of calculations)

1. Definition of the investigation area, and conversion into GIS format.
2. Choice of one or more time horizons.
3. Data preparation (pre-processing) in appropriate GIS formats, where required different GIS preparation tasks (e.g. spatial localisation of people in settlement areas in the land-use data, adjustments of asset values in accordance with consumption price index, or adjustments of population figures on the basis of population growth).

Within the tool

1. Integration of data/shapefiles into the instrument (see below details and clarifications in User Guide) for a time horizon (reference state first of all).
2. Repetition with other input data for other time horizons.
3. Calculations of the potential damage and/or the risk per flooding scenario and/or integrally. This can be done for one or more receptors, as well as with or without the impact of one or more measures/indicators.

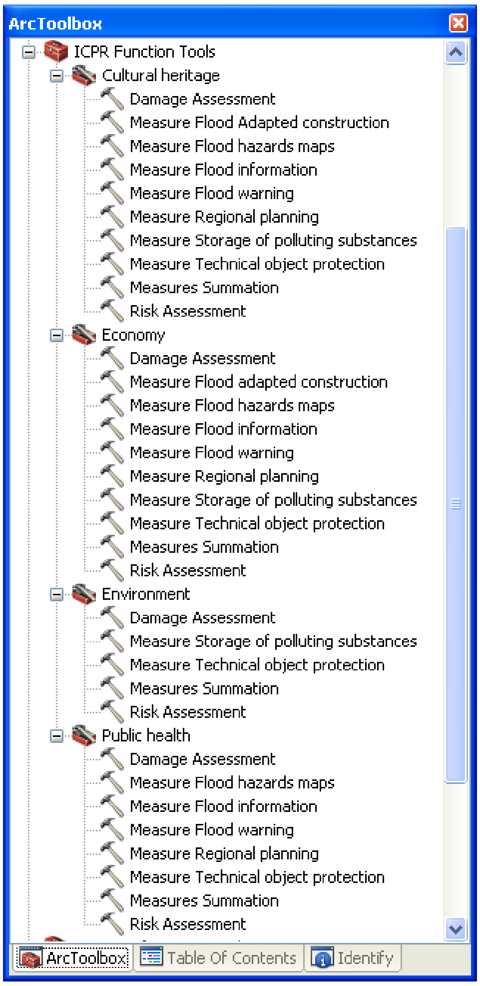
Possibility of visualising partial results/partial calculations cartographically or in tabular form.

Output: Outside of/separate from the tool (post-processing and analysis of the output data and/or calculation results)

If the calculations are carried out for different time horizons, the evolution or modification of the potential damage or risk can be calculated with the output data of the tool. The outputs of the tool are maps or tables, which show the damage in Euro or number of affected receptors for the pre-determined area. These can subsequently be evaluated separately from the tool, as desired, in Excel or ArcGIS.

5.2. General information about the tool

The application of the tool is carried out in the GIS through the use of "toolboxes" in ArcGIS and ModelBuilders. The structure of the tool under ArcGIS is outlined in Figure 23.

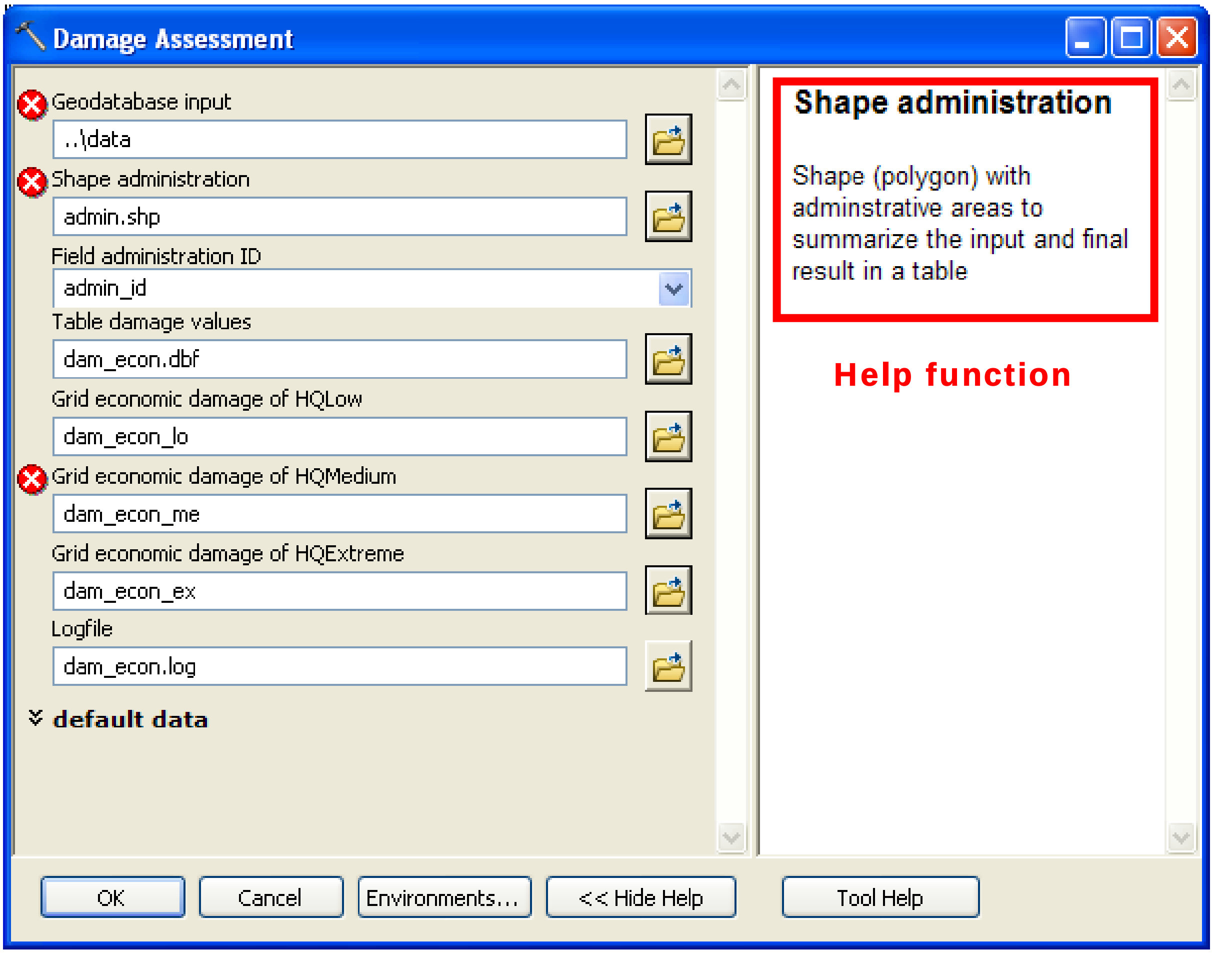


- ICPR Function Tools
  - Cultural heritage
    - Damage Assessment
    - Measure Flood Adapted construction
    - Measure Flood hazards maps
    - Measure Flood information
    - Measure Flood warning
    - Measure Regional planning
    - Measure Storage of polluting substances
    - Measure Technical object protection
    - Measures Summation
    - Risk Assessment
  - Economy
    - Damage Assessment
    - Measure Flood adapted construction
    - Measure Flood hazards maps
    - Measure Flood information
    - Measure Flood warning
    - Measure Regional planning
    - Measure Storage of polluting substances
    - Measure Technical object protection
    - Measures Summation
    - Risk Assessment
  - Environment
    - Damage Assessment
    - Measure Storage of polluting substances
    - Measure Technical object protection
    - Measures Summation
    - Risk Assessment
  - Public health
    - Damage Assessment
    - Measure Flood hazards maps
    - Measure Flood information
    - Measure Flood warning
    - Measure Regional planning
    - Measure Technical object protection
    - Measures Summation
    - Risk Assessment

Figure 23: Toolboxes/ModelBuilders in ArcGIS

Similarly to the four receptors of the EC FD, the tool consists of four toolboxes containing different numbers of ModelBuilders depending on the number of indicators defined. The ModelBuilders Damage Assessment, individual measures (Measure …), Measure Summation and Risk Assessment are contained in all of the toolboxes.

The ModelBuilder Damage Assessment for the receptor economic activity is shown here as an example (Figure 24). A detailed description of the individual toolboxes and ModelBuilders can be found in the technical User Guide (2016, see “Literature”). In addition, within the tool, explanations are available via the help function (Figure 24).



Geodatabase input
..\data
Shape administration
admin.shp
Field administration ID
admin_id
Table damage values
dam_econ.dbf
Grid economic damage of HQLow
dam_econ_lo
Grid economic damage of HQMedium
dam_econ_me
Grid economic damage of HQExtreme
dam_econ_ex
Logfile
dam_econ.log

Shape administration

Shape (polygon) with adminstrative areas to summarize the input and final result in a table

Figure 24: Example of the ModelBuilder Damage Assessment including help function

The calculations for the ICPR are carried out with 100 *100 m raster cells. The tool enables the use of smaller/other raster cell sizes. The influence of the raster cell size is explained in Annexe 15.

In order to calculate potential damage, a beta version of the tool "damage assessment/analysis" was developed for human health and the receptors environment, cultural heritage and economic activity. For each of the receptors, a calculation run takes place for a scenario (e.g., HQ100) and a year (e.g. 1995).

ModelBuilder "Damage Assessment"

- The results can be displayed in different scales. From the smallest unit (municipality) working upwards, these smaller polygons can be grouped into larger ones (regions/federal states, ICPR evaluation sections, cf. Annexe 1).
- The tool provides a further option, of generating results for a specific area by manual selection.
- Representations of partial results/output for "damage assessment" for human health, environment, cultural heritage and economic activity can be provided both in tabular form, as well as in map form.
- The risk calculation is carried out both separately for each scenario (HQ10, 100 and xtreme) as well as integrally (all scenarios together), based on the yearly expected value. The individual formulae for the calculation of risk are described in Sections 1 and 2.

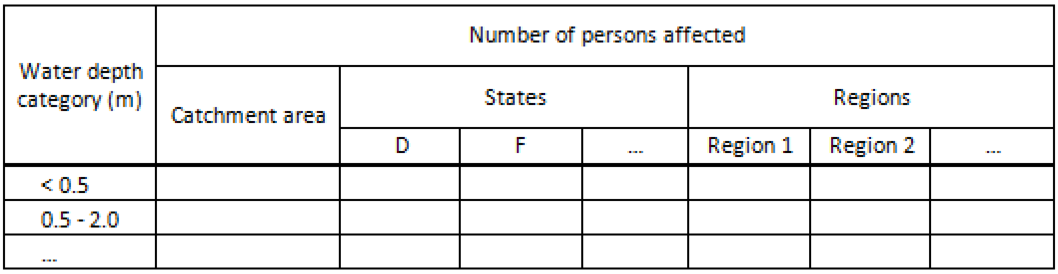
- The colour scheme of the tool output aligns with that of the legend of the Rhine Atlas 2015 (cf.http://geoportal.bafg.de/mapapps/resources/apps/ICPR_EN/index.html?lang=en)

The data input, the calculation stages and data output of each ModelBuilder are described below.

Toolbox "Human Health"

- The input is a polygon shapefile, which contains the affected people within an area (polygon). The attribute table contains the numbers of people affected and the safeguarding rate.
- The shapefile is converted with the attribute "number" (= "Anzahl") into a raster. The people affected are hereby exclusively spatially located within the built-up areas (CORINE category "Continuous urban fabric" and "Discontinuous urban fabric").
- By multiplying the number of people affected that are located in the built-up areas with the reciprocal value of the safeguarding rate, i.e. (1 - safeguarding rate), the number of people remaining and acutely at risk within the flooding area is calculated.
- In principle, it is possible, through the use of the ZONAL function, to summarise the GIS procedures for certain administrative areas (a shape file with the administrative boundaries must be present), meaning that the evaluation of Table 15, shown below, can also take place for selected areas.
- As an output for the receptor "human health", two tables corresponding to the 2 calculation stages for affected people, and affected people after evacuation, are exported per reference year and per flooding scenario.

Table 15: Example results table "Human health"



Water depth category (m)	Number of persons affected						
	Catchment area	States			Regions		
		D	F	...	Region 1	Region 2	...
< 0.5							
0.5 - 2.0							
...							

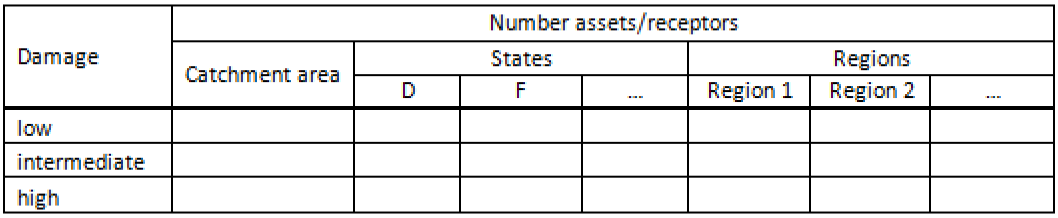
- The output is also stored as a raster for every two levels.

Toolbox "environment"

- The input is a point shapefile of the hazardous sources with the attribute of the quantitative hazard according to the pollution potential (toxicity) and an impact range as well as a polygon shapefile of the water-related receptors with the attribute sensitivity of the receptor.
- The shapefile of water-related receptors is converted to a raster with the value of the sensitivity.

- In order to calculate the average flood depth at the location of the hazardous source, a buffer is created around the object, and the value is extracted from the water depth raster of the corresponding scenario.
- Objects at which the water depth is zero or NoData values are present, are not considered in the process.
- For the objects at risk, a buffer is created in accordance with the established impact range, in the direction of flow.
- A raster is created using a conditional IF-AND statement, which contains the affected water-related environmental receptors.
- The output for the receptor "environment" is provided in tabular form (cf. Table 16) and as a shapefile.

Table 16: Example results table for the receptor environment

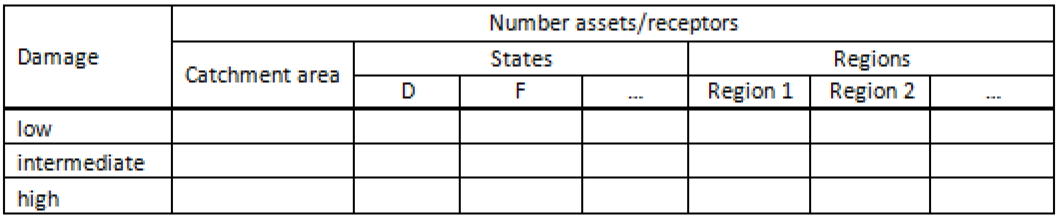


Damage	Number assets/receptors						
	Catchment area	States			Regions		
		D	F	...	Region 1	Region 2	...
low							
intermediate							
high							

Toolbox "Culture"

- Input is a point shapefile with the attribute "type", in accordance with the description "methodology for evaluating the receptor “culture”.
- In order to calculate the average flood depth at the location of the cultural object, a buffer is created around the object, and the value is extracted from the water depth raster of the corresponding scenario.
- Objects at which the water depth is zero or NoData values are present, are not considered in the process.
- An input table showing the relationship between the water depth and the cultural significance is used to determine the impact of flooding on the receptor “culture”.
- The output for the receptor "culture" is provided in tabular form (cf. Table 17) and as a shapefile.

Table 17: Example results table for the receptor culture



Damage	Number assets/receptors						
	Catchment area	States			Regions		
		D	F	...	Region 1	Region 2	...
low							
intermediate							
high							

- In principle, it is possible, through the use of the ZONAL function, to summarise the GIS procedures for certain administrative areas (a shape file with the administrative boundaries must be present), meaning that the evaluation of the table above can also take place for selected areas.

Toolbox "Economic activity"

- In order to make the tool as flexible as possible, an input table with the information about damage functions, a table with mobile and immobile assets (asset values) and a table showing the relationship of the CORINE land use and the damage categories of the Rhine Atlas 2001 are created (cf. Annexe 4).
- A total of 20 damage categories are provided, with 6 used here (cf. Annexe 4). If necessary, the above-specified tables can be supplemented by corresponding data (e.g. for other river basins).
- At the beginning of the tool set-up, the question is posed as to how many damage categories should be taken into account.
- The extent of the raster is based on the land use raster.
- The asset values are given for each observation date separately depending on the CORINE data. Using the RECLASS function, the asset values are converted into a corresponding raster format (with spatial reference).
- To calculate the damages, the raster of the asset values, the water depth raster of the corresponding scenario and the table with the information regarding the damage functions are used.
- In principle, it is possible, through the use of the ZONAL function, to summarise the GIS procedures for certain administrative areas (a shape file with the administrative boundaries must be present), meaning that the evaluation of Table 18, shown below, can also take place for selected areas.
- As a default setting, all intermediate data should be deleted. If the operator marks a tick-box, the intermediate data can be stored.
- The results of the receptor "economic activity" are represented in graphic form, as a raster (€/raster cell) and also presented in tabular form.

Table 18: Example results table economic damages

Damages (€) per flood scenario (e.g. HQ100) and for one time horizon (e.g. 2015)	Damage category					Total
	Settlement	Industry	Transport	Agricultural areas	Other	
Catchment area						
State/country						
D						
F						
...						
Total damages state						
Region						
Region 1						
Region 2						
....						
Total damages region						

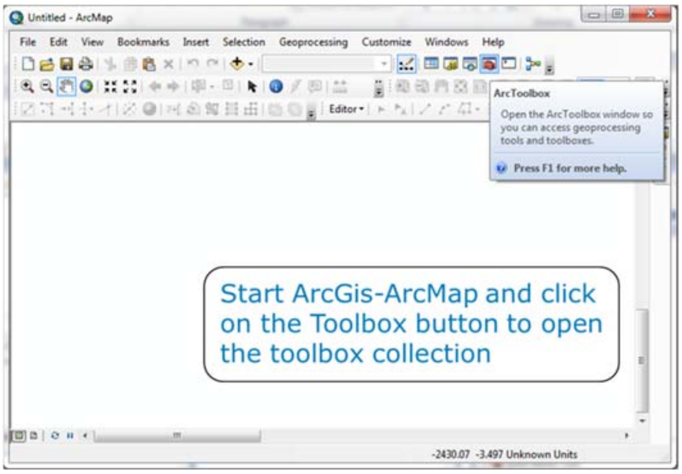
5.3. Example calculation: Use of the tool "economic activity"

This section provides an example of the use of the tool "economy" in the "damage assessment" section. With this tool, the impact of the flood on the receptor economy can be estimated in flood-prone areas, in Euros. The results of the tool are provided in map and table format.

The output of the tool for damage assessment is the input of the tool "measure" and "risk assessment". The impact of each measure is calculated with a separate tool. The impact of all measures is calculated with a summation tool. The results of the tool "risk assessment" are maps and tables.

To calculate the flood risk without the impact of the measures, the output of the damage assessment tool is used as the input of the risk assessment tool.

Step 1: Start ArcMap



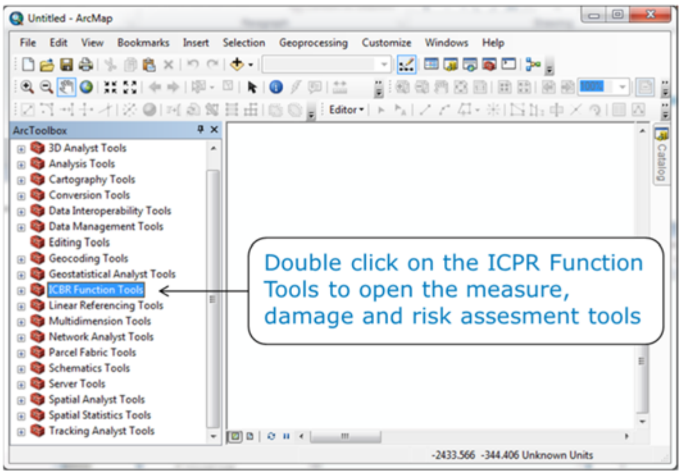
ArcToolbox

Open the ArcToolbox window so you can access geoprocessing tools and toolboxes.

Press F1 for more help.

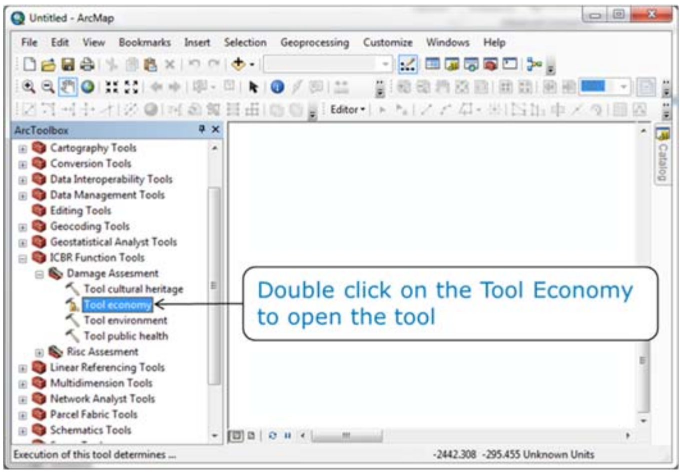
Start ArcGis-ArcMap and click on the Toolbox button to open the toolbox collection

Step 2: Open toolbox



Double click on the ICPR Function Tools to open the measure, damage and risk assesment tools

Step 3: Open tool

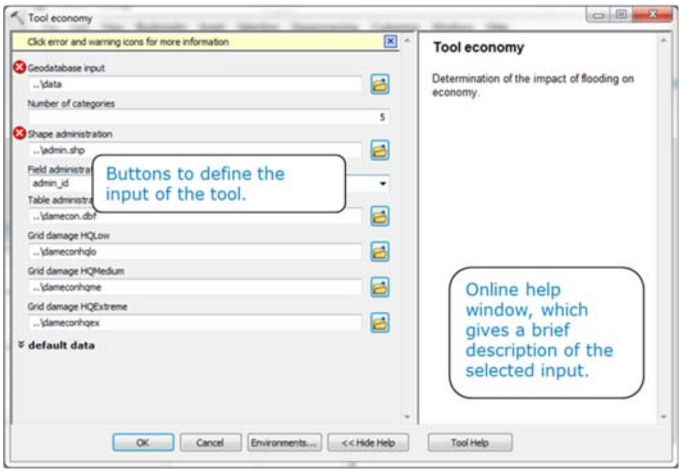


Double click on the Tool Economy to open the tool

Execution of this tool determines ...

-2442.308 -295.455 Unknown Units

Step 4: Define input



Click error and warning icons for more information

Geodatabase input
...\data

Number of categories
5

Shape administration
...\admin.shp

Field administra
admin_id

Table administra
...\damecon.dbf

Grid damage HQLow
...\dameconhqlo

Grid damage HQMedium
...\dameconhqme

Grid damage HQExtreme
...\dameconhqex

default data

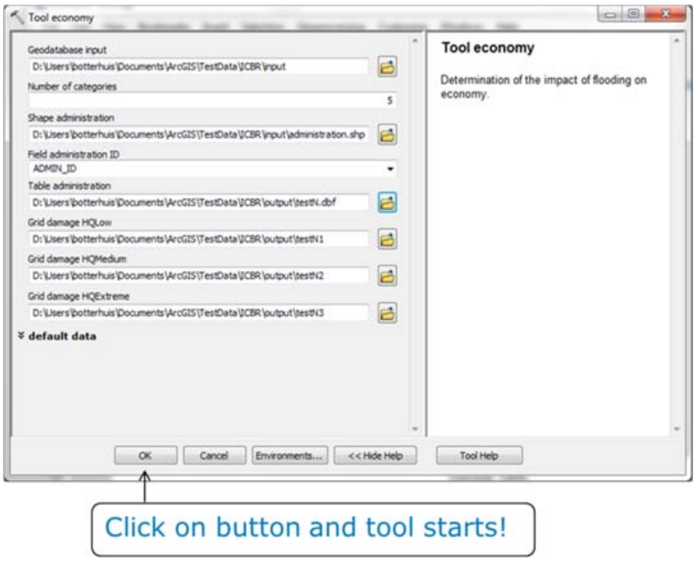
Buttons to define the input of the tool.

Tool economy

Determination of the impact of flooding on economy.

Online help window, which gives a brief description of the selected input.

Step 5: Execute tool



Geodatabase input: D:\Users\botterhuis\Documents\ArcGIS\TestData\ICBR\input

Number of categories: 5

Shape administration: D:\Users\botterhuis\Documents\ArcGIS\TestData\ICBR\input\administration.shp

Field administration ID: ADMIN_ID

Table administration: D:\Users\botterhuis\Documents\ArcGIS\TestData\ICBR\output\testN.dbf

Grid damage HQLow: D:\Users\botterhuis\Documents\ArcGIS\TestData\ICBR\output\testN1

Grid damage HQMedium: D:\Users\botterhuis\Documents\ArcGIS\TestData\ICBR\output\testN2

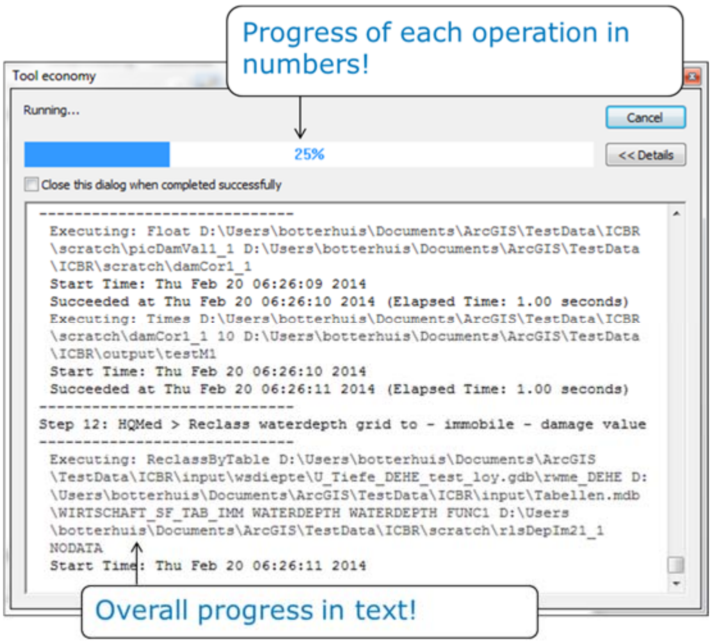
Grid damage HQExtreme: D:\Users\botterhuis\Documents\ArcGIS\TestData\ICBR\output\testN3

default data

Tool economy

Determination of the impact of flooding on economy.

Click on button and tool starts!



Progress of each operation in numbers!

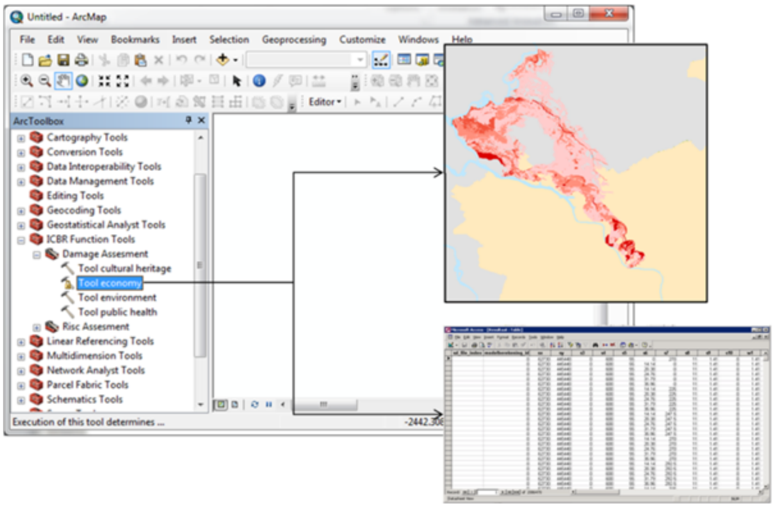
Running...

☐ Close this dialog when completed successfully

```
-----------------------------
 Executing: Float D:\Users\botterhuis\Documents\ArcGIS\TestData\ICBR
 \scratch\picDamVal1_1 D:\Users\botterhuis\Documents\ArcGIS\TestData
 \ICBR\scratch\damCor1_1
 Start Time: Thu Feb 20 06:26:09 2014
 Succeeded at Thu Feb 20 06:26:10 2014 (Elapsed Time: 1.00 seconds)
 Executing: Times D:\Users\botterhuis\Documents\ArcGIS\TestData\ICBR
 \scratch\damCor1_1 10 D:\Users\botterhuis\Documents\ArcGIS\TestData
 \ICBR\output\testM1
 Start Time: Thu Feb 20 06:26:10 2014
 Succeeded at Thu Feb 20 06:26:11 2014 (Elapsed Time: 1.00 seconds)
-----------------------------
Step 12: HQMed > Reclass waterdepth grid to - immobile - damage value
-----------------------------
 Executing: ReclassByTable D:\Users\botterhuis\Documents\ArcGIS
 \TestData\ICBR\input\wsdiepte\U_Tiefe_DEHE_test_loy.gdb\rwme_DEHE D:
 \Users\botterhuis\Documents\ArcGIS\TestData\ICBR\input\Tabellen.mdb
 \WIRTSCHAFT_SF_TAB_IMM WATERDEPTH WATERDEPTH FUNC1 D:\Users
 \botterhuis\Documents\ArcGIS\TestData\ICBR\scratch\rlsDepIm21_1
 NODATA
 Start Time: Thu Feb 20 06:26:11 2014
```

Overall progress in text!

Step 6: Examine output



6. Conclusions and general recommendations

Within the framework of the project, a comprehensive GIS-based tool has been developed, with which the change and the reduction of flood risk can be determined on a large scale for different receptors at the level of a river basin, as well as the influence of implemented or theoretical measures on the potential damage and the risk. To this end, various assumptions were made and different methods were refined or developed, which in part are still firmly rooted in (ICPR) expert knowledge. The added value here lies in the possibility of a macroscopic, temporally comparable and reproducible analysis. A rough estimate of the effect of measures on a large scale is possible. Due to the fact that numerous assessments were made on the basis of expertise in order to achieve this, a concrete evaluation of the impact of implementing concrete measures of the FRMP of the different German federal states is not possible. This would require a more specific analysis of both the fundamentals of assessing the risk, as well as the measures and their impact. For the Rhine catchment area, in 2014-2016 the first calculations were undertaken using the tool by HKV and the ICPR (cf. results of the calculations and recommendations in the ICPR report no. 236). The application of the tool at a local or regional level (e.g. state/federal states and regions/municipality) or also for other river basin districts can only be done with the appropriate database and data preparation. The estimates and assumptions regarding the methods underpinning the tool and the measures should be optimised in the future through improved knowledge and data.

With the aid of an improved database, the possible future execution of differentiated and regionally targeted analyses, and future findings in terms of monitoring measures and further (theoretical or real data-based) testing and alternative calculations/analysis with the tool, it should be possible to obtain statements concerning the (future) effectiveness and impact of individual actions within the context of flood risk management. In this way, an assessment of the achievement of objectives (at international and national level) as well as risk evolution would be possible, provided that the fundamental approaches taken and assumptions in place from the present perspective are validated and improved.

On the basis of the above, the ICPR plans in the future to use the assessment tool developed in the period 2014-2016 to **regularly review the FRMP for the IRBD Rhine** and to continuously refine the methodology.

The ICPR supports the **distribution and use of the tool and its methods** by regional and national authorities, both inside and outside of the Rhine basin (states/regions/federal states or even smaller areas) for other river basins/river commissions, research institutes, universities (e.g. as part of an internship or student work), IGO/NGOs. Theoretical or real calculations must be carried out with the appropriate database and data processing. A comparison of the calculations with the national/area-specific data can be a useful supplement for the assessment of the calculation results.

Annexes

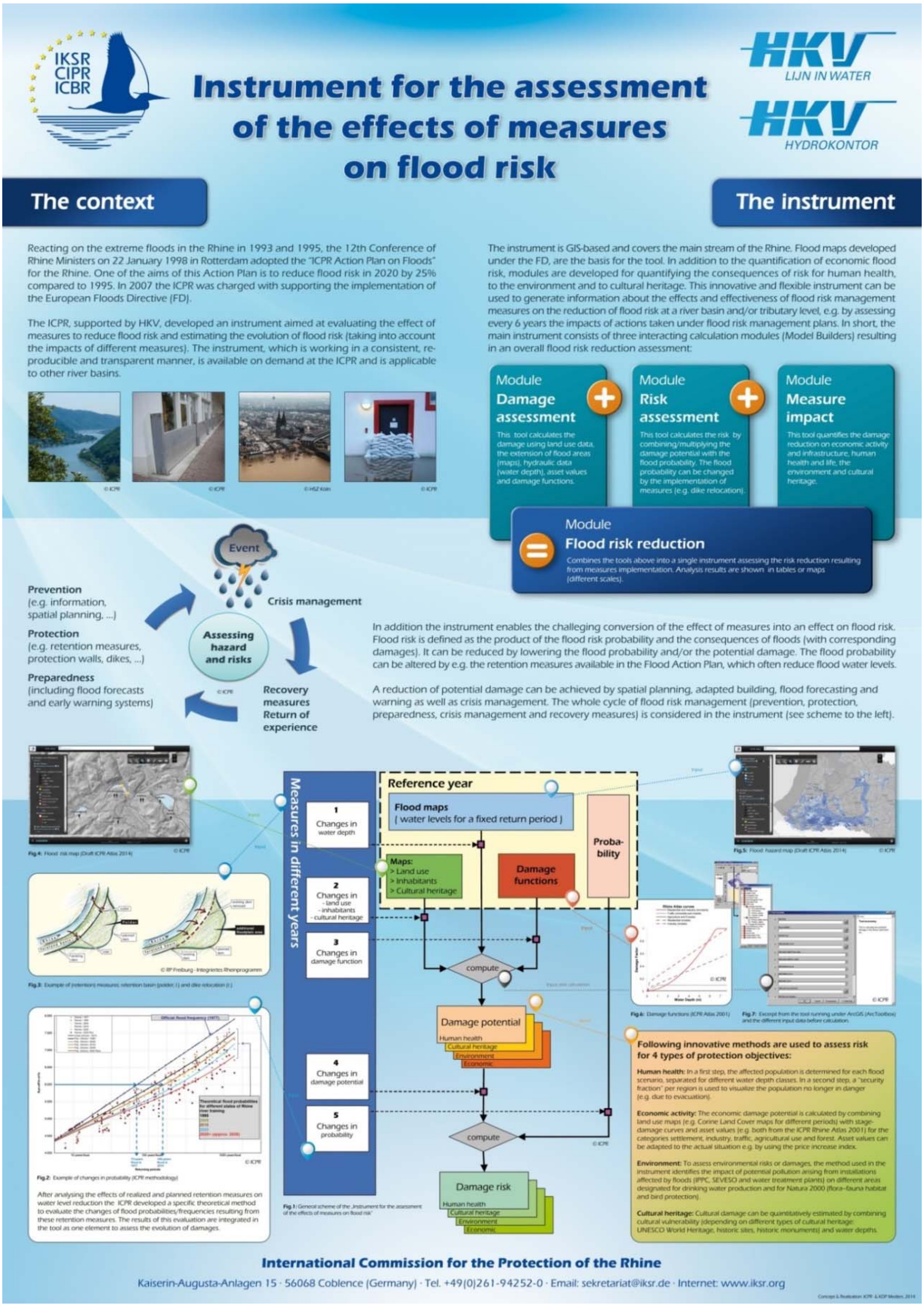
Annexe 1 – Stretches of the Rhine

Stretches under evaluation for the HIRI project

Stretch no.	Country	Rhine km		Description
		from	to	
a	Switzerland			Swiss Alpine Rhine/mouth of the Ill to confluence of Anterior and Posterior Rhine
b	International			International Alpine Rhine/ Lake Constance inlet to mouth of Ill
c	Switzerland			Lake Constance/Swiss side (South bank)
d	Germany			Lake Constance/German side (North bank)
1	Switzerland	0	102	High Rhine/Aare to Lake Constance outflow (Untersee)
2	Germany	0	102	High Rhine/Aare to Lake Constance outflow (Untersee)
2a	Switzerland	102	170	High Rhine/Aare to Basel
2b	Germany	102	170	High Rhine/Aare to Basel
3	Germany	170	334	Upper Rhine/Basel to Iffezheim barrage
4	France	170	334	High Rhine/Aare to Basel
5	Germany	334	428	Upper Rhine /downstream of Iffezheim - mouth of Neckar
5a	France	334	352	Upper Rhine /downstream of Iffezheim - border FR-DE
5b	Germany	352	428	Upper Rhine /border FR-DE – mouth of Neckar
6	Germany	428	497	Upper Rhine /mouth of the Neckar – mouth of Main
7	Germany	497	529	Upper Rhine/mouth of Main – mouth of Nahe
8	Germany	529	592	Middle Rhine/mouth of Nahe – mouth of Mosel
9	Germany	592	659	Middle Rhine/mouth of Mosel – mouth of Sieg; *640 - 659: Federal state border NRW - mouth of Sieg*
10	Germany	659	780	Lower Rhine / mouth of Sieg – mouth of Ruhr
11	Germany	780	862	Lower Rhine / mouth of Ruhr-Pannerdensche Kop (incl. Lobith; suggestion HVAL); *Further subdivisions possible:* *780 - 814: Mouth of Ruhr - Mouth of Lippe* *814 - 845: Mouth of Lippe – Grietherorter Altrhein* *845 - 862: Grietherorter Altrhein – Federal state border NRW/ Netherlands*
12	The Netherlands	867	883	Waal / South bank - DR (Dike ring) 42
13	The Netherlands	867	943	Nederrijn-Lek / South bank -DR 43
14	The Netherlands	862	897	IJssel / East bank - DR 48
15	The Netherlands	893	913	Nederrijn-Lek / South bank -DR 45
16	The Netherlands	913	947	Nederrijn-Lek / South bank -DR 44
17	The Netherlands	943	986	Nederrijn-Lek / South bank -DR 16
18	The Netherlands	947	986	Nederrijn-Lek / South bank -DR 15
19	The Netherlands	867	960	Waal / North bank - DR 43
20	The Netherlands	960	985	Waal / North bank - DR 16
21	The Netherlands	883	927	Waal / South bank - DR 41
22	The Netherlands	927	955	Waal / South bank - DR 38
23	The Netherlands	955	967	Waal / South bank - DR 24
24	The Netherlands	878	893	Nederrijn-Lek / South bank -DR 47
25	The Netherlands	897	912	IJssel / East bank - DR 49
26	The Netherlands	912	922	IJssel / East bank - DR 50
27	The Netherlands	922	933	IJssel / East bank - DR 51
28	The Netherlands	879	897	IJssel / South bank - DR 47
29	The Netherlands	897	968	IJssel / East bank - DR 53

Annexe 2 - General structure of the tool and of the calculations undertaken by the ICPR

This figure describes the ICPR tool for detecting the effect of measures on the reduction of flood risk, and the necessary data and calculation procedures.



Instrument for the assessment of the effects of measures on flood risk

The context

Reacting on the extreme floods in the Rhine in 1993 and 1995, the 12th Conference of Rhine Ministers on 22 January 1998 in Rotterdam adopted the "ICPR Action Plan on Floods" for the Rhine. One of the aims of this Action Plan is to reduce flood risk in 2020 by 25% compared to 1995. In 2007 the ICPR was charged with supporting the implementation of the European Floods Directive (FD).

The ICPR, supported by HKV, developed an instrument aimed at evaluating the effect of measures to reduce flood risk and estimating the evolution of flood risk (taking into account the impacts of different measures). The instrument, which is working in a consistent, reproducible and transparent manner, is available on demand at the ICPR and is applicable to other river basins.

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The instrument

The instrument is GIS-based and covers the main stream of the Rhine. Flood maps developed under the FD, are the basis for the tool. In addition to the quantification of economic flood risk, modules are developed for quantifying the consequences of risk for human health, to the environment and to cultural heritage. This innovative and flexible instrument can be used to generate information about the effects and effectiveness of flood risk management measures on the reduction of flood risk at a river basin and/or tributary level, e.g. by assessing every 6 years the impacts of actions taken under flood risk management plans. In short, the main instrument consists of three interacting calculation modules (Model Builders) resulting in an overall flood risk reduction assessment:

Module
Damage assessment
This tool calculates the damage using land use data, the extension of flood areas (maps), hydraulic data (water depth), asset values and damage functions.

+

Module
Risk assessment
This tool calculates the risk by combining/multiplying the damage potential with the flood probability. The flood probability can be changed by the implementation of measures (e.g. dike relocation).

+

Module
Measure impact
This tool quantifies the damage reduction on economic activity and infrastructure, human health and life, the environment and cultural heritage.

=

Module
Flood risk reduction
Combines the tools above into a single instrument assessing the risk reduction resulting from measures implementation. Analysis results are shown in tables or maps (different scales).

Event

Crisis management

Assessing hazard and risks

Recovery measures
Return of experience

Prevention
(e.g. information, spatial planning, ...)

Protection
(e.g. retention measures, protection walls, dikes, ...)

Preparedness
(including flood forecasts and early warning systems)

© ICPR

In addition the instrument enables the challeging conversion of the effect of measures into an effect on flood risk. Flood risk is defined as the product of the flood risk probability and the consequences of floods (with corresponding damages). It can be reduced by lowering the flood probability and/or the potential damage. The flood probability can be altered by e.g. the retention measures available in the Flood Action Plan, which often reduce flood water levels.

A reduction of potential damage can be achieved by spatial planning, adapted building, flood forecasting and warning as well as crisis management. The whole cycle of flood risk management (prevention, protection, preparedness, crisis management and recovery measures) is considered in the instrument (see scheme to the left).

Fig.4: Flood risk map (Draft ICPR Atlas 2014) © ICPR

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Fig.3: Example of (retention) measures: retention basin (polder; I) and dike relocation (II)

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Fig.2: Example of changes in probability (ICPR methodology)

After analysing the effects of realized and planned retention measures on water level reduction the ICPR developed a specific theoretical method to evaluate the changes of flood probabilities/frequencies resulting from these retention measures. The results of this evaluation are integrated in the tool as one element to assess the evolution of damages.

Measures in different years

1 Changes in water depth

2 Changes in
- land use
- inhabitants
- cultural heritage

3 Changes in damage function

4 Changes in damage potential

5 Changes in probability

Reference year

Flood maps
(water levels for a fixed return period)

Maps:
> Land use
> Inhabitants
> Cultural heritage

Damage functions

Probability

compute

Damage potential
Human health
Cultural heritage
Environment
Economic

compute

Damage risk
Human health
Cultural heritage
Environment
Economic

© ICPR

Fig.1: General scheme of the „Instrument for the assessment of the effects of measures on flood risk"

Fig.5: Flood hazard map (Draft ICPR Atlas 2014) © ICPR

© ICPR

Fig.6: Damage functions (ICPR Atlas 2001)

© ICPR

Fig.7: Excerpt from the tool running under ArcGIS (ArcToolbox) and the different input data before calculation.

Following innovative methods are used to assess risk for 4 types of protection objectives:

Human health: In a first step, the affected population is determined for each flood scenario, separated for different water depth classes. In a second step, a "security fraction" per region is used to visualize the population no longer in danger (e.g. due to evacuation).

Economic activity: The economic damage potential is calculated by combining land use maps (e.g. Corine Land Cover maps for different periods) with stage-damage curves and asset values (e.g. both from the ICPR Rhine Atlas 2001) for the categories settlement, industry, traffic, agricultural use and forest. Asset values can be adapted to the actual situation e.g. by using the price increase index.

Environment: To assess environmental risks or damages, the method used in the instrument identifies the impact of potential pollution arising from installations affected by floods (IPPC, SEVESO and water treatment plants) on different areas designated for drinking water production and for Natura 2000 (flora-fauna habitat and bird protection).

Cultural heritage: Cultural damage can be quantitatively estimated by combining cultural vulnerability (depending on different types of cultural heritage: UNESCO World Heritage, historic sites, historic monuments) and water depths.

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Concept & Realisation: ICPR & KDP Medien, 2014

Annexe 3 - Flood probabilities

The flood probabilities were provided as input data for the calculations by the ICPR Secretariat and by the EG HVAL. Further details regarding the calculation procedure, database and assumptions can be found in the ICPR report no. 229 "Assessment of probability change".

Flood probabilities north of Iffezheim, in accordance with the calculations of the EG HVAL (cf. report no. 229)

Section	**Probabilities**	**Discharges [m^3/s]**	**Theoretical return periods [a] related to the procedure accomplished with the HVAL investigation sample for the development stages**				
			1995	**2005**	**2010**	**2020**	**2020plus**
Evaluation per gauge							
Maxau gauging station (Upper Rhine/Iffezheim - mouth R. Neckar)							
Flood return periods related to the HVAL investigation sample	High probability	*4,100 m^3/s*	14 a	17 a	17 a	19 a	21 a
	Medium probability	*5,000 m^3/s*	145 a	182 a	182 a	209 a	282 a
	Low probability	*6,500 m^3/s*	1698 a	1778 a	1778 a	1778 a	1950 a
Worms gauging station (Upper Rhine / mouth R. Neckar - mouth R. Main)							
Flood return periods related to the HVAL investigation sample	High probability	*4,750 m^3/s*	12 a	12 a	12 a	14 a	14 a
	Medium probability	*6,000 m^3/s*	123 a	162 a	166 a	245 a	324 a
	Low probability	*7,600 m^3/s*	1585 a	1862 a	1862 a	2344 a	3631 a
Mainz gauging station (Upper Rhine / mouth R. Main - mouth R. Nahe)							
Flood return periods related to the HVAL investigation sample	High probability	*5,700 m^3/s*	11 a	11 a	11 a	13 a	13 a
	Medium probability	*7,900 m^3/s*	129 a	151 a	155 a	182 a	240 a
	Low probability	*10,300 m^3/s*	1622 a	1622 a	1622 a	1778 a	1995 a
Kaub gauging station (Middle Rhine/mouth R. Nahe-mouth R. Moselle)							
Flood return periods related to the HVAL investigation sample	High probability	*5,800 m^3/s*	11 a	11 a	12 a	13 a	13 a
	Medium probability	*8,000 m^3/s*	129 a	148 a	155 a	178 a	234 a
	Low probability	*10,400 m^3/s*	1622 a	1660 a	1660 a	1820 a	1905 a
Andernach gauging station (Middle Rhine/mouth R. Moselle-mouth R. Sieg)							
Flood return periods related to the HVAL investigation sample	High probability	*8,810 m^3/s*	11 a	11 a	11 a	12 a	12 a
	Medium probability	*11,850 m^3/s*	100 a	107 a	110 a	120 a	138 a
	Low probability	*15,250 m^3/s*	1023 a	1096 a	1122 a	1175 a	1259 a
Evaluation per section							
Mouth R. Sieg - mouth R. Ruhr							
Flood return periods related to the HVAL investigation sample	High probability	*8,900 m^3/s*	11 a	11 a	11 a	11 a	12 a
	Medium probability	*11,700 m^3/s*	94 a	93 a	96 a	106 a	120 a
	Low probability	*15,300 m^3/s*	1140 a	1130 a	1170 a	1358 a	1466 a
Mouth R. Ruhr - Pannerdensche Kop							
Flood return periods related to the HVAL investigation sample	High probability	*9,380 m^3/s*	10 a	10 a	10 a	12 a	12 a
	Medium probability	*12,200 m^3/s*	79 a	79 a	78 a	104 a	115 a
	Low probability	*15,800 m^3/s*	763 a	751 a	743 a	1402 a	1706 a
Waal (until km 938)*							
Flood return periods related to the HVAL investigation sample	High probability	*9,500 m^3/s*	10 a	11 a	11 a	13 a	13 a
	Medium probability	*12,700 m^3/s*	99 a	105 a	110 a	152 a	169 a
	Low probability	*16,000 m^3/s*	1050 a	1107 a	1161 a	1611 a	2178 a
Nederrijn-Lek*							
Flood return periods related to the HVAL investigation sample	High probability	*9,500 m^3/s*	10 a	10 a	10 a	13 a	13 a
	Medium probability	*12,700 m^3/s*	80 a	83 a	93 a	151 a	166 a
	Low probability	*16,000 m^3/s*	881 a	912 a	975 a	1611 a	2070 a
IJssel*							
Flood return periods related to the HVAL investigation sample	High probability	*9,500 m^3/s*	3 a	3 a	3 a	13 a	13 a
	Medium probability	*12,700 m^3/s*	20 a	22 a	22 a	147 a	158 a
	Low probability	*16,000 m^3/s*	344 a	364 a	392 a	1611 a	2080 a

**Discharge information for Lobith gauging station*

Flood probabilities south of Iffezheim, in accordance with the data supplied by the ICPR

Stretches under evaluation for the HIRI project (Version: 23 Sept. 2015)							
Stretch no.	**Country**	**Rhine km**		**Description**	**Actual return periods associated with the 3 flood scenarios of the FHM calculation**		
		from	**to**		**High probability (approx. HQ10)**	**Medium probability (≥ HQ100)**	**Low probability (HQextreme)**
	CH	0	23	**Alpine Rhine:** Reichenau (for **Lake Constance :** For details see below under "Lake Constance (Switzerland")) - Landquart	30	100	300-1000 *(Suggestion of Secretariat to HKV: for the HIRI stretches "Swiss Alpine Rhine/Confluence of Anterior and Posterior Rhine" apply **HQ 1000**)*
	CH (small stretch together with FL)	23	35	**Alpine Rhine:** Landquart - Sargans	30	100	CH: 300-1000 FL: 1000 *(Suggestion of Secretariat to HKV: for the HIRI stretches "Swiss Alpine Rhine/Confluence of Anterior and Posterior Rhine" apply **HQ 1000**)*
	CH/FL	35	65	**Alpine Rhine**: Sargans - mouth of Ill	30	100	CH: 300-1000 FL: 1000 *(Suggestion of Secretariat to HKV: for the HIRI stretches "Swiss Alpine Rhine/Confluence of Anterior and Posterior Rhine" apply **HQ 1000**)*
	CH/AT	65	95	**Alpine Rhine:** Mouth of Ill - Lake Constance ("International stretches of Rhine")	30	100	CH: 300-1000 AT: 300 *(Suggestion of Secretariat to HKV: for the HIRI stretches "Int. Alpine Rhine/mouth of Ill" apply **HQ 300**)*
	DE			**Lake Constance (Germany)**	10	100	1000
	AT			**Lake Constance (Austria)**	30	100	1000
	CH			**Lake Constance (Switzerland)**	30	100	CH: Canton SG=1000, Canton TG=300
1	Switzerland	0	170	**High Rhine/Lake Constance outflow to Basel**	30	100	Cantons TG and BL = 300, all other cantons 1000
2	Germany	0	170	**High Rhine/Lake Constance outflow to Basel**	see CH details for High Rhine: 30 (FHM BW shore current = CH calculation mirrored on D side. Notification: in 2016 updating BW calculation planned with HQ10)	see CH details for High Rhine: 100 (FHM BW shore current = CH calculation mirrored on D side. Notification: in 2016 updating BW calculation planned with HQ100)	see CH details for High Rhine: Before the cantons TG and BL 300, all other stretches 1000 (FHM BW shore current = CH calculation mirrored on D side. Notification: in 2016 updating of planned calculation in BW = HQ1000)
3	Germany	170	334	**Upper Rhine/Basel to Iffezheim barrage**	10 (theoretically, in practice: no calculation available, as no inland flooding areas)	100 (theoretically, in practice: no calculation available, as no inland flooding areas)	Scenario only for an area south Söllingen-Greffern; here HQ significantly greater than 200
4	France	170	334	**Upper Rhine/Basel to Iffezheim barrage**	No flooding of the Rhine at HQ10, thus no FHM (flood risk area / Territoire à Risques Importants TRI Agglomération strasbourgeoise, Rhin)	100 (flood risk area/TRI Agglomération strasbourgeoise, Rhin)	1000 (flood risk area/TRI Agglomération strasbourgeoise, Rhin)

Attribute table of shapefiles of 2014 flood probabilities (HVAL = 2010)

Stretch	PR_HQHigh	PR_HQMed	PR_HQExt
a_CH_Swiss Alpine Rhine/mouth of the Ill to confLBence of Anterior and Posterior Rhine_RB (right bank)	30.00	100.00	1000.00
b_INT_International Alpine Rhine/ Lake Constance inlet to mouth of Ill_RB	30.00	100.00	300.00
d_DE_Lake Constance/German side (North bank)	10.00	100.00	1000.00
2_DE_High Rhine/Aare to Lake Constance outflow (Untersee)	30.00	100.00	1000.00
2b_DE_High Rhine/Aare to Basel	30.00	100.00	1000.00
3_DE_Upper Rhine/Basel to Iffezheim barrage_RB	10.00	100.00	200.00
a_CH_Swiss Alpine Rhine/mouth of the Ill to confLBence of Anterior and Posterior Rhine_LB	30.00	100.00	1000.00
b_INT_International Alpine Rhine/ Lake Constance inlet to mouth of Ill_LB (left bank)	30.00	100.00	300.00
c_CH_Lake Constance/Swiss side (South bank)	30.00	100.00	1000.00
1_CH_High Rhine/Aare to Lake Constance outflow (Untersee)	30.00	100.00	1000.00
2a_CH_High Rhine/Aare to Basel	30.00	100.00	1000.00
4_FR_Upper Rhine/Basel to Iffezheim barrage	0.00	100.00	1000.00
5a_FR_Upper Rhine /downstream of Iffezheim - border FR-DE	17.00	182.00	1778.00
5_Upper Rhine /downstream of Iffezheim - mouth of Neckar	17.00	182.00	1778.00
5b_DE_Upper Rhine /border FR-DE – mouth of Neckar	17.00	182.00	1778.00
6_DE_Upper Rhine /mouth of Neckar - mouth of Main_RB	12.00	166.00	1862.00
6_DE_Upper Rhine /mouth of Neckar - mouth of Main_LB	12.00	166.00	1862.00
7_DE_Upper Rhine/mouth of Main - mouth of Nahe_LB	11.00	155.00	1622.00
7_DE_Upper Rhine/mouth of Main - mouth of Nahe_RB	11.00	155.00	1622.00
8_DE_Middle Rhine/mouth of Nahe - mouth of Mosel_LB	12.00	155.00	1660.00
8_DE_Middle Rhine/mouth of Nahe - mouth of Mosel_RB	12.00	155.00	1660.00
9_DE_Middle Rhine/mouth of Mosel – mouth of Sieg; 640 - 659: Federal state border NRW - mouth of Sieg_RB	11.00	110.00	1122.00
9_DE_Middle Rhine/mouth of Mosel – mouth of Sieg; 640 - 659: Federal state border NRW - mouth of Sieg_LB	11.00	110.00	1122.00
10_DE_Lower Rhine/ mouth of Sieg-mouth of RBhr_LB	11.00	96.00	1170.00
10_DE_Lower Rhine/ mouth of Sieg-mouth of RBhr_RB	11.00	96.00	1170.00
11_DE_Lower Rhine / mouth of RBhr-Pannerdensche Kop (incl. Lobith; suggestion HVAL)_LB	10.00	78.00	743.00
11_DE_Lower Rhine / mouth of RBhr-Pannerdensche Kop (incl. Lobith; suggestion HVAL)_RB	10.00	78.00	743.00
14_NL_IJssel / East bank - DR 48	2.88	22.03	391.74
12_NL_Waal / South bank - DR 42	10.81	109.65	1161.45
13_NL_Nederrijn-Lek/ South bank - DR 43	10.16	92.90	974.99
15_NL_Nederrijn-Lek/ North bank - DR 45	10.16	92.90	974.99
16_NL_Nederrijn-Lek/ North bank - DR 44	10.16	92.90	974.99
21_NL_Waal / South bank - DR 41	10.81	109.65	1161.45
22_NL_Waal / South bank - DR 38	10.81	109.65	1161.45
24_NL_Nederrijn-Lek/ North bank - DR 47	10.16	92.90	974.99
25_NL_IJssel / East bank - DR 49	2.88	22.03	391.74
26_NL_IJssel / East bank - DR 50	2.88	22.03	391.74
27_NL_IJssel / East bank - DR 51	2.88	22.03	391.74
29_NL_IJssel / East bank - DR 53	2.88	22.03	391.74
30_NL_IJssel/ West bank - DR 52	2.88	22.03	391.74
32_NL_Waal / South bank - DR 37	10.81	109.65	1161.45
31_NL_Waal / South bank - DR 39	10.81	109.65	1161.45
34_NL_Waal / South bank - DR 40	10.81	109.65	1161.45
35_NL_IJssel / West bank - DR 11	2.88	22.03	391.74
36_NL_IJssel / East bank - DR 10	2.88	22.03	391.74
30_NL_IJssel/ West bank / South - DR 52	2.88	22.03	391.74
37_NL_Waal / South bank - DR 24	10.00	100.00	1250.00
38_NL_Nederrijn-Lek/ South bank - DR 16	10.00	100.00	1250.00
39_NL_Nederrijn / North bank - DR 15	10.00	100.00	1250.00

Probability areas (excerpt)

For the calculations of the risk in the GIS tool, polygons with data/information on probability (see above) must be created.

Annexe 4 – Damage functions and CLC categories

Note: *for the calculation, the CLC records for 1990, 2000 and 2006 directly from the EEA were used and not the aggregated CLC records from the Rhine Atlas 2015.*

Aggregation of the types of use of CORINE in use categories (Rhine Atlas 2001 method)

Here, six use categories were summarised:
_ Use category 1: Settlement
_ Use category 2: Industry
_ Use category 3: Transport
_ Use category 4: Agricultural areas
_ Use category 5: Forest
_ Use category 6: Other

Damage functions used (source: ICPR 2001)

Damage functions ICPR Rhine Atlas 2001	
Use	**Type of function**
Settlement, immobile	$y=2*x^2+2x$
Industry, immobile	$y=2*x^2+2x$
Traffic, immobile	$y=10*x$ for $x<=1$; $y=10$ for $x>1$
Economic equipment	$y=11*x+7,5$
Settlement equipment	$y=12*x+16.25$ for $1<=x<=7$
Equipment, public goods	$y=7*x+5$
Settlement, mobile (35% economy, 60% settlement 5% public goods)	$y=11.4*x+12.625$
Industry, mobile	$y=7*x+5$
Traffics, mobile	$y=10*x$ for $x<=1$ $y=10$ for $x>1$
Agriculture	$y=1$
Forestry	$y=1$

x = water level and/or water depth (WD) (in metres)
y = relative damage function and/or degree of damage (%)

Key:
Immobile = immobile items of property (damages to building fabric, infrastructures, house, roads…)
Mobile = mobile items of property (production/products, activity…)
Fittings = Household fittings, damages possible to building interiors and/or items of value on exterior surfaces (mixture of immobile and mobile); for residential buildings as well as in the area of economic activity (activities/production + building) and in state areas (large variety: offices, buildings with a social or educational purpose, functional buildings, ...).

Correspondence CORINE Land Cover categories and use categories applied for the damage functions

CLC_VALUE	CLC_CODE	CAT_CODE	CAT_CLASS	CLC_LABLE
1	111	1	SIEDLUNG	Continuous urban fabric
2	112	1	SIEDLUNG	Discontinuous urban fabric
3	121	2	INDUSTRIE	Industrial or commercial units
4	122	3	VERKEHR	Road and rail networks and associated land
5	123	3	VERKEHR	Port areas
6	124	3	VERKEHR	Airports
12	211	4	lwNF	Non-irrigated arable land
13	212	4	lwNF	Permanently irrigated land
14	213	4	lwNF	Rice fields
15	221	4	lwNF	Vineyards
16	222	4	lwNF	Fruit trees and berry plantations
17	223	4	lwNF	Olive groves
18	231	4	lwNF	Pastures
19	241	4	lwNF	Annual crops associated with permanent crops
20	242	4	lwNF	Complex cultivation patterns
21	243	4	lwNF	Land principally occupied by agriculture, with significant areas of natural vegetation
22	244	4	lwNF	Agro-forestry areas
23	311	5	FORST	Broad-leaved forest
24	312	5	FORST	Coniferous forest
25	313	5	FORST	Mixed forest
28	323	5	FORST	Sclerophyllous vegetation
29	324	5	FORST	Transitional woodland-shrub
7	131	6	SONSTIGE	Mineral extraction sites
8	132	6	SONSTIGE	Dump sites
9	133	6	SONSTIGE	Construction sites
10	141	6	SONSTIGE	Green urban areas
11	142	6	SONSTIGE	Sport and leisure facilities
26	321	6	SONSTIGE	Natural grasslands
27	322	6	SONSTIGE	Moors and heathland
30	331	6	SONSTIGE	Beaches, dunes, sands
31	332	6	SONSTIGE	Bare rocks
32	333	6	SONSTIGE	Sparsely vegetated areas
33	334	6	SONSTIGE	Burnt areas
34	335	6	SONSTIGE	Glaciers and perpetual snow
35	411	6	SONSTIGE	Inland marshes
36	412	6	SONSTIGE	Peat bogs
37	421	6	SONSTIGE	Salt marshes
38	422	6	SONSTIGE	Salines
39	423	6	SONSTIGE	Intertidal flats
40	511	6	SONSTIGE	Water courses
41	512	6	SONSTIGE	Water bodies
42	521	6	SONSTIGE	Coastal lagoons
43	522	6	SONSTIGE	Estuaries
44	523	6	SONSTIGE	Sea and ocean
48	999	6	SONSTIGE	Differences from projection
49	990	6	SONSTIGE	UNCLASSIFIED LAND SURFACE
50	995	6	SONSTIGE	UNCLASSIFIED WATER BODIES

Annexe 5 - Specific asset values (€/m²)[18] 1995 to 2020+

(Note: As the sixth class "other" was not evaluated, the corresponding values were set to "0")

a) immobile

Baden-Württemberg						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	249.24	268.00	282.47	297.59	317.33	346.94
Industry	243.66	262.00	276.15	290.93	310.23	339.17
Traffic	228.78	246.00	259.28	273.16	291.28	318.46
Agriculture	5.58	6.00	6.32	6.66	7.10	7.77
Forestry	1.86	2.00	2.11	2.22	2.37	2.59

Hessen						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	215.29	231.00	241.16	252.75	268.38	291.83
Industry	240.46	258.00	269.35	282.30	299.75	325.94
Traffic	279.60	300.00	313.20	328.25	348.55	379.00
Agriculture	6.52	7.00	7.31	7.66	8.13	8.84
Forestry	0.93	1.00	1.04	1.09	1.16	1.26

Rhineland-Palatinate						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	168.69	181.00	190.05	200.07	212.92	232.20
Industry	241.39	259.00	271.95	286.29	304.68	332.27
Traffic	133.28	143.00	150.15	158.07	168.22	183.45
Agriculture	4.66	5.00	5.25	5.53	5.88	6.41
Forestry	0.93	1.00	1.05	1.11	1.18	1.28

NRW						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	214.37	231.00	242.78	254.67	271.39	296.47
Industry	214.37	231.00	242.78	254.67	271.39	296.47
Traffic	244.06	263.00	276.41	289.95	308.99	337.54
Agriculture	8.35	9.00	9.46	9.92	10.57	11.55
Forestry	0.93	1.00	1.05	1.10	1.17	1.28

Bavaria						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	249.78	268.00	283.81	300.48	320.79	351.25
Industry	244.18	262.00	277.46	293.75	313.61	343.38
Traffic	229.27	246.00	260.51	275.81	294.45	322.41
Agriculture	5.59	6.00	6.35	6.73	7.18	7.86
Forestry	1.86	2.00	2.12	2.24	2.39	2.62

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[18] In Section 2, for specific asset values, the abbreviated form "Asp (LU)" is used.

Switzerland						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	253.83	275.00	282.15	271.85	283.12	300.02
Industry	264.90	287.00	294.46	283.71	295.47	313.11
Traffic	269.52	292.00	299.59	288.65	300.62	318.57
Agriculture	6.46	7.00	7.18	6.92	7.21	7.64
Forestry	0.92	1.00	1.03	0.99	1.03	1.09

France						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	202.24	217.00	233.28	244.51	261.32	286.53
Industry	213.43	229.00	246.18	258.03	275.77	302.37
Traffic	216.22	232.00	249.40	261.41	279.38	306.34
Agriculture	6.52	7.00	7.53	7.89	8.43	9.24
Forestry	0.93	1.00	1.08	1.13	1.20	1.32

The Netherlands						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	220.50	252.00	271.66	274.74	299.28	336.10
Industry	229.25	262.00	282.44	285.65	311.16	349.43
Traffic	232.75	266.00	286.75	290.01	315.91	354.77
Agriculture	6.13	7.00	7.55	7.63	8.31	9.34
Forestry	0.88	1.00	1.08	1.09	1.19	1.33

Austria						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	221.65	242.24	259.68	278.84	301.65	335.86
Industry	234.02	255.76	274.17	294.39	318.48	354.60
Traffic	237.82	259.92	278.63	299.18	323.65	360.36
Agriculture	6.66	7.28	7.80	8.38	9.06	10.09
Forestry	0.95	1.04	1.11	1.20	1.29	1.44

Liechtenstein						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	597.80	564.81	799.03	1166.82	1430.20	1806.46
Industry	631.16	596.32	843.61	1231.92	1510.00	1907.25
Traffic	641.42	606.01	857.33	1251.95	1534.55	1938.27
Agriculture	17.96	16.97	24.01	35.05	42.97	54.27
Forestry	2.57	2.42	3.43	5.01	6.14	7.75

b) mobile

Baden-Württemberg						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	50.22	54.00	56.92	59.96	63.94	69.91
Industry	77.19	83.00	87.48	92.16	98.28	107.45
Traffic	1.86	2.00	2.11	2.22	2.37	2.59
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00

Hessen						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	47.53	51.00	53.24	55.80	59.25	64.43
Industry	74.56	80.00	83.52	87.53	92.95	101.07
Traffic	2.80	3.00	3.13	3.28	3.49	3.79
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00

Rhineland-Palatinate						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	38.21	41.00	43.05	45.32	48.23	52.60
Industry	75.49	81.00	85.05	89.53	95.29	103.91
Traffic	0.93	1.00	1.05	1.11	1.18	1.28
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00

NRW						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	54.75	59.00	62.01	65.05	69.32	75.72
Industry	74.24	80.00	84.08	88.20	93.99	102.67
Traffic	1.86	2.00	2.10	2.20	2.35	2.57
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00

Bavaria						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	50.33	54.00	57.19	60.54	64.64	70.77
Industry	77.36	83.00	87.90	93.06	99.35	108.78
Traffic	1.86	2.00	2.12	2.24	2.39	2.62
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00

Switzerland						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	60.00	65.00	66.69	64.25	66.92	70.91
Industry	88.61	96.00	98.50	94.90	98.83	104.73
Traffic	2.77	3.00	3.08	2.97	3.09	3.27
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00

France						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	47.53	51.00	54.83	57.47	61.42	67.34
Industry	70.83	76.00	81.70	85.64	91.52	100.35
Traffic	1.86	2.00	2.15	2.25	2.41	2.64
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00

The Netherlands						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	51.63	59.00	63.60	64.32	70.07	78.69
Industry	76.13	87.00	93.79	94.85	103.32	116.03
Traffic	1.75	2.00	2.16	2.18	2.38	2.67
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00

Austria						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	52.32	57.18	61.30	65.82	71.20	79.28
Industry	78.01	85.25	91.39	98.13	106.16	118.20
Traffic	1.90	2.08	2.23	2.39	2.59	2.88
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00

Liechtenstein						
Use	**1995**	**2001**	**2005**	**2015**	**2020**	**2020+**
Settlement	132.26	133.32	188.61	389.65	610.53	1246.25
Industry	197.71	198.77	281.20	580.93	910.25	1858.04
Traffic	3.79	4.85	6.86	14.17	22.20	45.32
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00

Annexe 6 - Survey form and example of table for data collection within the context of ICPR project, regarding implemented and planned measures relating to the indicators (cf. also Tables 9 and 10)

Data is collected for two tasks that need to be completed within the framework of the ICPR project:

- For the evaluation of the 1st action target in the ICPR Action Plan on Floods (reduction in flood [damage] risk since 1995)
- For the assessment of the effect of measures within the context of implementing the FD (and creating the FRMP) in the Rhine catchment.

The data is collected for the following years:

- 1995
- 2005
- 2014
- 2020 (estimate)
- 2020+ (estimate)

For the majority of indicators, collecting data at municipality level is optimal, however if this is not available, details at other levels (land, region, ...) are welcome.

Technical note:
In order for the data to be used in the new GIS-based ICPR tool, the data supplied should be entered into the Excel spreadsheets "Overview_datacollection_measures" (=”Übersicht_Datenerhebung_Maßnahmen”) (available from the Secretariat). The level of detail is dependent on the relevant measures and/or the data availability (see Tables 9 and 10).

I.1.1 Indicator "Building regulations and codes/building development plans, in which requirements for flood protection are contained (e.g. flood-adapted construction)”

Required data: the surface area [m²] of the area in which food-adapted construction is stipulated through building development plans, at municipality level or, where this is not possible, at another higher level. Data about areas with food-adapted construction should be supplied. Alternatively, a percentage figure for each municipality is conceivable.

Key question: Where and when (i.e. 1995, 2005, 2014, 2020 and 2020+) were/are the flood-adapted construction measures stipulated by building development plans?

I.1.2. Indicator "Modification of land use data (CLC data) within and outside of the flooding areas of the FHM under analysis."

→ No data required from delegations

I.3.1. Indicator "Number of measures implemented regarding flood-adapted building development"

Required data: Table with assessment of measures implemented (in %) (where possible at municipality level; otherwise at a higher level)

Key question: Where, when and how many measures relating to flood-adapted building development were/are being implemented?

I.3.2. Indicator "Flood proofing property: areas and installations protected by mobile systems (IPPC, SEVESO, waste water treatment plants)"

Municipalities/households/economy
Required data: Areas protected by mobile systems [m²] (where possible at municipality level; otherwise at a higher level)

Key question: Where and when were/are areas protected by (mobile) systems or flood-proofing property?

Hazardous installations (IPPC, SEVESO, water treatment plants)
Required data: Installations protected by technical flood protection measures and/or mobile systems.
Key question: Which installations are protected/unprotected, at which level of protection (HQ10; HQ100, HQextreme) and since when?
Note: The ICPR provides HKV with the list of installations using the 2015 Atlas and additional information regarding the waste water plants.

I.3.3. Indicators "Securing oil tanks and/or safe storage in upper storeys"

- in the case of households: Number of households (as proportion of affected households in %), that have safeguarded oil tanks or stored them in upper storeys (where possible per municipality or higher level).
Required data: Assessment of measures implemented in %.

Key question: How many measures regarding the securing of oil tanks and/or storage in upper storeys have been/are being implemented, and where and when were/are these implemented?

- in the case of hazardous installations (IPPC, SEVESO, waste water treatment plants):

Required data: Installations in which secured oil tanks are safeguarded or pollutants are stored in upper storeys.
Key question: At which installations are the oil tanks secured and/or pollutants stored in upper storeys, at which level of protection (HQ10; HQ100, HQextreme) and since when?
Note: The ICPR provides HKV with the list of installations using the 2015 Atlas and additional information regarding the waste water plants.

Key question: Where, when and at which level of protection were/are measures in place to secure an oil tank and/or store it in an upper storey at technical installations (IPPC plants, SEVESO, waste water treatment plants)

I.4.1. Indicator: "Frequency of information campaigns (incl. provision/presence of FHM and FRM)

Required data: Information about update frequency of map portals (in years) and frequency of information campaigns (in years). This information should be ascertained per federal state/state.

Key question: When and how often was/is the map portal updated and an information campaign carried out?

II. Indicator "Modification of flood probabilities due to improvement in protection through technical flood protection measures"

→ Data regarding the modification of flood probability was supplied by HVAL (ICPR). No data required from delegations.

III.1.1 Indicator "Improving flood forecasting within a defined period (inter alia by extending the forecast horizon)"

→ Specific survey for flood forecasting centres along the Rhine:

Information relating to your respective section (of the Rhine) with regard to the following 5 questions (the questions concern the current condition of forecasting/announcements, but also the past - reference year 1995 - and, where data is available, also the measures planned/intended for the future - reference year 2020):

1. Is there a flood forecasting system (for your area)? *YES /NO*
2. Is there a flood annoucement/warning system (for your area)? *YES /NO*
3. Which types of information/data are present in the flood forecasting systems?
    a. *discharges*
    b. *water depths*
    c. *flooded areas (representation in form of a dynamic map)*
4. Is the maximum forecasting period achieved *(i.e. the number of days a forecast is available in advance)*? *YES/NO* (Note: for the Rhine, it is considered that the forecast times were achieved in 2005)
5. Is the reliability of forecasts:
    a. *adequate*
    b. *good*
    c. *very good*

III.2.1 Indicator group "- Presence and update frequency of alarm and emergency response plan, - Number of warning systems (warning methods/ways and communication means) - Details of civil protection/crisis management exercises including frequency (frequency of exercises per year)"

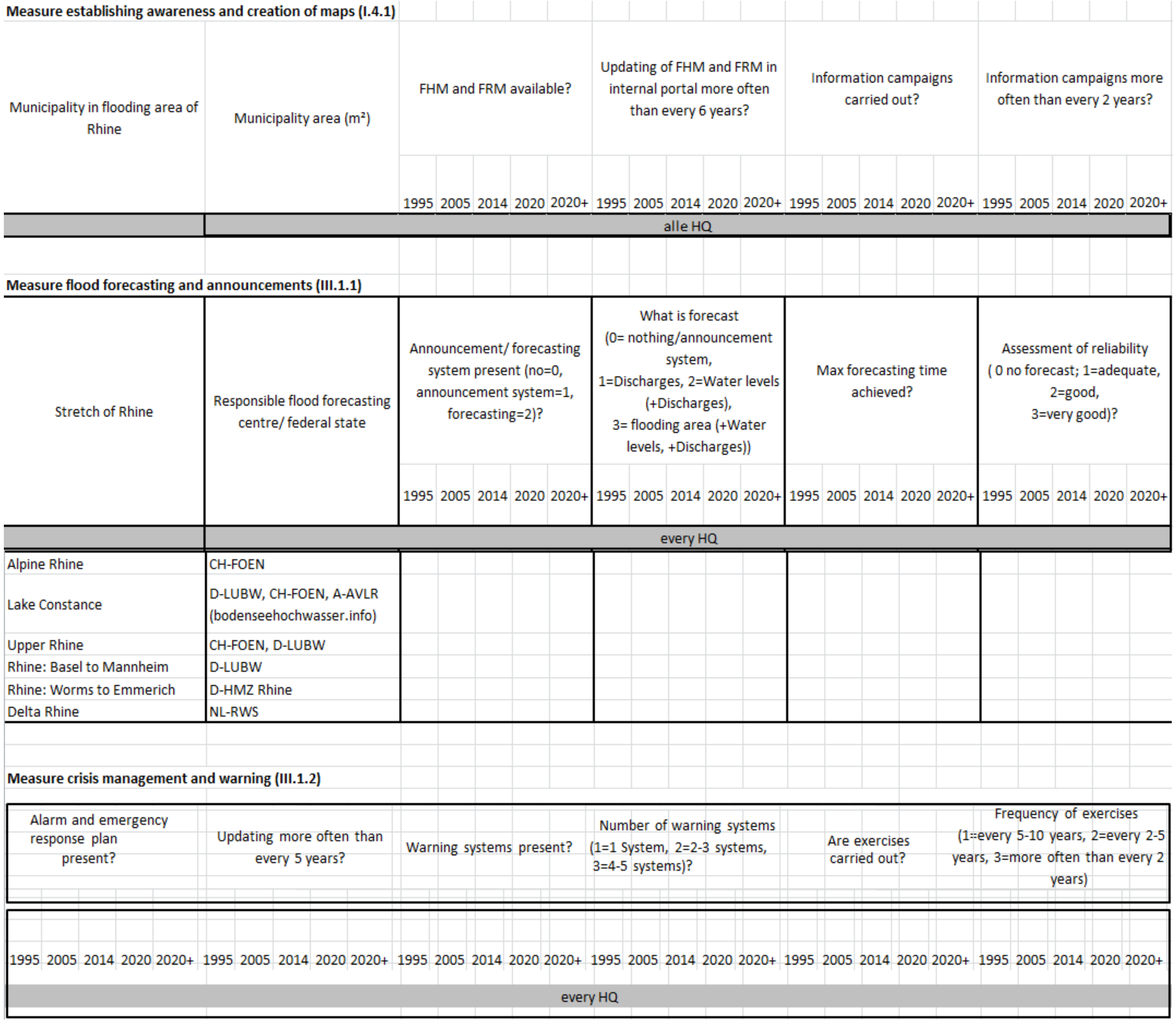
Required data: Content and creation/update date of alarm and emergency response plans, number of methods/ways of warning and means of communication (e.g.: "2" if the warning takes place both by internet and telephone), and number of exercises/training sessions. The realisation factor (%) of the package of measures should likewise be indicated.
Where possible, data should be collected at municipality level (where this is not possible, at a higher level).

Key questions:
- Where and since when was/is there an alarm and emergency response plan, and how often is this updated?
- How many warning systems are there?
- Where, since when, and how often (frequency per year) are there civil protection/crisis management exercises?

The following additional information is also required in terms of human health:
To be defined by the ICPR

• Details of the safeguarding rate in % for the reference point (for ICPR: 1995), for the area under review (e.g. at municipality level, dyke rings). (Here, the safeguarding rate without measures implemented is meant.)
• Details of maximally achievable safeguarding rate (2020+) in the area under review.

Example of data survey for measures relating to establishing awareness, flood forecasting, warning and crisis management



Measure establishing awareness and creation of maps (I.4.1)

Municipality in flooding area of Rhine	Municipality area (m²)	FHM and FRM available?					Updating of FHM and FRM in internal portal more often than every 6 years?					Information campaigns carried out?					Information campaigns more often than every 2 years?				
		1995	2005	2014	2020	2020+	1995	2005	2014	2020	2020+	1995	2005	2014	2020	2020+	1995	2005	2014	2020	2020+
	alle HQ																				

Measure flood forecasting and announcements (III.1.1)

Stretch of Rhine	Responsible flood forecasting centre/ federal state	Announcement/ forecasting system present (no=0, announcement system=1, forecasting=2)?					What is forecast (0= nothing/announcement system, 1=Discharges, 2=Water levels (+Discharges), 3= flooding area (+Water levels, +Discharges))					Max forecasting time achieved?					Assessment of reliability (0 no forecast; 1=adequate, 2=good, 3=very good)?				
		1995	2005	2014	2020	2020+	1995	2005	2014	2020	2020+	1995	2005	2014	2020	2020+	1995	2005	2014	2020	2020+
	every HQ																				
Alpine Rhine	CH-FOEN																				
Lake Constance	D-LUBW, CH-FOEN, A-AVLR (bodenseehochwasser.info)																				
Upper Rhine	CH-FOEN, D-LUBW																				
Rhine: Basel to Mannheim	D-LUBW																				
Rhine: Worms to Emmerich	D-HMZ Rhine																				
Delta Rhine	NL-RWS																				

Measure crisis management and warning (III.1.2)

Alarm and emergency response plan present?					Updating more often than every 5 years?					Warning systems present?					Number of warning systems (1=1 System, 2=2-3 systems, 3=4-5 systems)?					Are exercises carried out?					Frequency of exercises (1=every 5-10 years, 2=every 2-5 years, 3=more often than every 2 years)				
1995	2005	2014	2020	2020+	1995	2005	2014	2020	2020+	1995	2005	2014	2020	2020+	1995	2005	2014	2020	2020+	1995	2005	2014	2020	2020+	1995	2005	2014	2020	2020+
every HQ																													

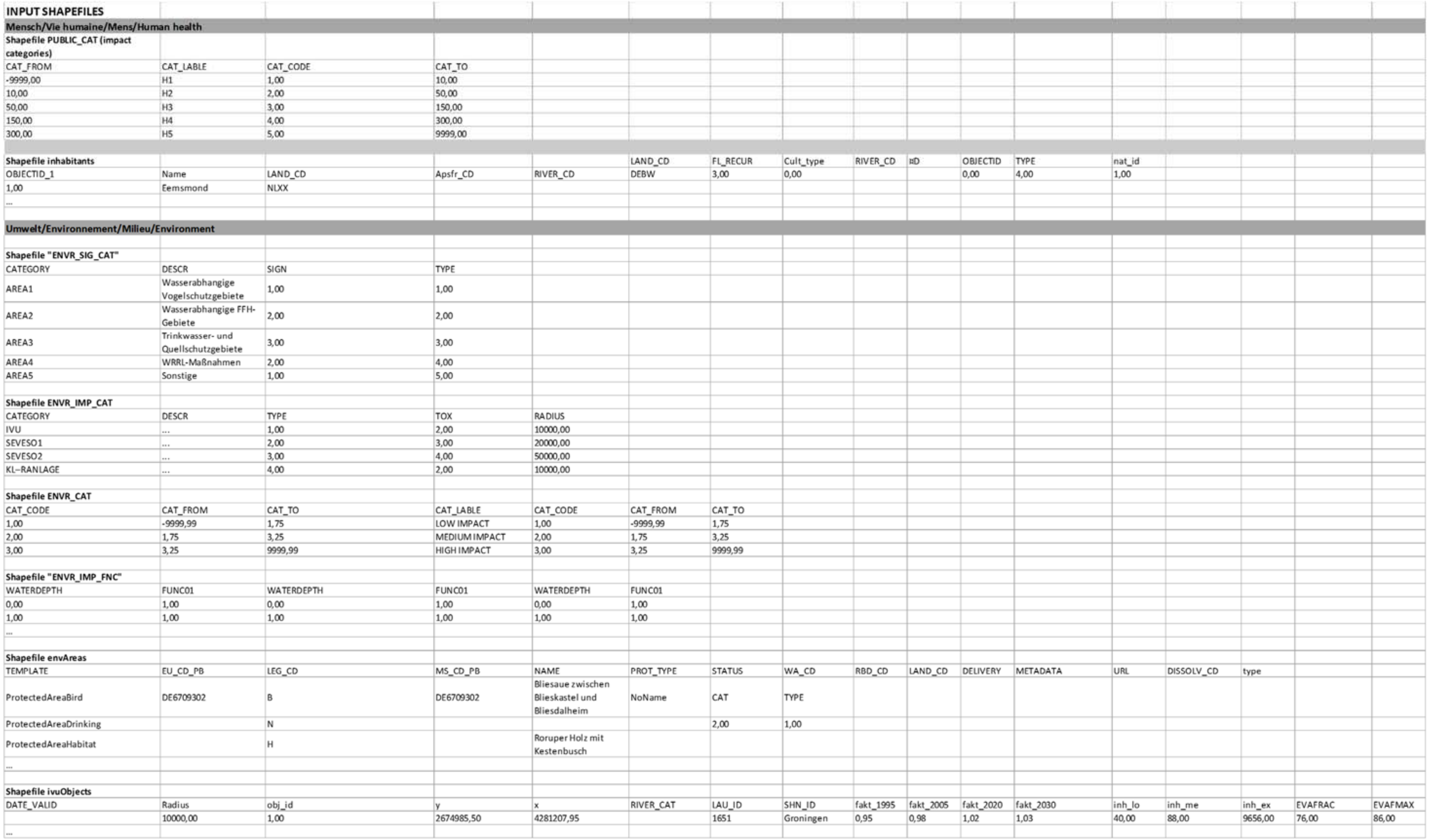
Annexe 7 - Population change

Country	Federal state or similar	Regional council (RC) or similar	County or similar	Absolute population					Relative population (1995 = 100%)				
SHN0NAMN1	SHN1NAMN1	SHN2NAMN1	SHN3NAMN1	1995	2005	2015	2020	2030	1995	2005	2015	2020	2030
Germany	Baden-Württemberg	RC Freiburg		1948098	2048579	2055266	2045572	2004058	100	105.16	105.50	105.00	102.87
Germany	Baden-Württemberg	RC Karlsruhe		1667112	1714207	1713617	1701614	1659389	100	102.82	102.79	102.07	99.54
Germany	Baden-Württemberg	RC Tübingen		574827	601559	614780	611119	598382	100	104.65	106.95	106.31	104.10
Germany	Bavaria	Swabia		75796	79467	80910	81510	81920	100	104.84	106.75	107.54	108.08
Germany	Hessen	RC Darmstadt		2455735	2512213	2569530	2585960	2574260	100	102.30	104.63	105.30	104.83
Germany	North Rhine-Westphalia	District government (DC) Düsseldorf		5238952	5278280	5127355	5077525	4726675	100	100.75	97.87	96.92	90.22
Germany	North Rhine-Westphalia	DG Cologne		2860124	2990507	3066030	3112075	3173251	100	104.56	107.20	108.81	110.95
Germany	North Rhine-Westphalia	DG Münster		1126261	1135026	1099628	1078432	1034087	100	100.78	97.64	95.75	91.82
Germany	Rhineland-Palatinate		Ahrweiler	125377	130467	124810	122280	117660	100	104.06	99.55	97.53	93.84
Germany	Rhineland-Palatinate		Altenkirchen (Westerwald)	134993	136425	128840	125750	119890	100	101.06	95.44	93.15	88.81
Germany	Rhineland-Palatinate		Alzey-Worms	116712	126328	122990	121630	118780	100	108.24	105.38	104.21	101.77
Germany	Rhineland-Palatinate		Bad Dürkheim	130558	135116	131380	129970	127000	100	103.49	100.63	99.55	97.27
Germany	Rhineland-Palatinate		Bad Kreuznach	155597	158319	153040	150770	145600	100	101.75	98.36	96.90	93.58
Germany	Rhineland-Palatinate		Cochem-Zell	64959	65732	61790	60260	57470	100	101.19	95.12	92.77	88.47
Germany	Rhineland-Palatinate		Donnersbergkreis	76302	78825	74040	72260	69010	100	103.31	97.04	94.70	90.44
Germany	Rhineland-Palatinate		Frankenthal (Pfalz)	48371	47225	46550	46210	45190	100	97.63	96.24	95.53	93.42
Germany	Rhineland-Palatinate		Germersheim	118836	125268	125230	124910	123080	100	105.41	105.38	105.11	103.57
Germany	Rhineland-Palatinate		Koblenz	109219	106501	106200	105440	102700	100	97.51	97.24	96.54	94.03
Germany	Rhineland-Palatinate		Landau in der Pfalz	39842	42028	44570	45300	45800	100	105.49	111.87	113.70	114.95
Germany	Rhineland-Palatinate		Ludwigshafen	167369	163343	164070	164080	161910	100	97.59	98.03	98.03	96.74
Germany	Rhineland-Palatinate		Mainz	183720	194372	202470	203730	201590	100	105.80	110.21	110.89	109.73
Germany	Rhineland-Palatinate		Mainz-Bingen	187361	200486	203010	203390	201840	100	107.01	108.35	108.56	107.73
Germany	Rhineland-Palatinate		Mayen-Koblenz	204452	213667	208180	205620	199480	100	104.51	101.82	100.57	97.57
Germany	Rhineland-Palatinate		Neustadt an der Weinstraße	53788	53628	54810	55420	55820	100	99.70	101.90	103.03	103.78
Germany	Rhineland-Palatinate		Neuwied	178479	185259	176610	172770	165420	100	103.80	98.95	96.80	92.68
Germany	Rhineland-Palatinate		Rhein-Hunsrück-Kreis	103392	105705	99430	97040	92640	100	102.24	96.17	93.86	89.60
Germany	Rhineland-Palatinate		Rhein-Lahn-Kreis	127456	128095	119690	116420	110400	100	100.50	93.91	91.34	86.62
Germany	Rhineland-Palatinate		Speyer	49664	50501	50170	50270	49820	100	101.69	101.02	101.22	100.31
Germany	Rhineland-Palatinate		Südliche Weinstraße	106835	110639	107400	106130	103670	100	103.56	100.53	99.34	97.04
Germany	Rhineland-Palatinate		Westerwaldkreis	195669	203541	194890	191190	183630	100	104.02	99.60	97.71	93.85
Germany	Rhineland-Palatinate		Worms	80014	81545	83350	84110	84240	100	101.91	104.17	105.12	105.28
France	Alsace	Bas-Rhin		1679052	1747080	1898000	1932000	1986000	100	104.05	113.04	115.06	118.28
France	Alsace	Haut-Rhin											
Liechtenstein				30948	34905	38035	39599	42183	100	112.79	122.90	127.95	136.30
The Netherlands	Drenthe			454864	483369	489200	485100	484200	100	106.27	107.55	106.65	106.45
The Netherlands	Flevoland			262325	365859	406900	426800	473400	100	139.47	155.11	162.70	180.46
The Netherlands	Friesland			609579	642977	646900	647400	644400	100	105.48	106.12	106.20	105.71
The Netherlands	Gelderland			1864732	1972010	2017500	2028600	2043200	100	105.75	108.19	108.79	109.57
The Netherlands	Groningen			557995	575072	585300	594100	602100	100	103.06	104.89	106.47	107.90
The Netherlands	Limburg			1130050	1136695	1116100	1103900	1075100	100	100.59	98.77	97.69	95.14
The Netherlands	Noord-Brabant			2276207	2411359	2482700	2518800	2579300	100	105.94	109.07	110.66	113.32
The Netherlands	Noord-Holland			2463611	2599103	2752100	2833200	2961000	100	105.50	111.71	115.00	120.19
The Netherlands	Overijssel			1050389	1109432	1143300	1154600	1170700	100	105.62	108.85	109.92	111.45
The Netherlands	Utrecht			1063460	1171291	1257500	1294200	1363400	100	110.14	118.25	121.70	128.20
The Netherlands	Zuid-Holland			3325064	3458381	3594400	3679300	3828500	100	104.01	108.10	110.65	115.14
Austria	Vorarlberg	Bludenz		66718	70144	62032	62367	62910	100	105.14	92.98	93.48	94.29
Austria	Vorarlberg	Bregenz		123124	124558	129175	131976	136293	100	101.16	104.91	107.19	110.70
Austria	Vorarlberg	Dornbirn		75582	81017	84736	87619	91805	100	107.19	112.11	115.93	121.46
Austria	Vorarlberg	Feldkirch		93030	101009	103320	106247	110589	100	108.58	111.06	114.21	118.87
Switzerland	Aargau			528887	569344	641319	670042	711936	100	107.65	121.26	126.69	134.61
Switzerland	Appenzell Ausserrhoden			54104	52561	53469	54204	55890	100	97.15	98.83	100.18	103.30
Switzerland	Appenzell Innerrhoden			14750	15220	16254	16678	17181	100	103.19	110.20	113.07	116.48
Switzerland	Basel-Land			252331	267273	280439	286920	296394	100	105.92	111.14	113.71	117.46
Switzerland	Basel-Stadt			195759	185601	194829	197781	197981	100	94.81	99.52	101.03	101.14
Switzerland	Bern			941950	957064	989397	1003781	1019014	100	101.60	105.04	106.56	108.18
Switzerland	Glarus			39410	38173	39289	39992	41129	100	96.86	99.69	101.48	104.36
Switzerland	Graubünden			185063	187803	194150	195519	198303	100	101.48	104.91	105.65	107.15
Switzerland	Jura			69190	69110	70833	71656	72199	100	99.88	102.37	103.56	104.35
Switzerland	Obwalden			31310	33269	36900	38350	40600	100	106.26	117.85	122.48	129.67
Switzerland	Schaffhausen			74035	73764	75835	76477	77583	100	99.63	102.43	103.30	104.79
Switzerland	Solothurn			239264	247937	260490	765667	274917	100	103.62	108.87	320.01	114.90
Switzerland	St. Gallen			442350	459999	484758	495520	508431	100	103.99	109.59	112.02	114.94
Switzerland	Thurgau			223372	234332	260965	271020	283694	100	104.91	116.83	121.33	127.01
Switzerland	Tessin			305199	322276	349084	355477	363135	100	105.60	114.38	116.47	118.98
Switzerland	Uri			35876	35087	35754	36950	36316	100	97.80	99.66	102.99	101.23
Switzerland	Vallais			271291	291575	322211	330616	341236	100	107.48	118.77	121.87	125.78
Switzerland	Zurich			1175457	1272590	1424093	1475482	1548413	100	108.26	121.15	125.52	131.73

Annexe 8 - Comparison of CORINE data relative changes in area and population

Country	Federal state or similar	Regional council (RC) or similar	County or similar	Relative area (1990 = 100%)			Relative population (1995 = 100%)					Relative population 2005 / Relative area 2006
SHN0NAMN1	SHN1NAMN1	SHN2NAMN1	SHN3NAMN1	1990	2000	2006	1995	2005	2015	2020	2030	
Germany	Baden-Württemberg	RC Freiburg		100	104.01	107.46	100	105.16	105.50	105.00	102.87	98%
Germany	Baden-Württemberg	RC Karlsruhe		100	103.51	105.95	100	102.82	102.79	102.07	99.54	97%
Germany	Baden-Württemberg	RC Tübingen		100	106.85	109.48	100	104.65	106.95	106.31	104.10	96%
Germany	Hessen	RC Darmstadt		100	100.99	103.70	100	102.30	104.63	105.30	104.83	99%
Germany	North Rhine-Westphalia	District government (DG) Düsseldorf		100	102.07	103.38	100	100.75	97.87	96.92	90.22	97%
Germany	North Rhine-Westphalia	DG Cologne		100	103.20	104.55	100	104.56	107.20	108.81	110.95	100%
Germany	North Rhine-Westphalia	DG Münster		100	107.31	112.76	100	100.78	97.64	95.75	91.82	89%
Germany	Rhineland-Palatinate		Ahrweiler	100	101.67	106.77	100	104.06	99.55	97.53	93.84	97%
Germany	Rhineland-Palatinate		Altenkirchen (Westerwald)	100	105.67	106.19	100	101.06	95.44	93.15	88.81	95%
Germany	Rhineland-Palatinate		Alzey-Worms	100	104.28	111.57	100	108.24	105.38	104.21	101.77	97%
Germany	Rhineland-Palatinate		Bad Dürkheim	100	100.68	102.64	100	103.49	100.63	99.55	97.27	101%
Germany	Rhineland-Palatinate		Bad Kreuznach	100	103.25	115.92	100	101.75	98.36	96.90	93.58	88%
Germany	Rhineland-Palatinate		Cochem-Zell	100	106.28	121.70	100	101.19	95.12	92.77	88.47	83%
Germany	Rhineland-Palatinate		Donnersbergkreis	100	102.46	115.57	100	103.31	97.04	94.70	90.44	89%
Germany	Rhineland-Palatinate		Frankenthal (Pfalz)	100	101.47	101.47	100	97.63	96.24	95.53	93.42	96%
Germany	Rhineland-Palatinate		Germersheim	100	105.36	110.34	100	105.41	105.38	105.11	103.57	96%
Germany	Rhineland-Palatinate		Koblenz	100	100.81	101.53	100	97.51	97.24	96.54	94.03	96%
Germany	Rhineland-Palatinate		Landau in der Pfalz	100	103.29	104.61	100	105.49	111.87	113.70	114.95	101%
Germany	Rhineland-Palatinate		Ludwigshafen	100	103.87	108.66	100	97.59	98.03	98.03	96.74	90%
Germany	Rhineland-Palatinate		Mainz	100	101.34	103.18	100	105.80	110.21	110.89	109.73	103%
Germany	Rhineland-Palatinate		Mainz-Bingen	100	102.58	108.12	100	107.01	108.35	108.56	107.73	99%
Germany	Rhineland-Palatinate		Mayen-Koblenz	100	108.27	113.62	100	104.51	101.82	100.57	97.57	92%
Germany	Rhineland-Palatinate		Neustadt an der Weinstraße	100	101.16	102.17	100	99.70	101.90	103.03	103.78	98%
Germany	Rhineland-Palatinate		Neuwied	100	104.97	111.51	100	103.80	98.95	96.80	92.68	93%
Germany	Rhineland-Palatinate		Rhein-Hunsrück-Kreis	100	109.35	108.28	100	102.24	96.17	93.86	89.60	94%
Germany	Rhineland-Palatinate		Rhein-Lahn-Kreis	100	109.46	119.03	100	100.50	93.91	91.34	86.62	84%
Germany	Rhineland-Palatinate		Speyer	100	100.00	100.00	100	101.69	101.02	101.22	100.31	102%
Germany	Rhineland-Palatinate		Südliche Weinstraße	100	103.87	113.10	100	103.56	100.53	99.34	97.04	92%
Germany	Rhineland-Palatinate		Westerwaldkreis	100	115.67	121.84	100	104.02	99.60	97.71	93.85	85%
Germany	Rhineland-Palatinate		Worms	100	101.20	103.31	100	101.91	104.17	105.12	105.28	99%
France	Alsace	Bas-Rhin		100	101.81	103.66	100	104.05	113.04	115.06	118.28	100%
France	Alsace	Haut-Rhin		100	102.78	105.99						
The Netherlands	Zeeland			100	116.85	139.51						0%
The Netherlands	Groningen			100	117.17	126.46						0%
The Netherlands	Drenthe			100	124.59	135.72	100	106.27	107.55	106.65	106.45	78%
The Netherlands	Flevoland			100	173.63	212.98	100	139.47	155.11	162.70	180.46	65%
The Netherlands	Friesland			100	131.56	143.45	100	105.48	106.12	106.20	105.71	74%
The Netherlands	Gelderland			100	113.29	118.80	100	105.75	108.19	108.79	109.57	89%
The Netherlands	Limburg			100	110.86	118.00	100	100.59	98.77	97.69	95.14	85%
The Netherlands	Noord-Brabant			100	117.07	123.99	100	105.94	109.07	110.66	113.32	85%
The Netherlands	Noord-Holland			100	116.18	123.97	100	105.50	111.71	115.00	120.19	85%
The Netherlands	Overijssel			100	118.68	127.95	100	105.62	108.85	109.92	111.45	83%
The Netherlands	Utrecht			100	115.22	124.49	100	110.14	118.25	121.70	128.20	88%
The Netherlands	Zuid-Holland			100	114.81	122.39	100	104.01	108.10	110.65	115.14	85%
Austria	Vorarlberg	Bludenz		-	-	-	100	105.14	92.98	93.48	94.29	-
Austria	Vorarlberg	Bregenz		100	100.00	98.05	100	101.16	104.91	107.19	110.70	103%
Austria	Vorarlberg	Dornbirn		100	100.00	96.67	100	107.19	112.11	115.93	121.46	111%
Austria	Vorarlberg	Feldkirch		-	-	-	100	108.58	111.06	114.21	118.87	-

Annexe 9 - Example of several input and output templates relating to economic risk *(cf. additional explanations e.g. for all input data and for measures in User Guide)*



INPUT SHAPEFILES

Mensch/Vie humaine/Mens/Human health

Shapefile PUBLIC_CAT (impact categories)

CAT_FROM	CAT_LABLE	CAT_CODE	CAT_TO
-9999,00	H1	1,00	10,00
10,00	H2	2,00	50,00
50,00	H3	3,00	150,00
150,00	H4	4,00	300,00
300,00	H5	5,00	9999,00

Shapefile inhabitants					LAND_CD	FL_RECUR	Cult_type	RIVER_CD	¤D	OBJECTID	TYPE	nat_id
OBJECTID_1	Name	LAND_CD	Apsfr_CD	RIVER_CD	DEBW	3,00	0,00			0,00	4,00	1,00
1,00	Eemsmond	NLXX										
...												

Umwelt/Environnement/Milieu/Environment

Shapefile "ENVR_SIG_CAT"

CATEGORY	DESCR	SIGN	TYPE
AREA1	Wasserabhangige Vogelschutzgebiete	1,00	1,00
AREA2	Wasserabhangige FFH-Gebiete	2,00	2,00
AREA3	Trinkwasser- und Quellschutzgebiete	3,00	3,00
AREA4	WRRL-Maßnahmen	2,00	4,00
AREA5	Sonstige	1,00	5,00

Shapefile ENVR_IMP_CAT

CATEGORY	DESCR	TYPE	TOX	RADIUS
IVU	...	1,00	2,00	10000,00
SEVESO1	...	2,00	3,00	20000,00
SEVESO2	...	3,00	4,00	50000,00
KL–RANLAGE	...	4,00	2,00	10000,00

Shapefile ENVR_CAT

CAT_CODE	CAT_FROM	CAT_TO	CAT_LABLE	CAT_CODE	CAT_FROM	CAT_TO
1,00	-9999,99	1,75	LOW IMPACT	1,00	-9999,99	1,75
2,00	1,75	3,25	MEDIUM IMPACT	2,00	1,75	3,25
3,00	3,25	9999,99	HIGH IMPACT	3,00	3,25	9999,99

Shapefile "ENVR_IMP_FNC"

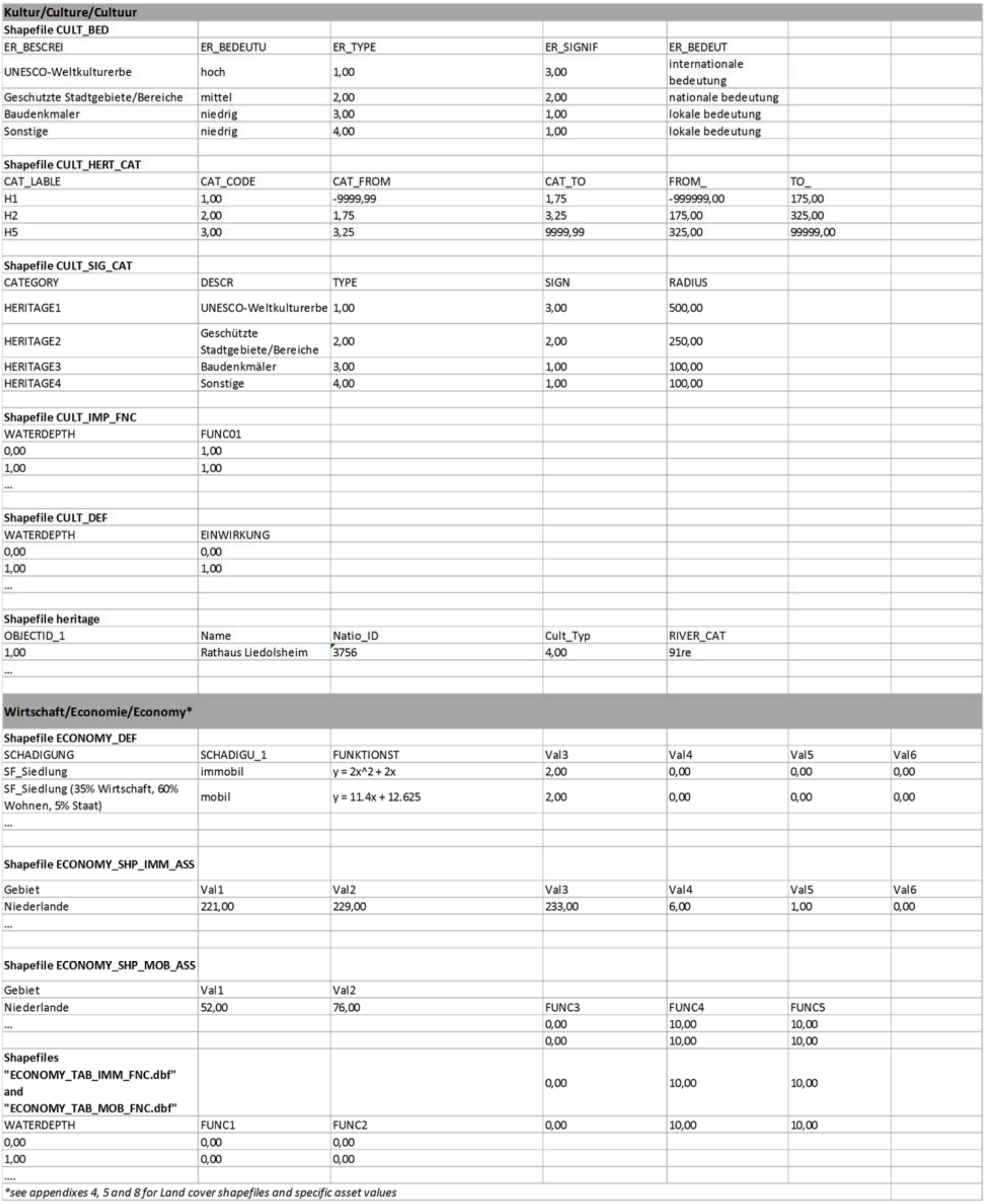
WATERDEPTH	FUNC01	WATERDEPTH	FUNC01	WATERDEPTH	FUNC01
0,00	1,00	0,00	1,00	0,00	1,00
1,00	1,00	1,00	1,00	1,00	1,00
...					

Shapefile envAreas

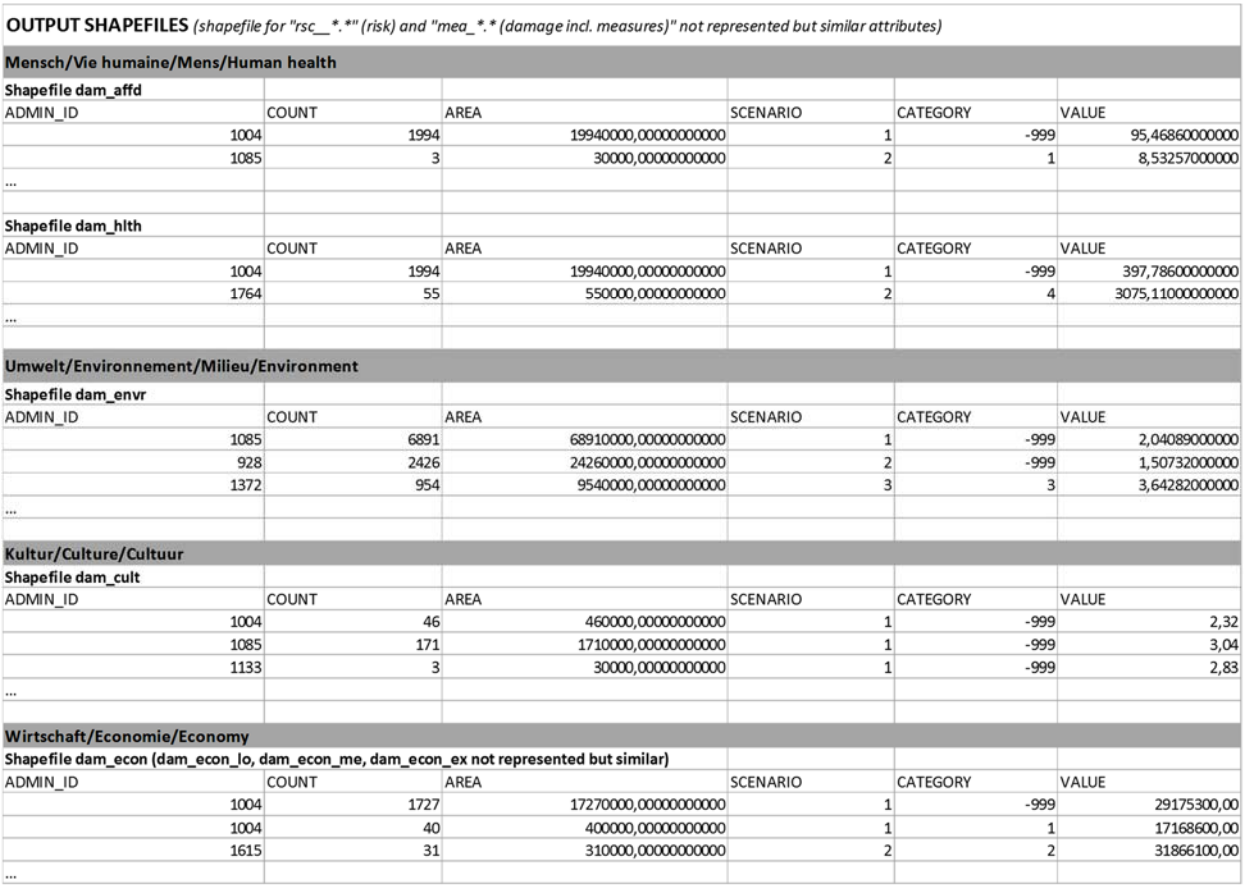
TEMPLATE	EU_CD_PB	LEG_CD	MS_CD_PB	NAME	PROT_TYPE	STATUS	WA_CD	RBD_CD	LAND_CD	DELIVERY	METADATA	URL	DISSOLV_CD	type
ProtectedAreaBird	DE6709302	B	DE6709302	Bliesaue zwischen Blieskastel und Bliesdalheim	NoName	CAT	TYPE							
ProtectedAreaDrinking		N				2,00	1,00							
ProtectedAreaHabitat		H		Roruper Holz mit Kestenbusch										
...														

Shapefile ivuObjects

DATE_VALID	Radius	obj_id	y	x	RIVER_CAT	LAU_ID	SHN_ID	fakt_1995	fakt_2005	fakt_2020	fakt_2030	inh_lo	inh_me	inh_ex	EVAFRAC	EVAFMAX
	10000,00	1,00	2674985,50	4281207,95		1651	Groningen	0,95	0,98	1,02	1,03	40,00	88,00	9656,00	76,00	86,00
...																



Kultur/Culture/Cultuur						
Shapefile CULT_BED						
ER_BESCREI	ER_BEDEUTU	ER_TYPE	ER_SIGNIF	ER_BEDEUT		
UNESCO-Weltkulturerbe	hoch	1,00	3,00	internationale bedeutung		
Geschutzte Stadtgebiete/Bereiche	mittel	2,00	2,00	nationale bedeutung		
Baudenkmaler	niedrig	3,00	1,00	lokale bedeutung		
Sonstige	niedrig	4,00	1,00	lokale bedeutung		
Shapefile CULT_HERT_CAT						
CAT_LABLE	CAT_CODE	CAT_FROM	CAT_TO	FROM_	TO_	
H1	1,00	-9999,99	1,75	-999999,00	175,00	
H2	2,00	1,75	3,25	175,00	325,00	
H5	3,00	3,25	9999,99	325,00	99999,00	
Shapefile CULT_SIG_CAT						
CATEGORY	DESCR	TYPE	SIGN	RADIUS		
HERITAGE1	UNESCO-Weltkulturerbe	1,00	3,00	500,00		
HERITAGE2	Geschützte Stadtgebiete/Bereiche	2,00	2,00	250,00		
HERITAGE3	Baudenkmäler	3,00	1,00	100,00		
HERITAGE4	Sonstige	4,00	1,00	100,00		
Shapefile CULT_IMP_FNC						
WATERDEPTH	FUNC01					
0,00	1,00					
1,00	1,00					
...						
Shapefile CULT_DEF						
WATERDEPTH	EINWIRKUNG					
0,00	0,00					
1,00	1,00					
...						
Shapefile heritage						
OBJECTID_1	Name	Natio_ID	Cult_Typ	RIVER_CAT		
1,00	Rathaus Liedolsheim	3756	4,00	91re		
...						
Wirtschaft/Economie/Economy*						
Shapefile ECONOMY_DEF						
SCHADIGUNG	SCHADIGU_1	FUNKTIONST	Val3	Val4	Val5	Val6
SF_Siedlung	immobil	y = 2x^2 + 2x	2,00	0,00	0,00	0,00
SF_Siedlung (35% Wirtschaft, 60% Wohnen, 5% Staat)	mobil	y = 11.4x + 12.625	2,00	0,00	0,00	0,00
...						
Shapefile ECONOMY_SHP_IMM_ASS						
Gebiet	Val1	Val2	Val3	Val4	Val5	Val6
Niederlande	221,00	229,00	233,00	6,00	1,00	0,00
...						
Shapefile ECONOMY_SHP_MOB_ASS						
Gebiet	Val1	Val2				
Niederlande	52,00	76,00	FUNC3	FUNC4	FUNC5	
...			0,00	10,00	10,00	
			0,00	10,00	10,00	
Shapefiles "ECONOMY_TAB_IMM_FNC.dbf" and "ECONOMY_TAB_MOB_FNC.dbf"			0,00	10,00	10,00	
WATERDEPTH	FUNC1	FUNC2	0,00	10,00	10,00	
0,00	0,00	0,00				
1,00	0,00	0,00				
....						
**see appendixes 4, 5 and 8 for Land cover shapefiles and specific asset values*						



OUTPUT SHAPEFILES *(shapefile for "rsc__*.*" (risk) and "mea_*.* (damage incl. measures)" not represented but similar attributes)*					
Mensch/Vie humaine/Mens/Human health					
Shapefile dam_affd					
ADMIN_ID	COUNT	AREA	SCENARIO	CATEGORY	VALUE
1004	1994	19940000,00000000000	1	-999	95,46860000000
1085	3	30000,00000000000	2	1	8,53257000000
...					
Shapefile dam_hlth					
ADMIN_ID	COUNT	AREA	SCENARIO	CATEGORY	VALUE
1004	1994	19940000,00000000000	1	-999	397,78600000000
1764	55	550000,00000000000	2	4	3075,11000000000
...					
Umwelt/Environnement/Milieu/Environment					
Shapefile dam_envr					
ADMIN_ID	COUNT	AREA	SCENARIO	CATEGORY	VALUE
1085	6891	68910000,00000000000	1	-999	2,04089000000
928	2426	24260000,00000000000	2	-999	1,50732000000
1372	954	9540000,00000000000	3	3	3,64282000000
...					
Kultur/Culture/Cultuur					
Shapefile dam_cult					
ADMIN_ID	COUNT	AREA	SCENARIO	CATEGORY	VALUE
1004	46	460000,00000000000	1	-999	2,32
1085	171	1710000,00000000000	1	-999	3,04
1133	3	30000,00000000000	1	-999	2,83
...					
Wirtschaft/Economie/Economy					
Shapefile dam_econ (dam_econ_lo, dam_econ_me, dam_econ_ex not represented but similar)					
ADMIN_ID	COUNT	AREA	SCENARIO	CATEGORY	VALUE
1004	1727	17270000,00000000000	1	-999	29175300,00
1004	40	400000,00000000000	1	1	17168600,00
1615	31	310000,00000000000	2	2	31866100,00
...					

Annexe 10 - Overview of supplied data, important notes and information on restrictions.

Necessary and supplied data		**Estimation of time/effort outlay, limitations and important notes**
Data	**Who/where?**	
General		
Topographical data	ICPR	Not so relevant for the calculations.
Administrative/political boundaries	ICPR	
Rhine kilometre marking	ICPR	Not so relevant for the calculations.
Flooding depth and probability		
Flooding raster 3 scenarios, 2015 period	WasserBlick/Rhine Atlas 2015	No great effort/time outlay if the data is already formatted for the Atlas. Problems with the flood depths from the BfG (illogical differences in the flood-prone areas for the 3 scenarios). It was necessary to correct the flood prone areas/flood depths (external order to the service provider).
Flooding polygons 3 scenarios, 2015 period	WasserBlick/Rhine Atlas 2015	Problems with the flood depths from the BfG (illogical differences in the flood-prone areas for the 3 scenarios). It was necessary to correct the flood extent/flood depths (external order to the service provider).
Flood probabilities - Alpine Rhine to Iffezheim	ICPR	Little information for above Iffezheim.
Flood probabilities - Iffezheim to Lobith	ICPR-HVAL	Associated with specific and complex calculations by the EG HVAL. HVAL methodology also has limitations.
Flood probabilities - Lobith to Delta Rhine	ICPR-HVAL	Associated with specific and complex calculations by the EG HVAL. HVAL methodology also has limitations.
Land use		
CORINE Land Cover 1990, 2000, 2006	ICPR/EEA or in the future, directly from WasserBlick/Rhine Atlas 2015	Here, there were specific problems, in particular: - Inaccuracies in the CLC 1990 compared to the CLC 2000 and 2006 - Not accurate enough for small scale analyses Due to the fact that after the calculations were carried out, different discrepancies/inconsistencies were identified in the CLC 1990 and CLC 2000, additional calculations were carried out for the economic activities using the same CLC data set (CLC 2006) for all time horizons. In the future, the new CLC 2012 data set could also be used.
Specific land use data for CH and LI		- For CH and LI, national land use data had to be added for individual data sets (no CLC). E.g. for Liechtenstein, this consisted of the areal statistics land use data 1996 (shapefile) as well as 2002 and 2008. This data is managed by the Office of Construction and Infrastructure (ABI). For CH, derived CLC data was used (1990 or 2000?) and for 2006, the data from the Rhine Atlas. *(To be checked with HKV)*
Receptor "economic activity"		
Damage functions Rhine Atlas 2001	ICPR	Outdated in parts; can produce discrepancies with the damage results and calculations of the states (e.g. BW, LI).
Specific asset values Rhine Atlas 2001	ICPR	Outdated in parts; can produce discrepancies with the damage results and calculations of the states (e.g. BW, LI).
Economic growth/consumer price index (including for scenario 2020/2020+)	Federal states/countries	Detailed information not available for all locations. The aim in the future is to redefine and calculate the specific asset values for Liechtenstein which were calculated on the basis of purchasing power parities, since these were set very high in comparison to Switzerland (Common Economic Space) and Austria, and are flawed. For this reason, the results from Liechtenstein regarding the economy were removed from the calculations, and the data must be re-calculated at a later time based on the correct parameters. For reasons of time, this was unfortunately not possible before the publication of this report.
Receptor "human health"		
Inhabitants 3 scenarios, 2013/2014 period	WasserBlick/Rhine Atlas 2015	Problems in terms of the geometry of the data from the Atlas. No great effort/time outlay if the data is already formatted for the Atlas. In the current calculations (2016 version) the population data for France, Liechtenstein and potentially Switzerland could not be taken into account.
Population change/prognosis	Statistical offices of the federal states/countries	
Evacuation rates	Federal states/countries	Not available in detail for all locations; in parts roughly estimated.
Receptor "cultural heritage"		
Cultural assets (shp files)	WasserBlick/Rhine Atlas 2015	No great effort/time outlay if the data is already formatted for the Atlas. Estimation of the impact range of the 4 types of cultural heritage remains (very) qualitative. Some inconsistencies between the states in the data supplied: Liechtenstein, for example, as opposed to Switzerland submitted a point data set, as LI does not have a planar representation. This higher accuracy, and presumably also the somewhat different approach to determining a cultural asset, leads to the disproportionate designation of cultural assets. No data for FR.
Receptor "environment"		
Drinking water protection and abstraction areas (shp files)	ICPR (WFD)/WasserBlick/Rhine Atlas 2015	No great effort/time outlay if the data is already formatted for the Atlas. The drinking water abstraction areas in France were not taken into account in the current calculations (2016 version). LI did not supply data here.
Natura 2000 sites	ICPR (WFD)/WasserBlick/Rhine Atlas 2015	No great effort/time outlay if the data is already formatted for the Atlas. LI did not supply data here.
Bird protection areas	ICPR (WFD)/WasserBlick/Rhine Atlas 2015	No great effort/time outlay if the data is already formatted for the Atlas. The bird protection areas in France were not taken into account in the current calculations (2016 version). LI did not supply data here.
IPPC plants/installations (shp files) and/or SEVESO operation areas (shp files)	ICPR (WFD)/WasserBlick/Rhine Atlas 2015	No great effort/time outlay if the data is already formatted for the Atlas. Estimation of impact range remains (very) qualitative (see remarks BW b) below). BW: No differentiation in the data between IPPC and SEVESO, and specific comments on the SEVESO of BW: a) The term 'Seveso installations' does not exist, it is not a question of installations but rather areas of operation; completely strike this term, since the quantity thresholds of the Seveso Directive were only a criterion for the selection of relevant IPPC installations. An IPPC installation is a plant to which a certain environmental hazard (water, soil, air, waste) is generally attributed under normal operations. A Seveso operation area consists of several plants/installations (which are not treated as separate units by the Seveso III Directive) and to which the particular danger of major accidents (incidents – fire, explosion, hazardous substance release) is attributed." b) "The allocation of 'Seveso I' and 'Seveso II' to 20 or 50 km cannot be understood. The dispersal of pollutants in the event of flooding is particularly dependent on material properties, on packaging, storage conditions and the failure of safety precautions/security measures."
Waste water treatment plants (shp files)	ICPR/EEA (or national databases)	Not available in the Rhine Atlas. Data set was generated from different sources (initial approximation, possibly incomplete). Estimation of impact range remains (very) qualitative (see remarks BW b) above).
Stretches with a good or very good ecological status (according to WFD).	ICPR (WFD)/WasserBlick	Data from the WFD area.
Measures/indicators *(see also separate and detailed tables in annexes 11 and 12)*		
Effect of measures	Literature/ICPR/HKV	Effects are still "qualitatively" oriented. Main sources: Brochure Effectiveness of Measures ICPR 2002, different risk analysis literature and expert assessments. Problem: Choice of other effects can significantly alter the calculations and results (deviations).
Implementation of the measures (except for water level reduction measures), georeferenced	Federal states/countries	Implementation is still "qualitatively" oriented to some extent, and can be interpreted and supplied in quite different ways depending on the federal state (data is heterogeneous). Large differences between the federal states and countries as far as data availability is concerned. For some measures, data is available in all federal states; for other measures, the data is sparse. For DE, up until now only BW. Problem with filling out data templates. Data was more likely to be delivered as an Excel table. Work in terms of data preparation for the tool.
Water level reduction measures	Federal states/countries/HVAL	See above "flood probabilities". Mainly supplied by HVAL. HVAL methodology also has limitations.
Flood protection infrastructure	WasserBlick/Rhine Atlas 2015	Taken into account by the classification "dyked/non-dyked"; in the future, flood protection could also be reflected/integrated through the flood protection level and its modification (best expressed in return periods).

Annexe 11 - Overview of data supplied relating to indicators

In order to calculate the effect of the measures (other than the measures which are expressed by the change of probabilities), indicators were defined (cf. Section 4) for which data was delivered by the delegates. The following table provides an overview of this data. Notes and comments regarding the data can be found in Annexes 10 and 12.

Table : Data regarding indicators supplied by the states/federal states

Indicators		States/federal states					
No.	Description	A	CH	D	FR	FL	NL
Receptors economy and culture							
I.1.1	Precautionary land use	+	+	+	+	-[19]	+
I.3.1	Flood-adapted construction	+	+	-	+	-[19]	+
I.3.2	Flood-proofing property (technical object protection)	+	+	-	+	-	+
I.3.3	Flood-adapted storage	+	-	-	+	-	-
I.4.1	Information campaigns/FHM and FRM	+	+	+	+	+	+
III.1.1	Forecast	+	+	+	+	+	+
III.2.1	Warnings etc.	+	+	+	+	+	+
Receptor environment							
I.3.2	Flood-proofing property (technical object protection)	-[20]	-	+	+	-[21]	+
I.3.3	Flood-adapted storage	-[20]	-	+	+	-	+
[redacted]							
Safeguarding rate							
Human health							
1995		20 %	20 %	20 %	20 %	20 %	76 %
2020+		80 %	80 %	80 %	80 %	80 %	86 %

In the case of the indicators that relate to the receptors economy and culture, it was possible to provide a great deal of data. Only in the case of the indicators relating to precautionary building was the provision of data often not possible, as this is a matter of very small-scale information at municipality level, and the indicator I.3.3 (flood-adapted storage) is not relevant in the Netherlands.

In the case of Austrian data, with regard to the indicators for "precautionary building" (I.3.1 to I.3.3), a differentiation was made between new-builds and existing buildings.

In terms of the indicators that concern the receptor the environment, data was only supplied by Germany (Baden-Württemberg), France and the Netherlands. From the Netherlands for the indicator I.3.2 (flood proofing property) and in France for the

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[19] I.1.1 and 1.3.1: These measures exist in FL. There are no data sets, however, as, just as is the case for most other countries, there are no requirements regarding extreme events. For the more frequent events, no areas are affected, and no areas can therefore be specified.

[20] There are installations with technical flood protection measures present in Austria, however as no details are provided about the degree of protection, the data has not been used for the calculations.

[21] I.3.2 (environment): in Liechtenstein there are no IPPC, SEVESO installations. This means that data was not supplied. There is one single waste water treatment plant, which is affected by HQext, and which cannot be adequately protected for the flood event.

indicator I.3.3 (flood-adapted storage), continuous zeros i.e. no information were/was recorded. The indicator I.3.3 was interpreted somewhat differently in the Netherlands. Here, a record was made of not only whether water-polluting substances were stored in a flood-adapted manner, but also whether the installations had alarm and emergency response plans etc. (cf. HKV, 2015).

While all states/federal states provided the data in xls tables, the Netherlands delivered the data directly as shapefiles for each of the individual time horizons. Both the data format of the xls tables and the shapefiles were predefined by the contractor.

Further comments regarding the data can be found in the indicator tables supplied by the different countries (available from the ICPR secretariat).

Explanation of the indicator I.1.1 (precautionary land use), receptors economy and culture

For the indicator I.1.1 (precautionary land use), a percentage is specified indicating how many development/construction plans exist that contain requirements relating to flood protection, per developed area of the individual municipalities. The information from Switzerland forms an exception. Here, the percentage specified relates to the developed area affected by flooding. When specifying the building regulations for the scenario 2020+, it is assumed that as regards extreme flooding events in the future, restrictions regarding the construction (flood-adapted construction) will be imposed.

In Germany and Baden-Württemberg, on 22.12.2013 flooding areas were established (as per § 76 Federal Water Act [WHG], in which regulations apply in accordance with § 78 WHG) which have a crucial effect on the development planning in the areas in question. For the indicator I.1.1, relevant measures will therefore be implemented in Baden-Württemberg from 2014 on a large scale. Because the building regulations do not reduce the current flood risk, but rather they curb the growth of the potential damage, the effect of the measures is a function of time. As the ICPR analysis tool for the entire Rhine catchment area in this regard is based on the implementation as of 1995, the realisations for Baden-Württemberg have been adjusted accordingly for the calculations, i.e. reduced by a percentage (see table below).

Table : Adapted realisation of the indicator I.1.1 for Baden-Württemberg

Realisation (R) (example of a municipality in BW)

Scenario	1995	2005	2014	2020	2020+
HQ10	0	0.2	1	1	1
HQ100	0	0.05	1	1	1
HQextreme	0	0	0.1	0.1	0.1

Adaptations realisation

Scenario	1995	2005	2014	2020	2020+
HQ10	no adaptation	no adaptation	R*0.25	R*0.5	R*0.75
HQ100	no adaptation	no adaptation	R*0.25	R*0.5	R*0.75
HQextreme	no adaptation	no adaptation	R*0.25	R*0.5	R*0.75

Explanation regarding the indicators I.3.2 (flood-proofing property) and I.3.3 (flood-adapted storage) receptor environment

For the indicator I.3.3, the Netherlands supplied a point shapefile, France and Germany (Baden-Württemberg) also supplied tabular data in xls table format, which requires the positioning of hazardous facilities (cf. "Data preparation indicators receptor environment" below).

Data preparation indicators receptors economy and culture

The polygon shapefiles were created on the basis of the information in the xls tables (except in the case of the Netherlands), whereby the information is linked to the administrative boundaries using the JOIN function in the GIS, via the attribute municipality name. Some of the values recorded were modified by changing the field functions (attribute field name) and the characteristics (YES = 1; NO = 0).

In accordance with the decisions of the ICPR, the data from Baden-Württemberg was transferred to the rest of the German federal states located on the Rhine in Germany. Finally, both the newly generated and previously existing shapefiles from the Netherlands were merged together.

As a result, polygon shapefiles are available for all time horizons and indicators; partially differentiated for the three scenarios HQ10, HQ100 and HQextreme.

Data preparation indicators receptor environment

The data from Baden-Württemberg and France first had to be geo-referenced, meaning that as the first stage for these two countries and for the Netherlands, a point shapefile with the corresponding attributes for the indicators I.3.2 (flood-proofing property) and I.3.3 (flood-adapted storage) was made available.

For the calculation of risk reduction for the receptor environment, however, a polygon shapefile is required indicating the area which is protected by mobile systems or in which flood-adapted storage takes place. By creating a buffer of 200 m around the hazardous installation, a polygon shapefile is generated.

A transfer of data from BW to the entire German Rhine catchment area for the indicators of the receptor environment is not possible due to the specific location of the hazardous installations.

Annexe 12 - Detail and supplementary notes regarding delivery of national indicator data

	Indicator	Data gathering time/effort outlay			Identified effects on the risk (relevance of the indicator for the Rhine/Rhine catchment area)						Key: Green: information supplied Yellow: partial information supplied Red: no information supplied	
		🟥 High	🟨 Medium	🟩 Low	🟩 High	🟨 Low to medium	DE (BW)	FR	NL	CH	AT	LI
I.1.1	Building regulations/building development plans		🟨		🟩		🟩	🟨 Only information for HQ100 Strasbourg and the future.	🟩	🟩 Very detailed	🟩 Mainly based on blue zone and specific degree of realisationI.1.1: Degree of implementation was partially identified specifically; realisation in terms of new buildings differs from old buildings.	🟥
I.1.2	Keeping flood prone areas open/clear and adapted usage of areas	🟩 Recorded using CLC data.					🟩 Recorded using CLC data.					
I.3.1	Flood-adapted design, construction, renovation	🟥				🟨	🟥	🟩 Basic information and only for Strasbourg and the future.	🟥 This measure was not enforced (value = '0').	🟩 Information only for the future	🟩 With regard to I.3.1 This depends to what extent the measures for establishing awareness contribute to a willingness to make investments in protection. If this is the case for those affected, a greater number of adapted properties are conceivable. The realisation of measures in new buildings differs from those in old buildings.	🟥
I.3.2	Flood-proofing property (within the flood-prone area) - Cultural heritage, economy - Environment (IPPC plants, waste water treatment plants, ...)	🟥				🟨 *Note: Relevance for the environment*	🟨 For households/municipalities/cultural heritage/economy: Difficult For industries (environment), detailed information	🟩 Information supplied, but it involves estimates.	🟨 This measure does not concern adjustments at the level of households, to cultural heritage and IPPC plants.	🟩 Only for the receptor economy etc. and information only for the future	🟩 With regard to I.3.2 Similar potential for existing property as in the private sector. There are businesses which, by their nature, do a great deal to protect their plants, as the loss of production would entail high costs. Here, if the risk is communicated appropriately, the same degree of implementation as in the private sector is possible. AT assumes, rather, that this is somewhat higher (see point I.3.1), as the cost of production losses can easily be compared to the cost of property protection measures.	🟥
I.3.3	Flood-adapted storage of water-polluting substances - Cultural heritage, economy - Environment (IPPC plants, waste water treatment plants, ...)	🟥				🟨 *Note: Relevance for the environment*	🟨 For households/municipalities/cultural heritage/economy: Difficult For industries (environment), detailed information	🟨 Information supplied, but this concerns a technical flood protection measure that protects the entire area.	🟨 Only for IPPC plants	🟥	🟩 With regard to I.3.3 The assessment from point I.3.1 can be applied here.	🟥
I.4.1	Provision of flood hazard and risk maps and establishing awareness for precautionary behaviour, education and preparation/preparedness for flood events			🟩	🟩		🟩	🟩	🟩	🟩	🟩 With regard to I.4.1 FHM and FRM are only available via the Flood Risk Management Plan (2014 version). Nevertheless, before this, discharge analyses were carried out including dam bursting scenarios, to estimate the hazard level along the Alpine Rhine. The updating of maps on the Internet is currently being carried out after the creation of new hazard zone plans and/or discharge analyses. In any case, digital information has been available to the public since 2014.	🟩
II.1	Modification of flood probability		🟨		🟩		🟩 HVAL information and H/HIRI information upstream of Iffezheim					
II.2	Flood protection: Adaptation of protection level/dyke redevelopment		🟨		🟩		🟨 Flood protection systems supplied through the Atlas 2015. Flood protection measures are incorporated into the calculations using the distinctions "dyke-protected / non-dyked-unprotected", which have different effects in the case of other measures. NL provided information regarding the improvement of flood protection.					
III.1.1	Flood information and forecasts			🟩	🟩		🟩 Flood forecasting centres - information					
III.2.1	Warning systems for those affected/alarm and emergency response plans/exercises and training			🟩	🟩		🟩	🟩 This concerns different types of warning methods, ways and routes, but on a large scale, not an individual one.	🟩	🟩	🟩 With regard to III.1.2 Alarm and emergency response plans have been in place for quite some time, as the law on hazard prevention requires this. The quality of these still varies, however. One of the main objectives of the Flood Risk Management Plan is the creation of a uniform standard, which is implemented by all municipalities alike. For the Alpine Rhine there is, at any rate, an Operation Guide.	🟩
General remarks per federal state							Data from BW was transferred to other federal states. See further notes in the BW indicator table.	Information only for the risk area "Agglomération strasbourgeoise".	Data collection (special commission to HKV). Only state that has supplied the measures in shapefiles.	See further notes in the CH indicator table.	Conversion of the national data list and structure into the measures defined by HIRI. Shapefile supplied for the blue zone (see further details in the AT indicator table).	Only details relating to points I.4.1 and III.1.2 provided. Points I.1.1 - I.3.3 are not relevant for the process source "Alpine Rhine", as flooding from the Rhine in Liechtenstein can be ruled out within the period of observation (recurrence period of up to 300 years).

Annexe 13 - Dependency matrix (dyked and non-dyked)

Dependencies - dyked		Protected by technical flood protection (dyked)	Not protected by technical flood protection (non-dyked)	**I) Prevention**	**(Flood protection measures)**	**1. Land use control**	Spatial planning, regional planning and land use planning	Keeping flood prone areas open/clear and adapted usage of areas	**3. Precautionary building**	Flood-adapted design, construction, renovation	Flood proofing property	Flood-adapted storage of water-polluting substances	**4. Other precautionary measures**	Provision of flood hazard and risk maps / establish awareness for precautionary behaviour, education and preparation/preparedness for flood events	**II) Flood protection (HVAL)**	**1. Restoration of natural water retention**	In the floodplains, in the catchment area, reconnection and recovery of flood prone areas	**2. Regulation of water discharge**	Flood water retention areas / water-retaining structures in/along the watercourse	Flood water retention areas / water-retaining structures in catchment area	Optimisation of control of water-retaining structures (e.g. for the purpose of hydroelectric power) for flood water retention	**3. Technical flood protection systems**	Dykes, dams, flood protection walls, mobile flood protection, beach walls and special constructions	**4. Waterway construction**	Waterway construction, flood channels and foreshore management in inland area	**5. Other technical measures**	Maintenance/renewal of technical flood protection systems	**III) Preparedness in case of flooding**	**1. Precautionary information**	Flood information and forecasts	**2. Emergency response and civil protection/crisis management**	Warning for those affected / alarm and emergency response plans (incl. recovery/aftercare) / exercises/training
I) Prevention **(Flood protection measures)**																																
1. Land use control																																
Spatial planning, regional planning and land use planning	Land use/ damage prevention	40%	40%				▨	100		40	90	40		40			HVAL		HVAL	HVAL	HVAL		HVAL		HVAL		HVAL			40		40
Keeping flood prone areas open/clear and adapted usage of areas	Land use	100%	100%				100	▨		100	100	100		100			HVAL		HVAL	HVAL	HVAL		HVAL		HVAL		HVAL			100		100
3. Precautionary building																																
Flood-adapted design, construction, renovation	Damage	35% h < 2 m (cellar 80%)	55% h < 2 m (cellar 80%)				40	100		▨	90	35		40			HVAL		HVAL	HVAL	HVAL		HVAL		HVAL		HVAL			35		35
Flood proofing property	Damage	90% not flooded	90% not flooded				90	100		90	▨	90		95			HVAL		HVAL	HVAL	HVAL		HVAL		HVAL		HVAL			90		90
Flood-adapted storage of water-polluting substances	Damage	30%	50%				40	100		35	90	▨		35			HVAL		HVAL	HVAL	HVAL		HVAL		HVAL		HVAL			30		30
4. Other precautionary measures																																
Provision of flood hazard and risk maps / establish awareness for precautionary behaviour, education and preparation/preparedness for flood events	(Damage)	5%	10%				40	100		40	95	35		▨			HVAL		HVAL	HVAL	HVAL		HVAL		HVAL		HVAL			22.5		22.5
II) Flood protection (HVAL)																																
1. Restoration of natural water retention																																
In the floodplains, in the catchment area, reconnection and recovery of flood prone areas	Flood probability						HVAL	HVAL		HVAL	HVAL	HVAL		HVAL			▨		HVAL	HVAL	HVAL		HVAL		HVAL		HVAL			HVAL		HVAL
2. Regulation of water discharge																																
Flood water retention areas / water-retaining structures in/along the watercourse	Flood probability						HVAL	HVAL		HVAL	HVAL	HVAL		HVAL			HVAL		▨	HVAL	HVAL		HVAL		HVAL		HVAL			HVAL		HVAL
Flood water retention areas / water-retaining structures in catchment area	Flood probability						HVAL	HVAL		HVAL	HVAL	HVAL		HVAL			HVAL		HVAL	▨	HVAL		HVAL		HVAL		HVAL			HVAL		HVAL
Optimisation of control of water-retaining structures (e.g. for the purpose of hydroelectric power) for flood	Flood probability						HVAL	HVAL		HVAL	HVAL	HVAL		HVAL			HVAL		HVAL	HVAL	▨		HVAL		HVAL		HVAL			HVAL		HVAL
3. Technical flood protection systems																																
Dykes, dams, flood protection walls, mobile flood protection, beach walls and special constructions	Flood probability						HVAL	HVAL		HVAL	HVAL	HVAL		HVAL			HVAL		HVAL	HVAL	HVAL		▨		HVAL		HVAL			HVAL		HVAL
4. Waterway construction																																
Waterway construction, flood channels and foreshore management in inland area	Flood probability						HVAL	HVAL		HVAL	HVAL	HVAL		HVAL			HVAL		HVAL	HVAL	HVAL		HVAL		▨		HVAL			HVAL		HVAL
5. Other technical measures																																
Maintenance/renewal of technical flood protection systems	Flood probability						HVAL	HVAL		HVAL	HVAL	HVAL		HVAL			HVAL		HVAL	HVAL	HVAL		HVAL		HVAL		▨			HVAL		HVAL
III) Preparedness in case of flooding																																
1. Precautionary information																																
Flood information and forecasts	Damage	15%	20%				40	100		35	90	30		22.5			HVAL		HVAL	HVAL	HVAL		HVAL		HVAL		HVAL			▨		22.5
2. Emergency response and civil protection/crisis management																																
Warning for those affected / alarm and emergency response plans (incl. recovery/aftercare) /	Damage	15%	30%				40	100		35	90	30		22.5			HVAL		HVAL	HVAL	HVAL		HVAL		HVAL		HVAL			22.5		▨

Dependencies - non-dyked

				I) Prevention	**(Flood protection measures)**	**1. Land use control**	Spatial planning, regional planning and land use planning	Keeping flood prone areas open/clear and adapted usage of areas	**3. Precautionary building**	Flood-adapted design, construction, renovation	Flood proofing property	Flood-adapted storage of water-polluting substances	**4. Other precautionary measures**	Provision of flood hazard and risk maps / establish awareness for precautionary behaviour, education and preparation/preparedness for flood events	**II) Flood protection (HVAL)**	**1. Restoration of natural water retention**	In the floodplains, in the catchment area, reconnection and recovery of flood prone areas	**2. Regulation of water discharge**	Flood water retention areas / water-retaining structures in/along the watercourse	Flood water retention areas / water-retaining structures in catchment area	Optimisation of control of water-retaining structures (e.g. for the purpose of hydroelectric power) for flood water retention	**3. Technical flood protection systems**	Dykes, dams, flood protection walls, mobile flood protection, beach walls and special constructions	**4. Waterway construction**	Waterway construction, flood channels and foreshore management in inland area	**5. Other technical measures**	Maintenance/renewal of technical flood protection systems	**III) Preparedness in case of flooding**	**1. Precautionary information**	Flood information and forecasts	**2. Emergency response and civil protection/crisis management**	Warning for those affected / alarm and emergency response plans (incl. recovery/aftercare) / exercises/training
I) Prevention **(Flood protection measures)**																																
1. Land use control																																
Spatial planning, regional planning and land use planning	Land use/ damage prevention	40%	40%				▨	100		40	90	40		40			HVAL		HVAL	HVAL	HVAL		HVAL		HVAL		HVAL			40		40
Keeping flood prone areas open/clear and adapted usage of areas	Land use	100%	100%				100	▨		100	100	100		100			HVAL		HVAL	HVAL	HVAL		HVAL		HVAL		HVAL			100		100
3. Precautionary building																																
Flood-adapted design, construction, renovation	Damage	35% h < 2 m (cellar 80%)	55% h < 2 m (cellar 80%)				55	100		▨	90	55		65			HVAL		HVAL	HVAL	HVAL		HVAL		HVAL		HVAL			55		55
Flood proofing property	Damage	90% not flooded	90% not flooded				90	100		90		80		100			HVAL		HVAL	HVAL	HVAL		HVAL		HVAL		HVAL			90		90
Flood-adapted storage of water-polluting substances	Damage	30%	50%				40	100		55	90	▨		60			HVAL		HVAL	HVAL	HVAL		HVAL		HVAL		HVAL			50		50
4. Other precautionary measures																																
Provision of flood hazard and risk maps / establish awareness for precautionary behaviour, education and preparation/preparedness for flood events	(Damage)	5%	10%				40	100		65	100	60		▨			HVAL		HVAL	HVAL	HVAL		HVAL		HVAL		HVAL			30		45
II) Flood protection (HVAL)																																
1. Restoration of natural water retention																																
In the floodplains, in the catchment area, reconnection and recovery of flood prone areas	Flood probability						HVAL	HVAL		HVAL	HVAL	HVAL		HVAL			▨		HVAL	HVAL	HVAL		HVAL		HVAL		HVAL			HVAL		HVAL
2. Regulation of water discharge																																
Flood water retention areas / water-retaining structures in/along the watercourse	Flood probability						HVAL	HVAL		HVAL	HVAL	HVAL		HVAL			HVAL		▨	HVAL	HVAL		HVAL		HVAL		HVAL			HVAL		HVAL
Flood water retention areas / water-retaining structures in catchment area	Flood probability						HVAL	HVAL		HVAL	HVAL	HVAL		HVAL			HVAL		HVAL	▨	HVAL		HVAL		HVAL		HVAL			HVAL		HVAL
Optimisation of control of water-retaining structures (e.g. for the purpose of hydroelectric power) for flood	Flood probability						HVAL	HVAL		HVAL	HVAL	HVAL		HVAL			HVAL		HVAL	HVAL	▨		HVAL		HVAL		HVAL			HVAL		HVAL
3. Technical flood protection systems																																
Dykes, dams, flood protection walls, mobile flood protection, beach walls and special constructions	Flood probability						HVAL	HVAL		HVAL	HVAL	HVAL		HVAL			HVAL		HVAL	HVAL	HVAL		▨		HVAL		HVAL			HVAL		HVAL
4. Waterway construction																																
Waterway construction, flood channels and foreshore management in inland area	Flood probability						HVAL	HVAL		HVAL	HVAL	HVAL		HVAL			HVAL		HVAL	HVAL	HVAL		HVAL		▨		HVAL			HVAL		HVAL
5. Other technical measures																																
Maintenance/renewal of technical flood protection systems	Flood probability						HVAL	HVAL		HVAL	HVAL	HVAL		HVAL			HVAL		HVAL	HVAL	HVAL		HVAL		HVAL		▨			HVAL		HVAL
III) Preparedness in case of flooding																																
1. Precautionary information																																
Flood information and forecasts	Damage	15%	20%				40	100		55	90	50		30			HVAL		HVAL	HVAL	HVAL		HVAL		HVAL		HVAL			▨		45
2. Emergency response and civil protection/crisis management																																
Warning for those affected / alarm and emergency response plans (incl. recovery/aftercare) /	Damage	15%	30%				40	100		55	90	50		45			HVAL		HVAL	HVAL	HVAL		HVAL		HVAL		HVAL			45		▨

Annexe 14 - Explanation of calculation methodology for "human health" including measures using the example of a cell

Example input	**Water depth**	**Dyke**	**Regarding people**		**MEAS_I11**	**MEAS_I32**	**MEAS_I41**	**MEAS_III11**	**MEAS_III21**
Value	0.195 cm	dyked	EvaMin = 0.75 (Eva = evacuation/safeguarding rate) EvaMax = 0.95		0.95	0.16	*Path:* 1 1 1 1	*Path:* 2 2 1 2	*Path:* 1 1 1 1 1 2
Example output	**dam_hlth**	**dam_affd**	**Mea_hlth**	**Mea_affd**	**i11**	**i32**	**i41**	**iii11**	**iii21**
Value	0.478805	0.119701	0.402196	0.04002	-*	0.16	8	18	10

The description "path" relates here to the input data, i.e. which path is taken in the flowchart.

The output "dam_hlth" of the tool "damage assessment" corresponds to the number of people affected by flooding per raster cell in the relevant area. The output "dam_affd" corresponds to the number of people affected per raster cell after evacuation (here 75 %: 0.478805*(1-0.75) = 0.119701). The calculation of the potential for improvement through the individual measures is undertaken based on the output "dam_hlth". The results after measures have been implemented, at a point in time x (1995 < x < 2020+) are described by Mea_hlth (decreased number of people due to measure i32 or i11) and Mea_affd (decreased number of people affected after evacuation (or taken to safe area) due to measures i41, iii11 and iii21).

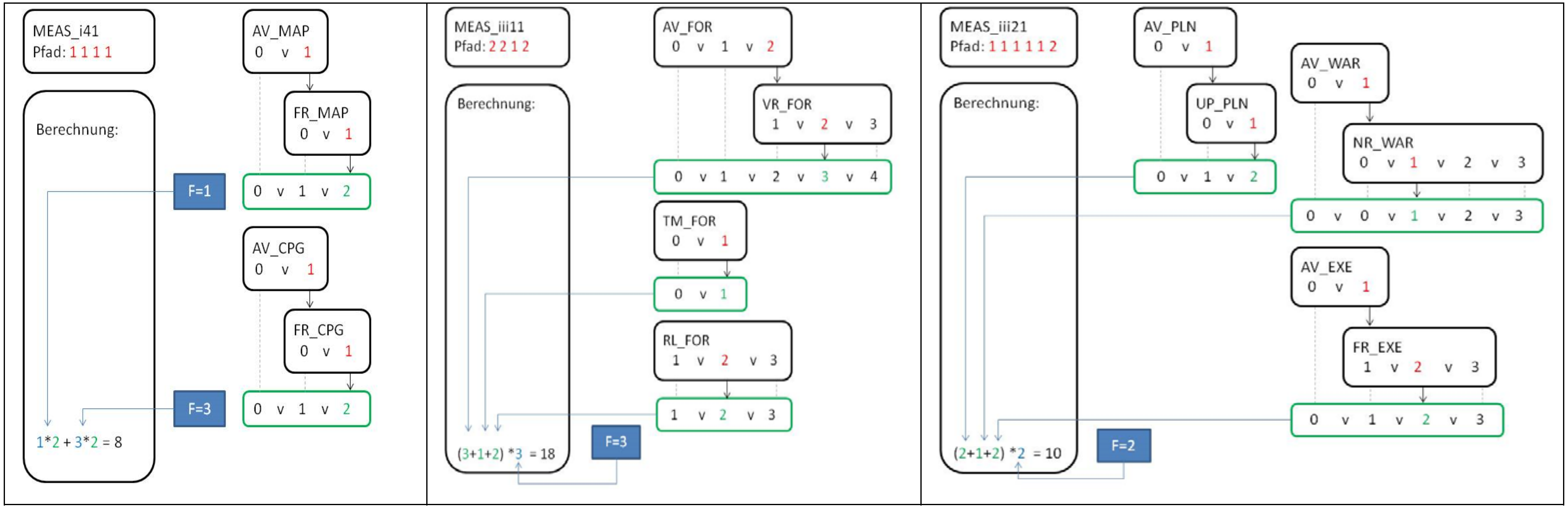
1) Protected inhabitants:

$$\left.\begin{array}{l} i32 > 0 \rightarrow i32 \\ \\ i32 < 0 \rightarrow i11 \end{array}\right\} \textit{Value} * \textit{dam\_hlth} = \boldsymbol{mea\_hlth} \quad \Rightarrow \quad i32 = 0.16 > 0 \rightarrow (1-0.16) * 0.478805 \boxed{= 0.402196}$$

Due to measures i32 and i11, the number of people affected is modified. All other measures have an effect on the people that need to be safeguarded/evacuated.

* When combining measures i11 with one of the precautionary building measures, in summing up the measures, the precautionary building measure is selected.

2) Safeguarding rate:



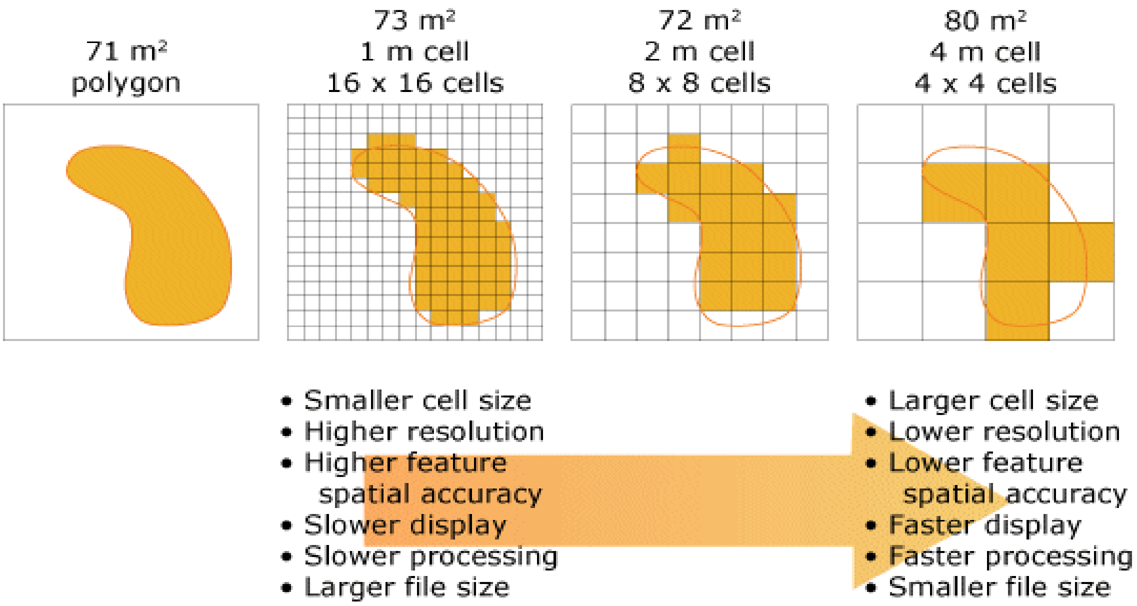
*EvaMin + (SUM(i41, iii11, iii21)) / maxPoints * Δ Eva = Sr→ (1 – Sr) * mea_hlth = mea_affd*

⇨ 0.75 + (8+18+10) / 48 * 0.2 = 0.90 → (1- 0,90) * 0.402196 = 0.04002

Annexe 15 - Influence of raster cell size

The raster cell size should be chosen so that the area is mapped with sufficient accuracy, while at the same time the storage capacity of the computer is not exceeded.

The figure below shows the basic advantages and disadvantages of a high and low resolution of raster cells.



To quantify the raster cell size based on the computing time, as an example, three GIS operations with different cell sizes were carried out (PC: Dell Latitude E6530 processed (Intel CPU 64-bit 2.90 GHz)).

extent	cell size	uncompressed size	tool	processing time
Flussgebiet Rhein	100x100	42 MB	reclassify	12 s
Flussgebiet Rhein	25x25	672 MB	reclassify	70 s
Flussgebiet Rhein	5x5	16410 MB	reclassify	1800 s
Flussgebiet Rhein	100x100	42 MB	times	8 s
Flussgebiet Rhein	25x25	672 MB	times	108 s
Flussgebiet Rhein	5x5	16410 MB	times	2945 s
Flussgebiet Rhein	100x100	42 MB	plus	8 s
Flussgebiet Rhein	25x25	672 MB	plus	110 s
Flussgebiet Rhein	5x5	16410 MB	plus	2917 s

The results show an exponential increase in computing time in the case of smaller cell sizes. As the tool consists of 6 to 10 ModelBuilders, the computation time must also be multiplied accordingly.

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